

**concept economics**

**REPORT**

**REVIEW OF INPUTS TO COST  
MODELLING OF THE NEM**

**Prepared for:**  
Queensland Competition  
Authority

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## **1. INTRODUCTION**

Concept Economics has been engaged by the Queensland Competition Authority to:

1. review inputs prepared by ACIL Tasman to inform long-run marginal cost projections by CRA International;
2. develop a set of estimates of generation cost data and costs of fuels if required; and
3. offer opinion on the appropriateness of various aspects of a regression analysis of capital costs.

The inputs are for consideration for use in a CRA International model of long run marginal cost (LRMC) of supplying energy to the parts of Queensland connected to the National Electricity Market (NEM). The modelling approach sought by the Queensland Competition Authority is that the LRMC be estimated based on the hypothetical situation that the existing portfolio of generating assets be replaced with a portfolio that minimises cost. For this reason, all technologies that are currently feasible or likely to become feasible in the NEM should be considered by CRA International's model. There are currently a broad range of technologies that are committed to supplying the NEM (in other words, receive orders for supply from NEMMCO).

This report is structured in three parts. Chapter 2 examines capital cost assumptions and describes a proposed new methodology for projecting capital costs. Chapter 3 discusses gas and coal price projections and Chapter 4 presents other parameters required for the LRMC calculation such as thermal efficiencies and operating costs.

## 2. CAPITAL COSTS

This chapter reviews the capital cost projection methodology used by ACIL Tasman in its report *Fuel and Capital Costs in the NEM*. In particular, Concept Economics has been asked to provide a view on ACIL Tasman's proposition that a 'step change' in capital costs occurred in the 24 months leading up to the release of ACIL Tasman's report in October 2008. It is this proposition that led ACIL Tasman to adopt a method of forecasting that differed from the approach used in the past of basing projections on regression techniques.

### 2.1. ANALYSIS OF 'STEP CHANGE' PROPOSITION

ACIL Tasman states that '[their] analysis of actual capital costs to date suggests there is clear evidence of a step like change in capital costs over the past 24 months – mainly driven by changes in steel prices, and to a lesser extent, labour costs' (p. ix). Concept Economics takes a 'step change' to mean a structural break in the time series of nominal capital costs provided by ACIL Tasman in Figures 29 and 36 (for CCGT and coal-fired power plants respectively) of their report.

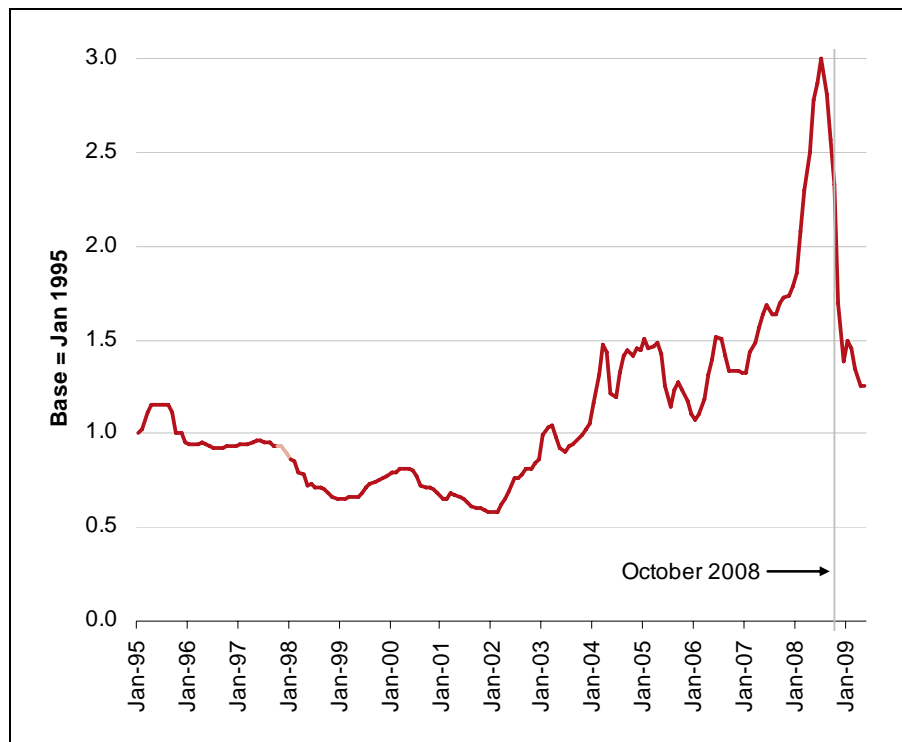
Concept Economics' view is that the data provided in ACIL Tasman's report in October 2008 do show evidence of a step change for CCGT capital costs particularly, but draws attention to two important caveats. The first is that new information revealing substantial moderation in steel prices has become available since October 2008. The second is that the capital cost data that ACIL Tasman used to form its initial view are likely to be the best available, but may not be entirely appropriate for the purpose. These issues are discussed in turn.

