Final Report

Project Aqua: Security of Supply and Cost Impacts

Prepared for

Ministry of Economic Development

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Executive Summary

This report examines the security of supply and cost implications of Project Aqua. It has been produced to complement other reports commissioned by the Ministry of Economic Development (MED). The report is based on a review of work by Concept Consulting; it extends the analysis and reports new findings.

The report suggests that Project Aqua is likely to lead to reduced levels of security of electricity supply during dry years. This can be compensated for by the construction of additional reserve generation.

The analysis of costs and benefits of the project suggests that, including the costs of reserve generation, Project Aqua would yield positive net present values (NPVs) at 10%, 7.5% and 5% discount rates. The results are shown below for base case assumptions and high and low project value scenarios.

The positive NPVs of the project would need to be compared with the environmental or other effects of construction that have not been included in this analysis.

Summary of Effects of Project Aqua (Discounted to 2004)

	Effect of Project Aqua ($ million)								
	10% Discount rate			7.5% Discount rate			5% Discount rate		
	Base Case	High	Low	Base Case	High	Low	Base Case	High	Low
Supply cost	-19	-19	-19	27	27	27	95	95	95
Residual value/ post-2020 supply cost	138	175	116	247	322	202	460	620	364
Welfare gain from greater consumption	4	4	4	5	5	5	6	6	6
Reserve requirement	-9	-2	-85	-12	-3	-109	-16	-5	-142
Total	**114**	**158**	**16**	**266**	**350**	**124**	**545**	**717**	**324**

Security of Supply

The security of supply implications of Project Aqua were examined relative to a counter-factual scenario without the project. The analysis used assumptions provided by MED about the new plant that would be built in the years to 2020 in both scenarios. The analysis examined the maximum level of potential supply during a dry year. It undertook this for periods of a year and a week.

Overall, the picture is of a small reduced level of security (measured as total potential generation) in the “with Aqua” scenario, largely because the alternative plant without

Aqua, although lower in total capacity, provide greater certainty of output. The analysis suggests that reserve capacity requirements to make up the reduced level of potential supply would be:

- 9-38 MW in the worst week; and
- 247 MW on the worst day in a dry year, assuming no output from Project Aqua.

The cost analysis has concentrated on the requirements in a dry week, but the results are very sensitive to assumptions made about the extent to which generation can be shifted during a year through storage management. To better understand this requires more detailed modelling than we have undertaken here; such analysis would be useful. Our analysis is of the difference in potential national supply. It has not considered transmission capacity constraints in the system; location of new plant under the two scenarios would also affect security and vulnerability to transmission capacity failure; this requires more detailed modelling beyond the scope of this study.

Costs and Benefits

The analysis has examined the costs and benefits of Project Aqua through an analysis of the relative costs of meeting given demand. It has also included an analysis of the price implications of Project Aqua on demand. The effects are summarised in the Table above.

In the period to 2020, Project Aqua is projected to result in an increased cost of supply, discounted to 2004 at a 10% rate, of $19 million. However, Project Aqua has a value beyond 2020; extending the analysis to the expected economic lifetime of the project (40 years), results in a base case additional positive value of $138 million for the "with Project Aqua" scenario relative to without the project. This significant effect results because Project Aqua has effectively zero ongoing costs of generation compared with alternative generation sources.

Project Aqua is projected to result in a reduced wholesale price of electricity. Increased electricity consumption is expected as a result, with associated gains in consumer and producer surpluses estimated total $4 million in value.

The estimated positive effects of Project Aqua are highly sensitive to the discount rate used for analysis. Arguably, a discount rate lower than 10% should be used for national cost-benefit analysis. At 7.5% and 5% rates the NPVs are higher.

1. Introduction

This report examines the security of supply and cost implications of Project Aqua. It has been produced to complement other reports commissioned by the Ministry of Economic Development (MED).

Project Aqua is the collective name for six proposed new hydro power stations on the Waitaki River that have the potential to add 524MW of generation capacity to the New Zealand power system. However, low flows during dry years reduce the generation potential of hydro plants. And as commissioning Project Aqua will mean that other power plants will not be built, or will be delayed, it has the potential to reduce the security of electricity supply in dry years.

Because of this, Concept Consulting Ltd was commissioned by MED to undertake two pieces of work relating to Project Aqua:

- a review of the potential security of supply contribution[1]; and
- an evaluation of the economic impact as an input to a national cost-benefit analysis[2].

Covec has been asked by MED to:

- review Concept Consulting's work;
- comment on the appropriateness of the approach taken and the meaningfulness of the results;
- propose an approach for comparing the costs of with and without Aqua scenarios;
- assess the level of back-up generation that might be required to deliver equivalent security to the case without Project Aqua.

The analysis presented here revisits the analysis of security of supply contribution and the economic analysis. Quantities of back-up generation to provide equivalent security of supply are estimated. A methodology is proposed for the economic analysis which uses an approach better suited to a national cost-benefit analysis, using public rather than private costs. Estimates are made of the net costs and benefits of Project Aqua using this methodology.

[1] Concept Consulting Group (2003a) Project Aqua. Potential Security of Supply Contribution in 2011/12

[2] Concept Consulting Group (2003b) Project Aqua. An Evaluation of the Economic Impact

2. Security of Supply

2.1. Defining Security of Supply for Analysis

Physical disruptions to supply can occur where levels of demand exceed supply. Although various responses will often avoid this impact, including those of:

- the market, resulting in large price spikes that lead to reductions in demand; and
- the government, via emergency conservation programmes,

both are costly and the result of market failures. These market failures occur when market participants either do not have full information regarding the probability of supply and demand imbalances, or there is no means for them to signal their willingness to pay for lower price volatility. There can also be elements of moral hazard—the likelihood of government intervention in the form of emergency conservation programmes reduces the incentive for companies to hedge.

Without trying to define security of supply with precision, it implies that demand is met at all times, with **reasonable** price certainty and without the need for emergency government conservation programmes.