#### 2.1.1. New information about a moderation of steel prices

ACIL Tasman's view of a possible step change in capital costs over the past 24 months is that it was 'mainly driven by a change in steel prices' (p. ix). It is the case that steel prices rose steeply over the two or three years prior to October 2008 and that capital costs appeared to increase concurrently. A CRU index of steel prices in the Asian market (based in January 1995) rose from 1.5 in March 2007 to a peak of 3.0 by July 2008 (CRU 2009) (Figure 1).

However, since the release of ACIL Tasman's report, steel prices have fallen by more than 45 per cent by the same indicator. In January 2009 the index series had returned to its March 2007 value of 1.5, and by May 2009 it had fallen to 1.26. Given that the initial basis for ACIL Tasman's step-change hypothesis was the recent increase in steel prices, it follows that the more recent cyclical downturn in steel prices may count against it.

Figure 1. Asia steel price index, base = January 1995



Source: CRUspi, www.crugroup.com

### 2.1.2. Suitability and use of data

It may be that the capital costs data available to ACIL Tasman to draw conclusions about the existence of a step change are not wholly applicable to Australian power plant capital costs. Although the capital costs appear to have been drawn from a range of international projects, it is not clear how the estimates have been treated subsequently in regards to exchange rates. Of course, Australia is too small a market for a consistent, long term series of the capital costs of generation to exist. However, Concept Economics has misgivings about the representativeness of international data if capital costs are converted to Australian dollars at prevailing market exchange rates. Market rates are appropriate for converting the price of internationally-tradable goods between currencies, but the cost of a power plant includes a non-trivial share of non-tradable factors such as labour and land.

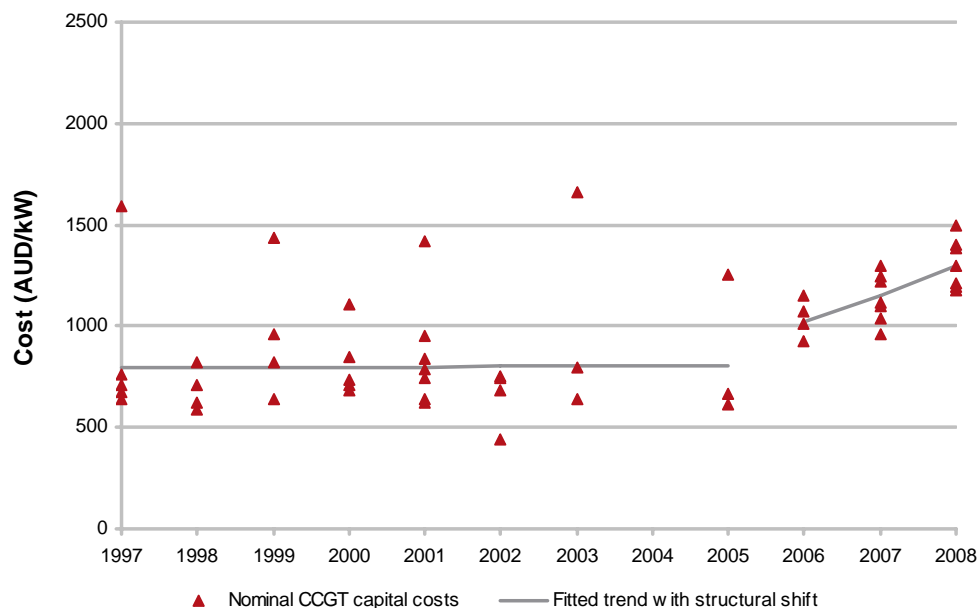
It is noted that the distribution of the estimated costs of CCGT capital projects is much tighter in the years 2006, 2007 and 2008 than in previous years (see Figure 2 on page 4 of this report). The average range of capital costs within a year prior to 2006 is A\$649 (in other words, this is the average of the annual differences between the highest cost project and the lowest cost project in the year). After 2006, the average is A\$295. The non-constant variance can affect the efficiency of statistics tests based on standard errors but more data would be required to comprehensively correct for it.

### 2.1.3. Evidence of a structural break

Despite the fact that commodity prices have fallen by 50 per cent in some cases since October 2008, thereby largely invalidating a step change hypothesis based on a ramp-up in commodity prices, it is still interesting to consider whether a step change can be discerned from the historical data provided in the ACIL Tasman report. Data from Figure 29 in the ACIL Tasman report (that show nominal capital costs for a CCGT power plant) are reproduced as Figure 2<sup>1</sup>. Two separate lines of best fit have been applied (technically, they are log-level models to account for the compounding effect of inflation), and visually these tend to support the conclusion of a step change. There is indeed a sharp rise in estimated CCGT capital costs; after 2005 capital costs increase at a rate of 12 per cent per year, in contrast to years prior when nominal capital cost were barely rising, and certainly at a rate well below inflation.

The two regression lines fitted to the data in Figure 2 have a different slope and intercept, and a F-test was used to determine whether the lines were statistically different or whether it was likely that the differences could have arisen by chance. A significant structural break was found to have occurred and it is concluded that the capital cost data series does show evidence of a step change.

**Figure 2: Nominal capital cost for CCGT**



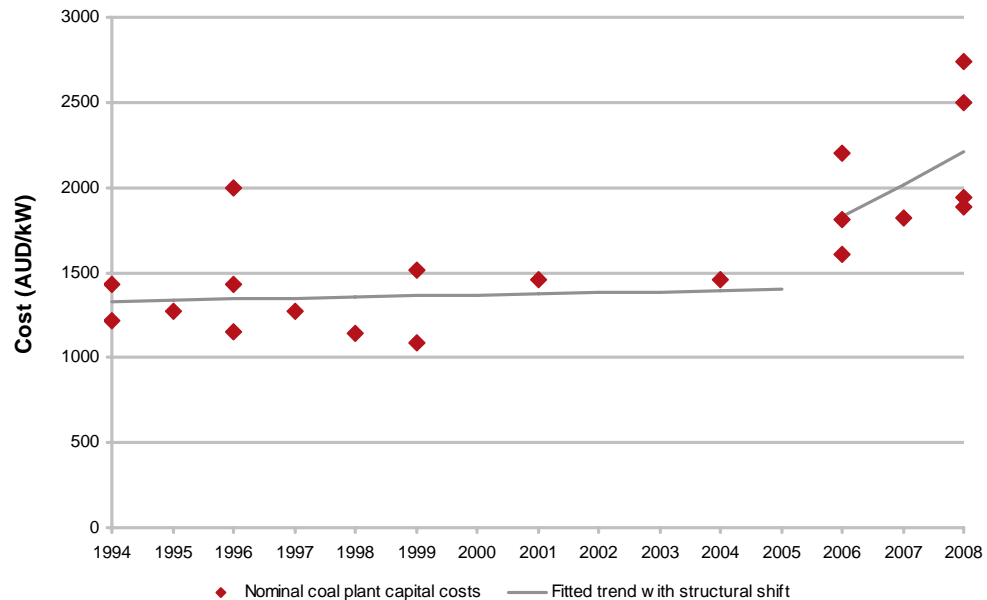
Source: Inferred from charts in ACIL Tasman, *Fuel and capital costs in NEM: Greenfield cost data for the calculation of the 2009/10 BRCI*.

A log-linear model was also applied to the coal power plant capital costs. A structural break, similar to that found in the CCGT capital price series, seems visually to be present in coal power plant capital costs. However, at the 95 percent confidence level it was not possible to conclude that a significant break had occurred. Although the differences in slope appear greater in Figure 3 than in Figure 2, there are fewer datapoints in Figure 3, and those points

<sup>1</sup> Concept Economics did not have access to the data used to generate the charts but inferred it from the charts themselves.

are more dispersed in terms of costs in each year than in Figure 2. More detailed results relating to both regressions are presented in Appendix A.

**Figure 3: Nominal capital cost for new build coal power plant**



Source: Inferred from charts in ACIL Tasman, *Fuel and capital costs in NEM: Greenfield cost data for the calculation of the 2009/10 BRCI*.