For this analysis we measure relative levels of security with and without Project Aqua as the difference between levels of demand and supply. And because there is little change in demand, this is effectively the change in quantities of potential supply. We make no estimate of the value of increased security. The analysis estimates the requirements, in terms of additional capacity, to achieve the same level of security in the (higher of the) two scenarios, without estimating whether this is an optimal level of security.

2.2. Analytical Approach

Concept suggests[3] that Project Aqua is unlikely to alter the underlying hydro variability risk in 2011/12. They also suggest that Aqua will lead to an increase in annual variability of hydro production by "between 4 and 12% (depending on whether variability is considered on a South Island or NZ basis)"[4]. Concept uses this in sensitivity analysis by assuming an 8% increase in the Electricity Commission's reserve requirement.

We have revisited this analysis below using the limited information available in order to extend it beyond 2012/12. Concept have provided output from model runs that show the projected weekly generation in 2011/12 from Project Aqua, the

[3] Concept Consulting Group (2003a) Project Aqua. Potential Security of Supply Contribution in 2011/12.

[4] Concept Consulting Group (2003b) Project Aqua. An Evaluation of the Economic Impact. Appendix 2, p41.

Waitaki system as a whole, other South Island hydro and other plant under different hydrological input assumptions. The analysis to produce these projections has used historical hydrological input data for the years 1931 to 2002.

For our analysis we examines the time period in which generation output is lowest from the hydro system in both "with" and "without Aqua" scenarios. We combine this with assumptions regarding potential load factors for the plants that are different between the two scenarios to estimate the difference in potential output from the system as a whole.

As we are examining the period with the lowest projected output, we assume that there are no transmission capacity constraints that affect the results. Where analysing weekly output, we assess levels of generation output for the same week in years with different assumed level of hydrological input to ensure that demand is not the constraint on output. On the basis of these checks and assumptions, we are reasonably confident that the recorded output is the maximum potential output from the hydro system in that time period.

However, there are limitations to this analysis and to the conclusions that can be drawn. Most importantly because we have not used a full system model to examine supply-demand balances in all sub-periods, we have had to make assumptions about the extent to which generation can be shifted within a year through storage management. This can have a considerable impact on the risk of supply-demand imbalance.

2.3. Annual Supply Risk

The security test assesses the total potential supply in the system at the weakest point, which is chosen on the basis of demand relative to potential supply. Concept provides estimates of additional system capacity in different years under the "with" and "without Aqua" scenarios. The assumptions for 2011 and 2020 are shown in Table 1 alongside estimates of generation potential. If Project Aqua is built, there will be a number of other plants built, in addition, in the years before and after. There will be a different number built if Project Aqua is not commissioned. In Table 1, and following Concept's approach, we record only the aggregate difference in capacity. The Project Aqua scenario is recorded as that project alone. The capacity and generation estimates in the "without Aqua" scenario represents the difference between the additional generation in the two scenarios. For example, the "with Aqua" scenario includes 250MW of additional installed coal capacity by 2020, whereas the "without Aqua" scenario includes 350MW, ie a difference of 100MW.

The additional generation potential in the "without Aqua" scenarios can be compared with the estimated minimum net generation from Project Aqua. This is estimated from Concept's data that record expected minimum output from the South Island hydro system as a whole under with and without Project Aqua scenarios. The smallest difference, representing the smallest expected net contribution from Project Aqua, is 2,038 GWh.

Table 1: Potential generation from Aqua compared to additional plant without Aqua

	With Aqua		Without Aqua (2011)[1]		Without Aqua (2020)[2]	
Plant type	Capacity (MW)	Annual Generation (GWh)	Capacity (MW)	Annual Generation (GWh)	Capacity (MW)	Annual Generation (GWh)[3]
Hydro	524	3000	39	188	13	63
Cogen			75	624	70	583
Wind			75	276	87	320
Geothermal			50	416	105	874
Coal					100	701
Total		3000	239	1504	375	2540

[1] Concept Consulting (2003a), Table 3, page 10; [2] Concept Consulting (2003b) Table 9, page 24; [3] Not provided by Concept but estimated using the same load factors as for 2001 (hydro=55%, cogen=95%; wind=42%;geothermal=95%) plus an 80% load factor for coal

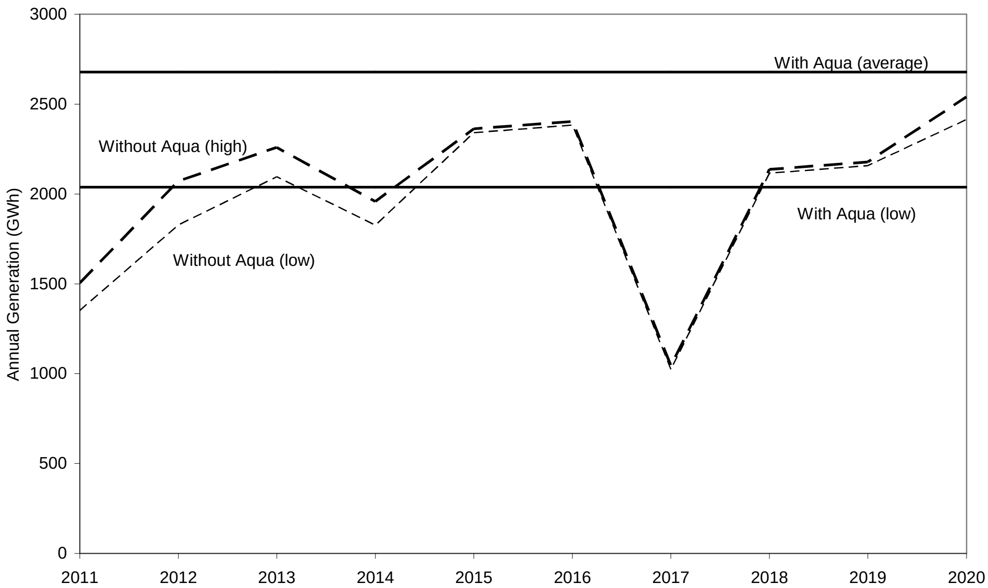
In the "without Aqua" scenario, the additional small-scale Hydro plants would be similarly vulnerable to dry-year risk, and wind vulnerable to low-wind year risk. Assuming either full or no output from those two source types, Project Aqua would provide security of supply benefits in 2011 but not in 2020.