It should be noted that while it might be possible with more data to conclude that a step change occurred in the years around 2006, it is not necessarily possible to attribute the increase to any particular factor, unless the reasoned cause can be included in the regression model. The visual step change certainly appears to coincide with a run-up in the price of cement, steel and EPC services but this cannot be stated with certainty with the data presented.

## 2.2. ACIL TASMAN'S APPROACH TO ESTIMATING CAPITAL COSTS

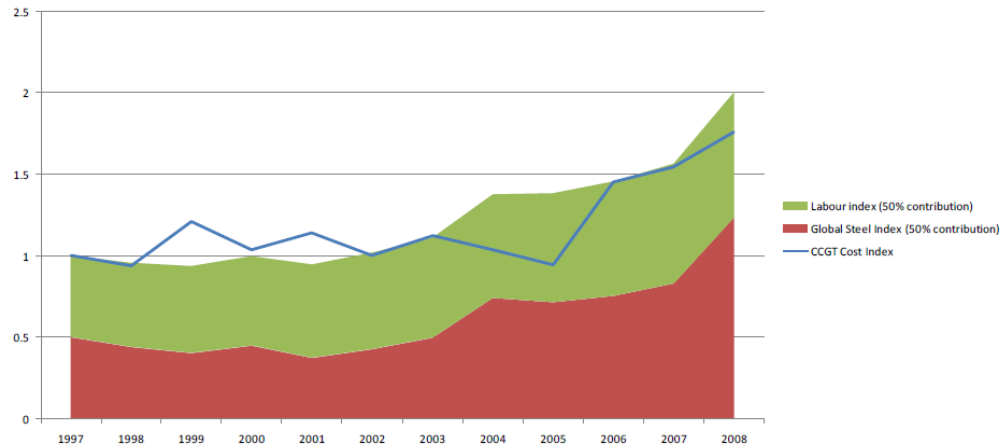
### 2.2.1. CCGT plant capital cost projections

Given the apparent step change in capital costs, ACIL Tasman reasoned that persisting with a regression approach for projections was likely to underestimate future capital costs. Indeed, a regression line would not reflect the recent run-up in capital costs because other points in the historical series would also be given weight.

ACIL Tasman instead projects capital costs by combining indexes of steel and labour prices. The methodology is justified by a visual examination of the fit of the constructed index to an historical index of capital costs. Whether the combined index is a good fit for ACIL Tasman's CCGT capital cost index (where labour and steel are given equal weighting) is subjective (see Figure 4). Nevertheless, there are several points that should be noted.

- Labour and steel are given a 50 per cent contribution to the index in the base year (1997) to reflect relative shares of total cost. Subsequent movements in the steel and labour price indexes change the shares each makes to total cost so that by 2008 the relative contribution of steel and labour costs is approximately 60 and 40 per cent respectively. This is not necessarily in error but may not have been intended.

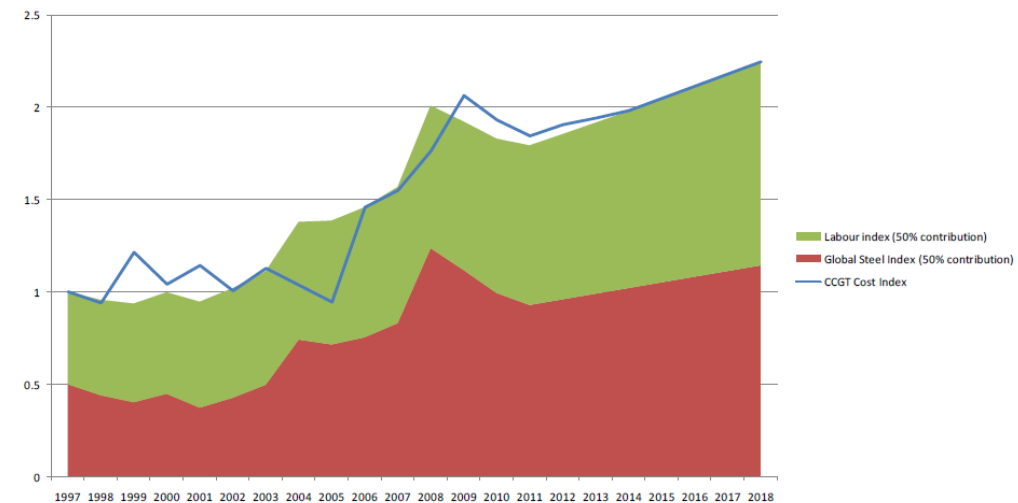
**Figure 4: ACIL Tasman’s comparison between their historic CCGT capital cost index and combined steel and labour cost index**



Source: ACIL Tasman, *Fuel and capital costs in NEM: Greenfield cost data for the calculation of the 2009/10 BRCI*.

On the basis of the historical fit of the CCGT cost index to the labour and steel indexes, ACIL Tasman projects future capital costs by combining projections of a labour price and steel price series out to 2018 (Figure 5).

**Figure 5: ACIL Tasman's projection of the CCGT capital cost index**

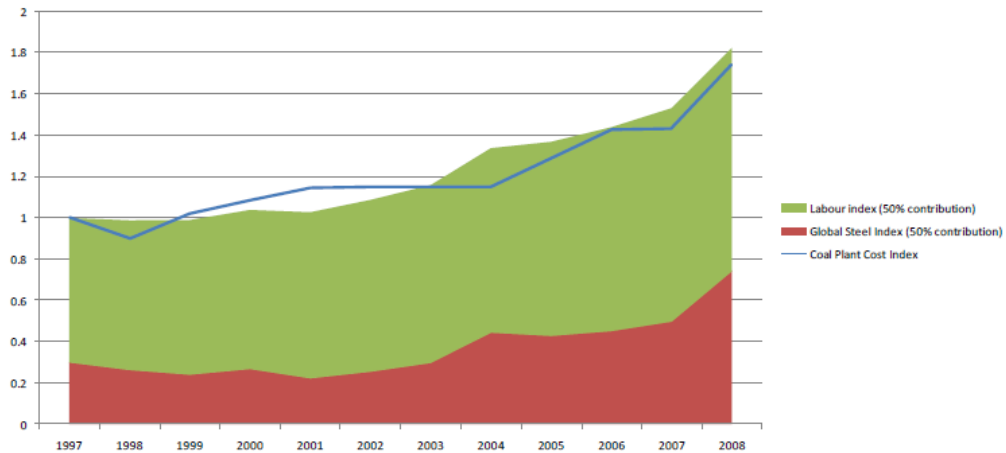


Source: ACIL Tasman, *Fuel and capital costs in NEM: Greenfield cost data for the calculation of the 2009/10 BRCI*.

2.2.2. Black coal plant capital cost projections

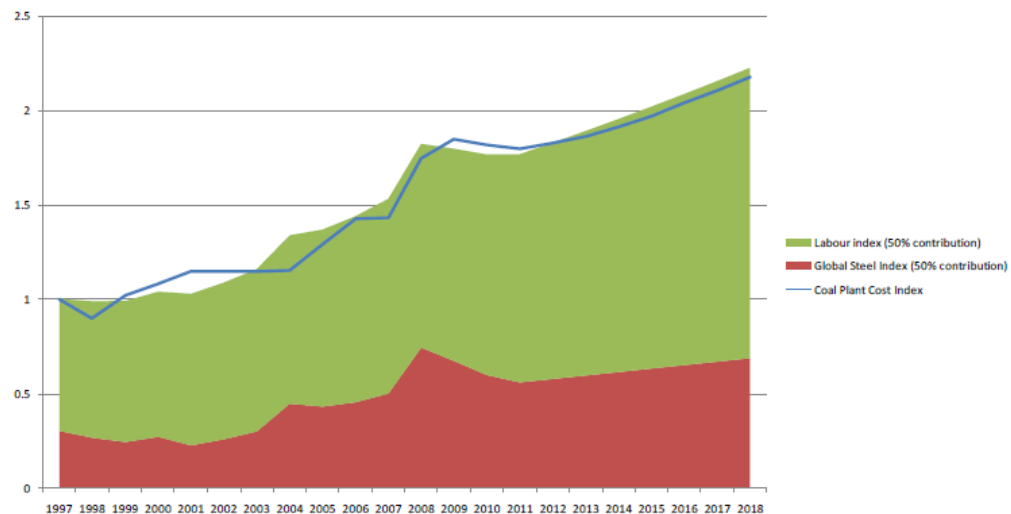
The same methodology with different parameters was used to project black coal plant costs. An index was constructed from steel and labour indexes but this time with a weighting of 30 per cent for steel and 70 per cent for labour. As for the CCGT plant, this weighting only holds for the base year of 1997, which, again, is not necessarily in error.