Figure 1 shows the picture over time for two "without Aqua" scenarios. It compares generation from Aqua with potential generation from the plant that would be additional in the "without Aqua" scenario.

- The high scenario assumes that all additional plant can generate at the load factors in the note to Table 1 above.
- The low scenario assumes that load factors are reduced by one third for hydro and wind generation.

The "with Aqua" scenario is pictured solely as the generation from Project Aqua, ie either 2678GWh (Concept's model output) or 2038MW (minimum dry year net contribution). The "without Aqua" scenario represents the difference in output from all the additional plant in the two scenarios. So, in 2011, it is estimated that in the "with Aqua" scenario there is 523GWh of generation from new plant additional to Aqua (ie the mix of new small hydro, cogen, wind, geothermal and coal plant), compared with 2027GWh from additional plant in the "without Aqua" scenario, a difference of 1504GWh.

Figure 1: Estimated annual generation from Aqua and from additional plant without Aqua



The "without Aqua" scenario provides greater security of supply in most years after 2011, apart from 2014 and, more dramatically, 2017 when a 200MW Southland lignite plant is assumed to come on line in the with Aqua scenario. In the "without Aqua" scenario a 150MW lignite plant comes on stream in 2018; bringing this lignite plant forward by one year would eliminate the lower security of supply risk trough in the "without Aqua" scenario.

Overall, the picture is of a reduced level of security (measured as total potential generation) in the "with Aqua" scenario, largely because the alternative plant without Aqua, although lower in total capacity, provide greater certainty of output. By 2020 there is a gap of 376-502 GWh. This could be covered by 43-57MW of reserve capacity. Although, if the gap was concentrated over a shorter (eg 4-month) period of the year, this reserve capacity to achieve the same level of potential output would need to be larger (129-172 MW).

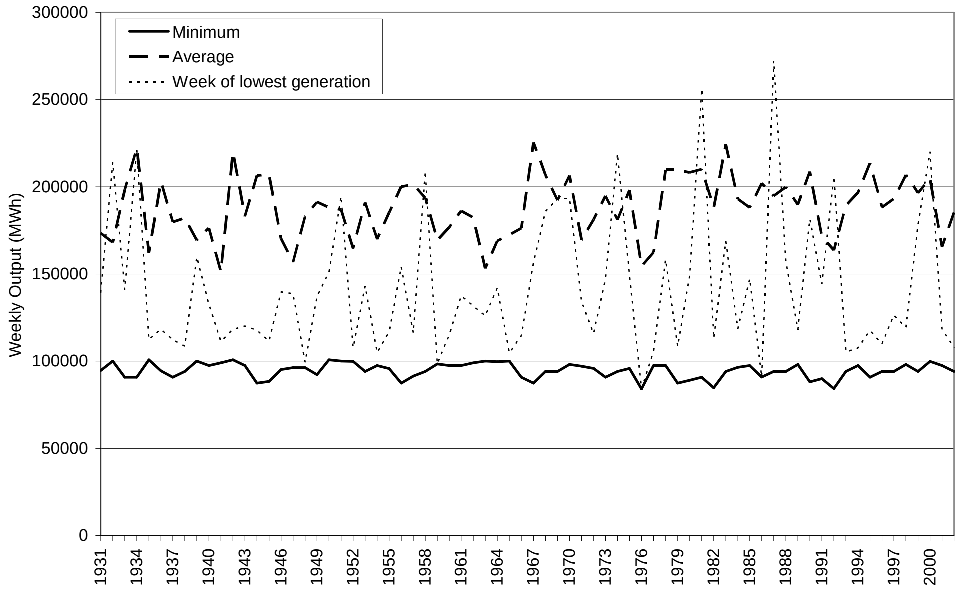
2.4. Weekly Supply Risk

An alternative way to analyse the security issue is to examine the total level of supply at the lowest point, measured across a much shorter period. Concept suggests "the possibility that Project Aqua may itself need to be shut down altogether at times of low flows so as to maintain residual flows in the lower Waitaki River"[5]; this is consistent with Meridian Energy's resource consent application. The effect that this has depends on what happens in the rest of the system.

[5] Concept Consulting Group (2003a) Project Aqua. Potential Security of Supply Contribution in 2011/12, page 5

Figure 2 shows the minimum and average weekly output from the Waitaki system, with Project Aqua in 2011/12. The minimum weekly output is 84,000MWh in the week starting on 13th June 2011 in a 1976 hydro input year. The graph shows that this is also a year with a very low average output, which confirms that this is the constraining factor. And the line showing output in the week of lowest generation (starting 13th June) in other hydro input years shows that this low output is not demand constrained. In contrast, the lowest weekly output from the Waitaki system in a "without Aqua" scenario is 30,240MWh, suggesting a minimum net weekly contribution of 53,760. This assumes that, within any year, generation can be shifted between weeks. In practice there will be constraints on this. The same analysis undertaken for the South Island hydro systems as a whole (Waitaki + Clutha + Manapouri) suggests a minimum net weekly contribution from Project Aqua of 42,388 MWh.

Figure 2: Weekly Output from Waitaki System

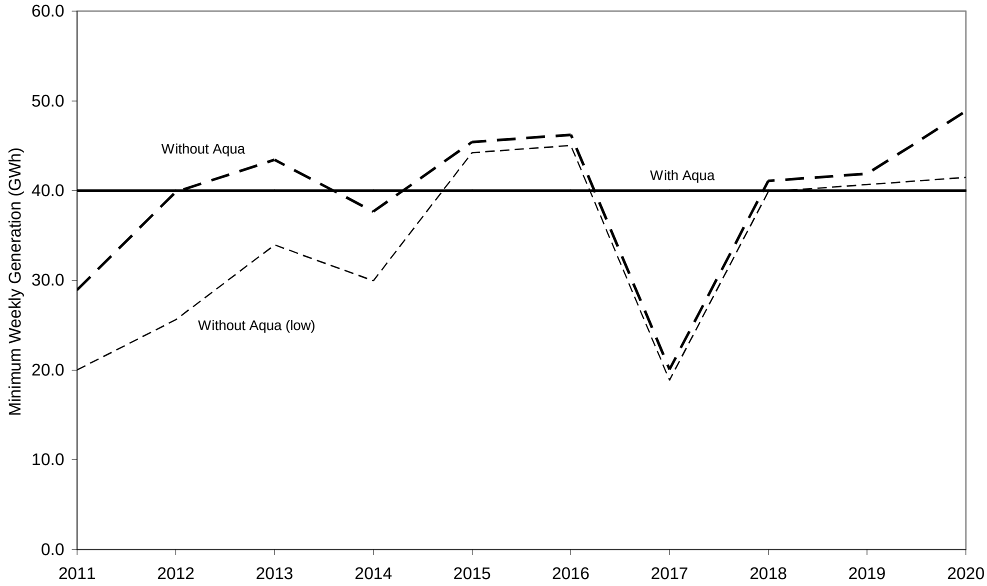


The numbers suggest a larger lowest potential net contribution from Project Aqua than is estimated using the annual analysis.

Taking an alternative approach—the difference, between scenarios, in weekly generation in the week with the smallest difference between scenarios, produces a weekly greater net output of 43,848 MWh for the Waitaki system with Project Aqua; and if analysed for the South Island hydro system as a whole, there are some weeks in which output is greater in the "without Aqua" scenario, ie there is no or a negative net contribution from Project Aqua. This is obviously an underestimate, largely because there is some ability to shift generation between weeks which this analysis does not take account of.

The extent to which there is the potential to shift generation between weeks, via storage management, determines the actual potential net contribution of project Aqua. If we assume a high ability to shift generation, we should adopt a figure closer to the higher figure for the South Island system analysis, eg 40,000MWh. This, together with expected output from the other generation options, suggests a small difference between scenarios in terms of minimum potential output. It implies a reserve capacity requirement in 2020 in the order of 9-38MW to ensure the same level of potential output; the low end of this range assumes no output from wind plant. The effect is much less pronounced than for the annual analysis and there are longer periods in which the "with Aqua" scenario is contributing more to security of supply (Figure 3).

Figure 3: Estimated weekly generation from Aqua and from additional plant without Aqua



Taking the more dramatic assumption of no net contribution from Aqua, in comparison with the "without Aqua" scenario that included no output from additional hydro and wind, the reserve capacity in 2020 to provide the same level of security of supply would be 247MW.

These effects can be modelled as additional capital expenditure required under the "with Aqua" scenario. Three scenarios of reserve capacity requirement, and their costs, are shown in Table 2. Note these reserve requirements are simply an assessment of the costs of ensuring that the minimum quantity of potential generation output is the same in the two scenarios. It makes no assumption about whether this level of reserve should be provided.

For the base case, we have assumed a 40,000MWh weekly potential net contribution from Project Aqua and a 31MW reserve requirement, which assumes new wind and small hydro at 50% of average load factor in the "without Aqua" scenario. This has been assumed to come on line in two blocks of 15.5MW—one in 2015, the other in 2020.

The high reserve scenario takes the more dramatic assumption of covering periods with a zero net contribution from Project Aqua.

The low reserve scenario assumes a 9MW reserve requirement. This is based on the same assumptions as the base case but a zero load factor for wind and small hydro.

Table 2: Reserve Generation to Cover Dry Year Risk from Project Aqua

	Base Case		High Reserve		Low Reserve	
	Reserve Capacity (MW)	Cost ($ M)	Reserve Capacity (MW)	Cost ($ M)	Reserve Capacity (MW)	Cost ($ M)
2010			50	50		
2011						
2012						
2013						
2014						
2015	15.5	15.5	100	100		
2016						
2017						
2018					9	9
2019						
2020	15.5	15.5	100	100		
Total	**31**		**250**		**9**	
NPV in 2004 @ 10%		**8.81**		**85.04**		**2.37**

Note: assumes capital cost of $1,000/KW

2.5. Limitations of the Analysis

There are limits on how these results should be interpreted and in the analysis.

The costs summarised in Table 2 are estimates of the capital costs to ensure the level of potential generation, when potential generation is at its lowest point, is the same in both scenarios—with and without Project Aqua. This has not compared levels of supply with levels of demand at that point, nor has it assessed the value of making up this difference in potential generation.

In terms of analysis, we have used data produced for 2011/12 and assumed that the lowest output figures represent maximum potential generation in those time periods, constrained by hydrological input. We believe that this assumption is reasonable. However, the estimates require assumptions to be made about the extent to which generation within the hydro system can be shifted over time within a year through storage management. Our base case analysis assumes a relatively high ability to shift generation.

The analysis has been undertaken at the national level and has not taken into account capacity constraint in parts of the system. Levels of security of supply will be affected also by the location of supply.

The security of supply implications would be better assessed through modelling the location of new supply against transmission capacity constraints, and through assessing vulnerability to loss of transmission capacity. For example, Project Aqua is located in the South Island but its commissioning might result in less North Island capacity and mean the system is more vulnerable to loss of the HVDC transmission failure. This analysis is beyond the scope of this work.