Figure 6: ACIL Tasman's comparison between their historic coal plant capital cost and combined labour and steel price index



Based on the historical relationship and a projection of labour and steel prices, a projected coal plant cost index is created (see Figure 7).

Figure 7: ACIL Tasman's projection of the coal plant capital cost index



## 2.3. A NEW METHOD OF ESTIMATING CAPITAL COSTS

Concept Economics proposes a new method of projecting power plant capital costs. The approach is a combination of the original regression approach adopted for previous notified price determinations and ACIL Tasman's approach of decomposing capital cost movements into their component parts. In essence, an historical fixed weight index of power plant capital costs is constructed from freely-available and easily-updated data. Then, the constructed fixed weight index is projected into the future over the desired horizon. Well-known international examples of power plant capital cost indexes are the Handy-Whitman index of public utility construction costs and CERA's Power Capital Cost Index. One of the advantages that Concept Economics sees with the proposed approach is that it uses information compiled by the Australian Bureau of Statistics. Another is that it retains the approach of regression analysis that was used in previous notified price determinations.

The proposed index is based on four items:

- A producer price index (PPI) for basic metals. This is intended to account for movements in steel and non-ferrous metals prices used in the construction of power plants (ABS cat. no. 6427.0, tables 10 and 11). Being based on the output of the Australian basic metals industry, movements in the Australian dollar are accounted for.
- A PPI for cement (ABS cat. no. 6427.0, tables 10 and 11) based on output prices of the Australian cement industry.
- A price index for imported materials (ABS cat. no. 6427.0, Tables 12 and 13) that is intended to account for movements in the Australian dollar price of imported components, which would typically be the generating equipment itself.
- An index of average weekly earnings of workers in the construction industry (derived from ABS cat. no. 6302.0 Average Weekly Earnings, table 10I).

### 2.3.1. Determining the weighting for each index in each technology's capital cost

Different power plant technologies differ in the contribution of various inputs to total cost. The index adopted here is a fixed weight index, where the weights refer to an estimate of the contribution of each input to total cost in 2007-08. The same approach was used in ACIL Tasman's report. The weighting scheme adopted for various technologies is shown in Table 1.

**Table 1. Assumed capital cost weighting in 2007-08, by technology**

Factor	Black coal	Brown coal	CCGT	OCGT	Wind	Geothermal	Biomass
	%	%	%	%	%	%	%
Labour	30.0	30.0	32.5	31.5	7.5	30.0	30.0
Cement	7.5	7.5	6.9	7.1	7.5	10.0	7.5
Imported materials	40.0	40.0	40.0	40.0	85.0	40.0	40.0
Basic metals	22.5	22.5	20.6	21.4	0.0	20.0	22.5
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

Labour shares are based on Tegen et al. (2006) and EIA (2007), and are between 30 and 33 per cent (although these sources do not cover all the generating technologies), except for wind where the labour input is assumed to be low relative to the cost of imported turbines and towers. The remaining 70 per cent of non-labour costs (or thereabouts) are assumed to be related to materials (again, except for wind power). Based on Graham et al. (2005), about 40 per cent of the materials cost is assumed to be exposed to a foreign market (and this is taken to be the generating equipment mainly). Basic metals (assumed to be sourced locally) makes a relatively large contribution across the generating technologies except for wind where the turbine and towers are assumed to be imported. Given the relatively small differences in the weighting of each input for each generating technology, the constructed index series are generally similar (for example, compare Figure 8 and Figure 13). The recent runup in capital costs evident in ACIL Tasman's power plant construction data is evident in the constructed index.

The length of the ABS data series allow indexes to be constructed to as far back as late 1983. However, it is important to keep in mind that the weighting of each cost to total costs refers to the base year, 2007-08. Thereafter, relative movements in the indexes mean that the share of each cost in total is likely to change. An implicit assumption is being made that the actual ratios of physical inputs is constant (for example, that the ratio of person-hours to say tonnes of cement is constant). Of course, over time ratios are likely to change as technology changes, and some substitution is likely to be motivated by the relative price movements (say if the price of capital decreased relative to labour). Also, in the case of indexes that refer to more than one technology (e.g. black coal and brown coal have the same weightings) the approach assumes that the ratios of inputs are the same.