3. Inputs to Cost Benefit Analysis

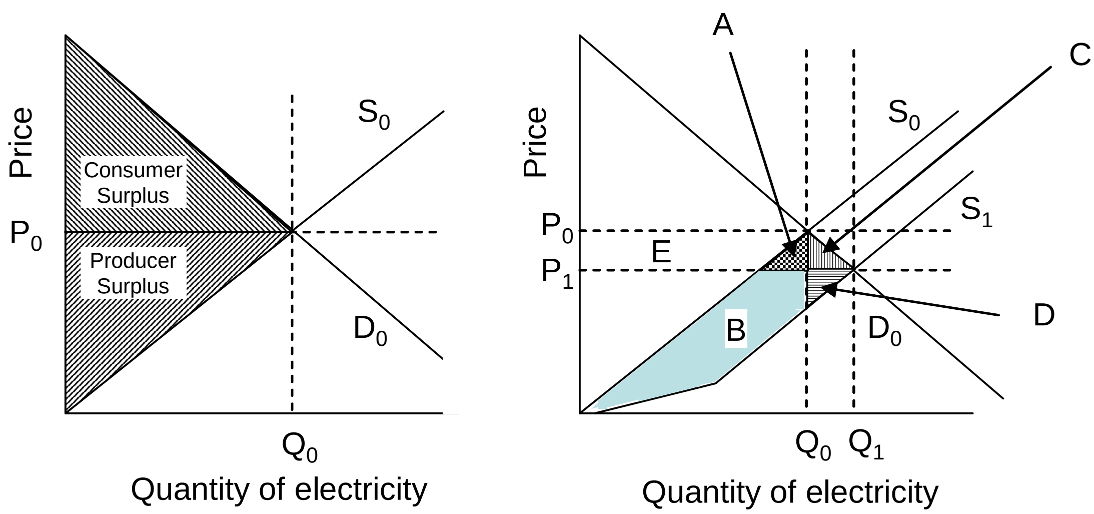
3.1. Approach to Analysis

This section sets out a proposed approach to calculating the differences in costs and benefit of Project Aqua versus a without Project Aqua counter-factual.

The national cost benefit analysis of Project Aqua is seeking to identify the total net national benefit of the project. This is explained in Figures 4a and 4b. The net benefit of current electricity supply is shown in Figure 4a as the shaded area between the supply curve (S_0) and the demand curve (D_0). The demand curve represents consumers' marginal willingness to pay for electricity, ie the benefit that they gain from electricity use; at the left hand side of the figure some consumers are willing to pay a very large amount per MWh and gain a significant benefit (consumer surplus) when purchasing electricity at the lower market price (P_0). As we move towards the right in the diagram, successive consumers have reduced willingness to pay and the quantity consumed stops at the point (Q_0) where marginal willingness to pay is equal to the market price. The shaded area below the demand curve and above the market price is the consumer surplus.

Figure 4: Impacts of Project Aqua

4a Benefits of Current Supply **4b** Benefits of Project Aqua



The other shaded area in Figure 4a is the producer surplus. The supply curve represents the marginal cost of supplying electricity. The difference between the marginal cost of supply and the market price represents the producer surplus.

Figure 4b shows the potential gains from Project Aqua. As a result of Project Aqua, the marginal cost of supply drops to S_1. This assumes some initial lower marginal cost of generation and then generation costs increasing at the same rate as before. As a result marginal costs are lower for a given level of generation, so the market price falls to P_1 and consumption increases to Q_1. The net benefits of the project are made up of the four shaded areas. This includes:

- (A) = additional consumer surplus, representing the net benefits of a price drop to current consumers;
- (B) = additional producer surplus because of lower costs of generation;
- (C) and (D) which represent additional consumer and producer surpluses associated with any additional electricity consumption.

Unshaded area (E) is a transfer from producer to consumer surplus. It represents the price cut for consumers that reduces producer profit.

The separate components of welfare gain are calculated below.

3.2. Changes in costs of supply

The analysis in this section estimates the size of shaded areas A and B in Figure 4b.

Concept Consulting has undertaken an NPV analysis of the two scenarios. It estimates the difference in total generation costs for the New Zealand electricity system, including capital, fixed operating costs, fuel and carbon costs. This can be used to estimate the areas under the supply curve[6]. We have not questioned the basic annual cash flows used in the analysis. However, some of the data that Concept has used to estimate residual values are not suitable for a national cost benefit analysis; these have been estimated in Section 4.

Concept Consulting's estimates of the differences in costs between with and without Project Aqua scenarios are shown in Table 3. The negative numbers represent a period when the "with Aqua" scenario has lower costs, eg in 2004 when there is cogen capacity built in the "without Aqua" scenario and thus a lower capital expenditure in the Aqua scenario. The analysis suggests that, ignoring residual values, Project Aqua has a net national additional cost of supply of $19million in 2004.

The Concept analysis estimates the costs to supply the same amount of electricity in with and without Project Aqua scenarios. No demand response to the lower projected marginal electricity price has been assumed. Thus the difference in costs represents shaded areas A and B in Figure 4b above, although, as Project Aqua has a higher net cost in some periods, the supply curve (S_1) is above S_0 for at least some of its length.

[6] Strictly speaking the diagram shows the marginal cost of supply curve. We have treated annualised capital costs as an element of marginal cost. This does not matter as the analysis has not been used to define market price. But as producer surpluses must be used to cover the cost of capital, including them within the estimate of supply costs takes away the need for a second step.

Table 3: Economic Impact of Project Aqua – Differences between with and "without Aqua" scenarios ($ million)

	Capital Expenditure			Annual Cost			
Year	Generation	Transmission	Reserve	O&M	Fuel	Emissions	Total Cost
2003	0	0	0	0	0	0	0
2004	-13	0	0	0	0	0	-13
2005	-13	0	0	0	2	0	-11
2006	107	0	0	0	2	1	109
2007	107	0	0	-1	1	0	108
2008	113	0	0	1	4	1	119
2009	-106	0	0	3	-23	-6	-132
2010	75	80	0	-2	-30	-7	116
2011	-150	0	0	-1	-45	-11	-207
2012	132	0	0	-7	-24	-5	96
2013	122	0	0	-7	-24	-8	83
2014	-23	0	0	-5	-34	-11	-73
2015	-19	-80	0	-6	-24	-19	-147
2016	401	0	0	-6	-23	-18	354
2017	-334	0	0	2	-59	-10	-401
2018	-19	0	0	-5	-29	-16	-68
2019	-200	0	0	-5	-28	-15	-248
2020	0	0	0	-10	-15	-11	-37
NPV @10%	197	17	0	-17	-132	-47	19

Note: Adapted from Concept Consulting (2003b) and excludes Residual Values.

3.3. Welfare gains from additional generation

The analysis in this section estimates the welfare gains pictured as shaded areas C and D in Figure 4.b above.

The analysis described above provides a comparison of the differences in costs between generation with Project Aqua and without.

Project Aqua is expected to result in a difference in electricity prices that, in turn, is expected to result in some change in electricity demand. The welfare gains associated with these changes needs to be considered. As a result of the additional electricity sold there will be additional consumer and producer surpluses.

The demand response to the price effects of Project Aqua are estimated using price elasticities of demand provided by MED (Table 4). Thus a 1% increase in the price of electricity leads to an immediate 0.08% reduction in residential consumption. These were combined with the demand data used by Concept Consulting in its analysis.

Table 4: Price elasticities of demand

Timeframe		
Industrial & Commercial	Short-run	-0.06
	Long-run	-0.28
Residential	Short-run	-0.08
	Long-run	-0.21

Source: MED (2003) New Zealand Energy Outlook to 2025.

Wholesale prices were converted to a weighted set of final prices to examine the price changes. Using MED demand projections[7], an annual proportion of total demand was split between industrial & commercial and residential sectors; this averaged 67.5% industrial and commercial over the period to 2020. Of this, 67% was assumed to be industrial and 33% commercial, on the basis of current demand[8]. Using current prices, price adders to wholesale prices for the different markets were assumed to be: 2c/kWh (industrial), 5c/kWh (commercial) and 9c/kWh (residential).

The short-run elasticities were used with annual differences in price. The long-run elasticities were combined with lagged estimates of price changes. After five years of lower prices, the long run elasticity was combined with the smallest change in price during that period as an estimate of the market's estimate of the long-run change in price, ie if every year saw at least a 10% reduction in price this was taken as the long run price change. The short run elasticity was then combined with the difference between the long run and short run estimates of price change, so if the long run estimate was a 10% reduction but this year the price fell by 25%, the short run elasticity was multiplied by 15%. This produced the results shown in Table 5.

These estimates of price and demand change can be used to estimate the change in consumer surplus for the additional quantity of electricity sold. This is estimated as half of the product of the change in price and the change in quantity.

The estimate of the change in producer surplus is estimated by assuming that the shape of the supply curve where it meets the demand curve will be the same in both scenarios, ie the additional generation under the Project Aqua scenario introduces some low cost generation and pushes the remaining supply curve to the right. Thus the angle of the supply curve can be estimated from the change in electricity price and the difference in generation from the additional plant in the two scenarios. Using these two approaches, the discounted sum of the consumer and producer surpluses to 2020 are estimated to total $3.2 million and $1.2 million respectively in 2004.

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[7] Ministry of Economic Development (2003) New Zealand Energy Outlook to 2025.

[8] Ministry of Economic Development (2003) Energy Data File

Table 5: Price and demand responses to Project Aqua

Year	Wholesale Price (c/kWh)		Weighted Final Price (c/kWh)		Quantity (GWh)	
	With Aqua	Without Aqua	With Aqua	Without Aqua	With Aqua	Without Aqua
2005	5.65	5.65	10.62	10.62	42,057	42,057
2006	5.90	5.90	10.86	10.86	42,829	42,829
2007	5.90	5.90	10.85	10.85	43,543	43,543
2008	6.20	6.05	11.14	10.99	44,146	44,225
2009	6.30	6.38	11.23	11.32	44,920	44,877
2010	6.30	6.76	11.22	11.68	45,732	45,498
2011	6.30	7.14	11.23	12.06	46,531	46,114
2012	6.31	7.21	11.24	12.14	47,177	46,724
2013	6.55	7.35	11.48	12.28	47,735	47,330
2014	6.95	7.40	11.88	12.33	48,156	47,930
2015	7.28	7.40	12.21	12.34	48,572	48,524
2016	7.40	7.40	12.34	12.34	49,107	49,112
2017	7.40	7.40	12.34	12.34	49,693	49,693
2018	7.40	7.40	12.35	12.35	50,267	50,267
2019	7.40	7.40	12.35	12.35	50,833	50,833
2020	7.40	7.40	12.35	12.35	51,391	51,391

Source: Wholesale Price and "without Aqua" quantity data from Concept Consulting

4. Residual Values

4.1. Approach to Calculation

The analysis of costs to this point has been undertaken over the period to 2020. However, plant will have an economic life that extends beyond this time. To take account of this the residual values of Project Aqua and other new plant at the end of 2020 have been estimated by Concept.

The estimate of residual value is significant. Concept estimates a difference in residual value between with and without Aqua scenarios of $637million in 2021. The present (2004) value of this sum, at a 10% discount rate, is a $126million benefit of Project Aqua, ie greater than the estimated total cost of the project ($19million). It results in a project NPV of $108 million in 2004.

The residual value calculation should be the same as for the current analysis of costs and benefits; the value to society is the sum of surpluses going forward associated with the plant with residual life. And as above, most readily the difference in residual value is estimated from the difference in costs of generation in the two scenarios, ie there is some transfer between consumer and producer surplus associated with any ongoing price reduction, and an absolute gain in producer surplus from the lower generation costs.

Concept has measured average savings in annual O&M, fuel and emissions costs for the period 2018-2020 associated with the "with Project Aqua" scenario, relative to "without". These have been extended over the next 30 years. For capital costs, they have used an accounting approach which depreciates the capital assets over time to provide a final book value as a proxy for future capital expenditure savings.

We have adopted a different approach which attempts to extend the existing analysis forward for the lifetime of Project Aqua.

Concept's analysis has not extended the estimates of electricity price differences beyond 2020. This means that the estimate of welfare increases associated with any ongoing increases in electricity consumption cannot be estimated. This is not a major shortfall in the analysis as the price differences would not be expected to be significant.