A period of slightly more than 15 years (spanning March 1994 to March 2009) is judged to be an appropriate length of time for fitting the regression given that it is longer than the projection period by half; is unlikely to span substantial changes in construction techniques; and is half of the assumed life of the power plants themselves.

### 2.3.2. What is the appropriate form of the regression?

Once constructed, the capital cost indexes can be projected into the future. One approach — the one adopted by ACIL Tasman — is to project the component parts separately and then combine them to form a view on overall future capital costs. This method allows specific projections to be made where good information is available about the likely future value of the component parts of the index. On the other hand, where there is little information available, a methodology is needed in turn for projecting the component parts themselves. Rather than

attempting to project cement, metals, labour and imported materials prices separately, Concept Economics has adopted a second approach of fitting a regression line to the historical index series and then using this fitted line to project forward. In this way, Concept Economics' approach is a combination of ACIL Tasman's approach (an index of capital costs is created) and QCA's preferred approach (of using regression techniques to project costs).

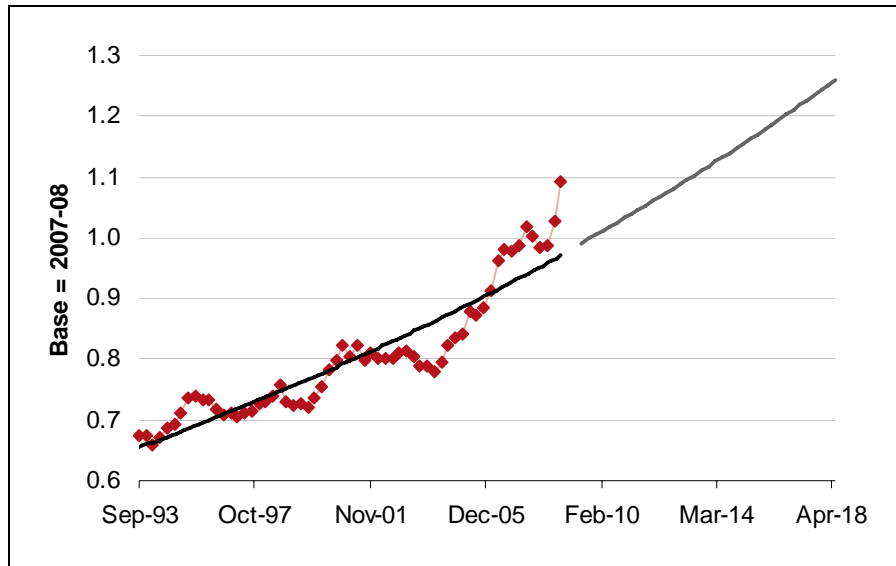
There are choices to make about the functional form of the fitted regression line. One approach is to fit an exponential curve to the historical nominal capital cost index (a linear curve is unlikely to be appropriate because of the inherent compounding effect of inflation). A second approach is to fit a linear curve to the growth in the index series. This will result in the growth rate changing over time (if the regression line has some slope) but the changes will be either forever increasing or decreasing depending on whether the slope is positive or negative. A third approach is to remove general increases in the price level from the nominal capital cost index and then fit a linear curve to the real series. Concept Economics has adopted the method of fitting an exponential curve to the nominal capital cost series. It has the advantage of not requiring any manipulation to the series before the regression is fitted.

ACIL Tasman (2008) adopts a 1 per cent annual learning rate after 2012 based on a recent CRC-CCSD report (probably *Options for Electricity Generation in Australia*). At page 46 of the CRC-CCSD report, the authors state their assumption of average learning rates for mature technologies of between 0 and 5 per cent. Concept Economics has adopted a rate of 0.5 per cent. However, it has been applied from the first quarter of 2008-09 rather than from 2012 as in the ACIL Tasman report.

## 2.4. BLACK COAL POWER PLANTS

The capital cost indexes for black coal and brown coal power plants are assumed to be identical in this report, although different base year capital costs are used. Figure 8 shows the fit of the exponential regression line to the historical nominal capital cost index. It also shows a projection of the fitted regression line to the end of the financial year 2017-18. The index (and all other capital cost indexes in this chapter) are based in 2007-08. However, dollar values are based in 2009-10.