4.2. Estimates of Residual Value

Our analysis below has two elements:

- An analysis of the value of the new plant that are different between the two scenarios;
- An analysis of the differences in other costs in the system, including future expected differences in capital costs.

4.2.1. Cost Difference for New (2004-2020) Plant

In Section 3, the costs differences were estimated for the new plant that were assumed for the "with" and "without Project Aqua" scenarios. The cost differences for these plants beyond 2020 by using assumptions about future load factors and operating costs, including fuel and carbon costs. Plants are assumed to retain constant load factors over time and then close at the end of their estimated economic lifetime; we have used the assumptions listed in Table 6.

Table 6: Assumptions for Residual Value Analysis

	Hydro (incl Aqua)	Cogen	Wind	Geo-thermal	Coal (lignite)	Coal (other)
Plant life (years) [1]	40	30	20	30	30	30
Load factor	55%	95%	42%	95%	80%	80%
Fuel costs ($/GJ) [2]	0	5	0	0	0.33	1.2
Emission rate (t CO_2/GJ) [2]	0	0.0528	0	0	0.0952	0.0912
Plant efficiency [3]		35%			35%	35%

[1] Source = MED. [2] Source = Concept; carbon is priced at $15/t CO_2. [3] Source = Concept, except 35% efficiency for Cogen is Covec assumption on efficiency for the electricity cycle, ie it is used to estimate fuel (and emissions) to generate a given quantity (kWh) of electricity rather than kWh of electricity and heat combined.

The difference in residual value between the two scenarios is estimated from the difference in future costs of generation. In years where a plant is still generating, we estimate the costs using fuel costs, emission costs and O&M costs. The cost difference is estimated at $462 million discounted to 2020—this is the reduction in costs under the Project Aqua scenario—or $508 million in 2021. It has a value of $101 million in 2004.

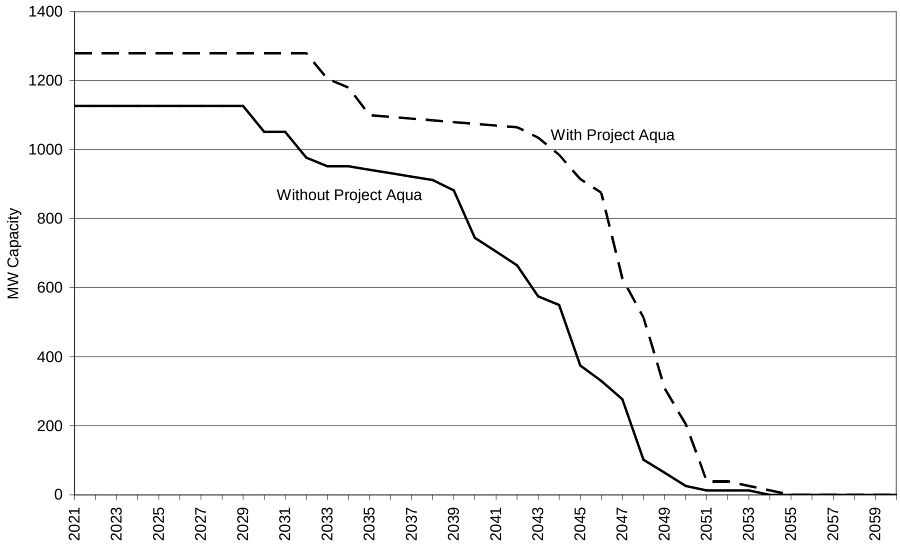
4.2.2. Additional Cost Estimates

The analysis of costs at these new plants does not take account of all the cost differences.

Firstly, as a result of the different investment scenarios, there will be different levels of generation at existing plant (ie plant existing in 2004) and thus differences in their residual values in 2020. There would be expected to be higher load factors at some of these existing plants in the "without Project Aqua" scenario, which increase their running costs.

Secondly, because Project Aqua (and other hydro plants) are expected to have longer lifetimes than other plant types, the "without Aqua" scenario would show additional levels of capital investment after 2020. Figure 5 shows the total cumulative new capacity in the "with" and "without Aqua" scenarios on the basis of the assumptions made about investments in the 2004 to 2020 period. The volume of this new capacity declines over time as the plants reach the end of their economic lives. In all years there is more new capacity in the "with" scenario. As a result, there will be some additional consumption (because of price changes), some changes in load factors at existing plant (lower with Aqua), but there will also be a greater requirement for investment in new plant in the period after 2020 in the without Aqua scenario.

Figure5: Additional plant capacity in with and without Project Aqua scenarios

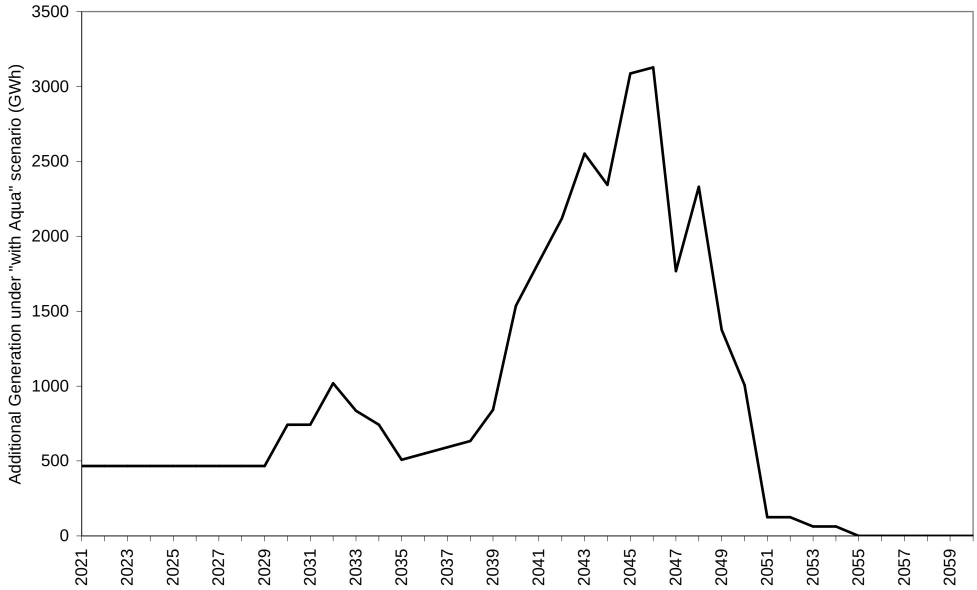


Clearly any additional investments cannot be considered as elements of residual value of plants in the analysis to 2020. But, by extending the analysis beyond 2020 (which is what consideration of residual value does), the differences in levels of investment beyond 2020 matter. Including these considerations would result in additional costs in the "without Aqua" scenario.

Some additional costs should be added to the "without Aqua" scenario. As a means of estimating these costs, the difference in expected generation from the additional capacity in the "with" compared to the "without Aqua" scenario is shown in Figure 6 This sums the expected generation from Project Aqua and the other new plants assumed in the "with Aqua" scenario, and subtracts the expected generation from new plant in the "without Aqua" scenario. The quantity goes up over time because many of the new plant in the "without Aqua" scenario have shorter expected lifetimes.

If we are simulating the differences in costs over the lifetime of Project Aqua, we need to assess the costs of making up this gap as an additional element of costs to the $101 million in 2004 estimated above. A simple method is to assume an average cost per MWh to represent some average of avoidable costs, which in practice would be a mix of the costs of additional generation at existing (in 2004) plant, and the annualised capital plus operating costs of new plant commissioned after 2020; it would tend over time towards including more capital costs as more new plants were required. At an average of $25/MWh this would result in total additional costs of the "without Aqua" scenario of $172 million in 2020 or $37 million in 2004.

Figure 6: Additional generation from new capacity in "with Aqua" scenario relative to generation "without Aqua"



For our analysis we have taken the assumptions shown in Table 7 in estimating the residual values. Our base case figure of $138 million is slightly higher than Concept's estimate, using a different methodology, that discounts to $126 million in 2004.

Table 7: Residual value of Project Aqua in 2020 relative to the Without Project Aqua Scenario discounted to 2004

	Assumptions for costs of meeting generation shortfall	Future costs for 2004-20 plant	Meeting generation shortfall	Difference in total future costs
			$ million	
Base Case	$25/MWh	100.63	37.37	138.00
High Case	$50/MWh	100.63	74.74	175.38
Low Case	$10/MWh	100.63	14.95	115.58

These are significant and uncertain elements of the analysis and are the result of Project Aqua having a long project life and insignificant ongoing operating costs. The better way to estimate these cost differences would be to extend Concept's more detailed analysis, undertaken to 2020, out to the end of the expected lifetime of Project Aqua.

5. Summary of Impacts

Table 8 summarises the net impacts of Project Aqua in 2004 using a 10% discount rate. It shows net benefits of Project Aqua of $114 million in the base case, $158 million under a high value scenario and $16 million under a low value scenario. The analysis does not include sensitivity around the initial cost estimates as included in the Concept analysis. These net benefits of the project would need to be compared with any environmental effects of construction not considered in analysis here.

Table 8: Summary of Effects of Project Aqua
(Discounted to 2004 @10% discount rate)

	Corresponding shaded area in Figure 3b	Effect of Project Aqua ($ million)		
		Base Case	High	Low
Supply Cost	A + B	-19.18	-19.18	-19.18
Residual value/post-2020 cost reduction	A + B	138.00	175.38	115.58
Welfare (deadweight) gain from increased consumption	C + D	4.30	4.30	4.30
Reserve requirement	A + B	-8.81	-2.37	-85.04
Total		**114**	**158**	**16**

In addition to the sensitivities shown above, the discount rate can be varied. For national cost benefit analysis the appropriate discount rate is a social rate of time preference, made up of pure time preference[9] and a measure of future marginal utility of income[10]. It can also be measured as the social opportunity cost of capital, ie the cost of displacing capital from some other use which would have yielded net benefits to society. Assessments of public sector rates often yield lower discount rates than used by the private sector.

Using 7.5% and 5% rates produces the results shown in Tables 9 and 10 below.

[9] The rate at which individuals discount future consumption over current consumption

[10] reflects the assumption that future individuals are likely to be better off, ie have greater total consumption, whereby marginal additional consumption is less highly valued

Table 9: Summary of Effects of Project Aqua
(Discounted to 2004 @7.5% discount rate)

	Corresponding shaded area in Figure 3b	Effect of Project Aqua ($ million)		
		Base Case	High	Low
Supply Cost	A + B	26.50	26.50	26.50
Residual value/post-2020 cost reduction	A + B	246.64	321.70	201.61
Welfare (deadweight) gain from increased consumption	C + D	5.15	5.15	5.15
Reserve requirement	A + B	-11.87	-3.27	-108.97
Total		**266**	**350**	**124**

Table 10: Summary of Effects of Project Aqua
(Discounted to 2004 @5% discount rate)

	Corresponding shaded area in Figure 3b	Effect of Project Aqua ($ million)		
		Base Case	High	Low
Supply Cost	A + B	95.18	95.18	95.18
Residual value/post-2020 cost reduction	A + B	459.90	619.81	363.96
Welfare (deadweight) gain from increased consumption	C + D	6.21	6.21	6.21
Reserve requirement	A + B	-16.16	-4.55	-141.59
Total		**545**	**717**	**324**

The net benefit of the project is larger under the lower discount rates; dramatically so at a 5% rate. This is particularly because of the long project life and the net benefit of post 2020 generation when Project Aqua has effectively zero costs of generation. The longer time-frame for analysis is crucial to understanding the full benefits of this project. There are also net cost reductions in the period to 2020 because of the greater weighting given to cost savings in later years.

The sensitivity of the analysis to discount rate, and the uncertainty over the current use of the 10% rate, suggests that consideration of the appropriate rate for analysis of large projects such as Aqua needs to be considered with some urgency.