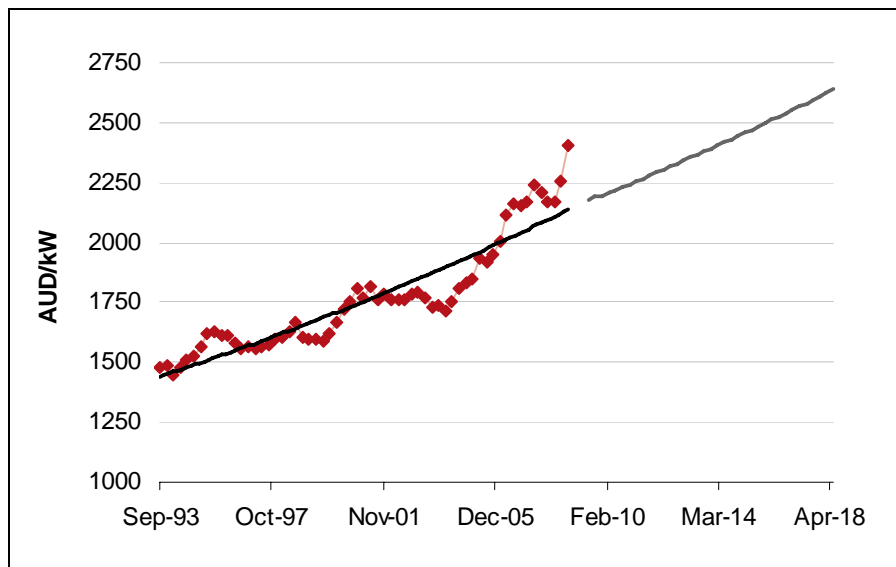
Figure 8. Estimated historical and projected nominal black coal and brown coal power plant capital cost index



As part of the process of converting the nominal index to actual construction costs, Concept Economics reviewed ACIL Tasman’s assumption about the cost of constructing various power plants in 2007-08. ACIL Tasman’s analysis was based on a variety of published sources that were corroborated by other reports available to Concept Economics.

Applying ACIL Tasman’s estimated base year black coal power plant construction cost of A\$2200/kW to the nominal index (and incorporating a 0.5 per cent per year learning rate) leads to the price trajectory shown in Figure 9. Nominal capital costs with learning rise to A\$2615 per kW by 2017-18.

Figure 9. Estimated historical and projected nominal black coal capital costs



In real terms, capital costs were generally trending downward prior to the mid-2000s, before rapidly increasing (Figure 10). The regression approach captures this long-term falling trend of real capital costs. In 2009-10 dollars, black coal power plant construction costs are projected to fall from \$2305 per kW in 2007-08 to \$2147 per kW in 2017-18 (Table 2).

Figure 10. Estimated historical and projected real black coal power plant capital costs

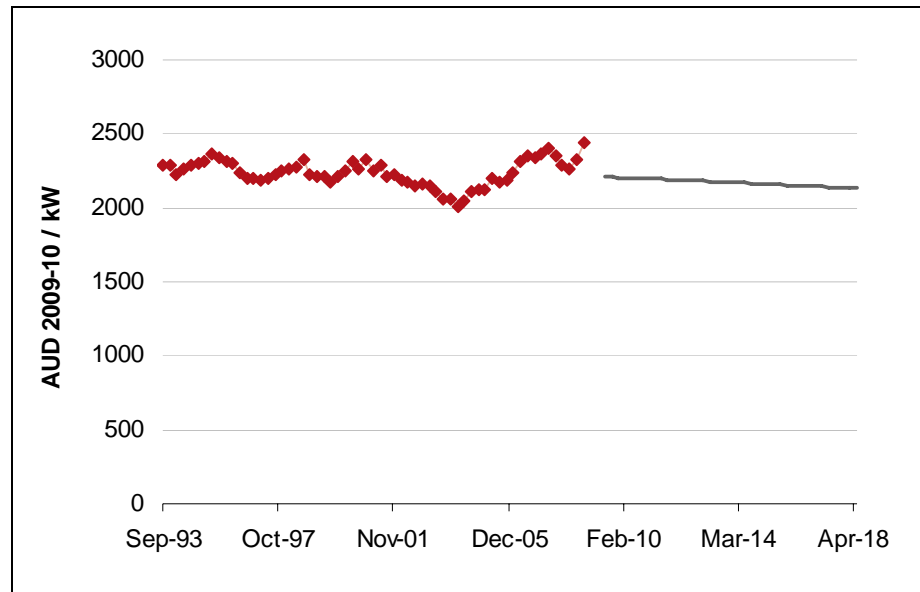


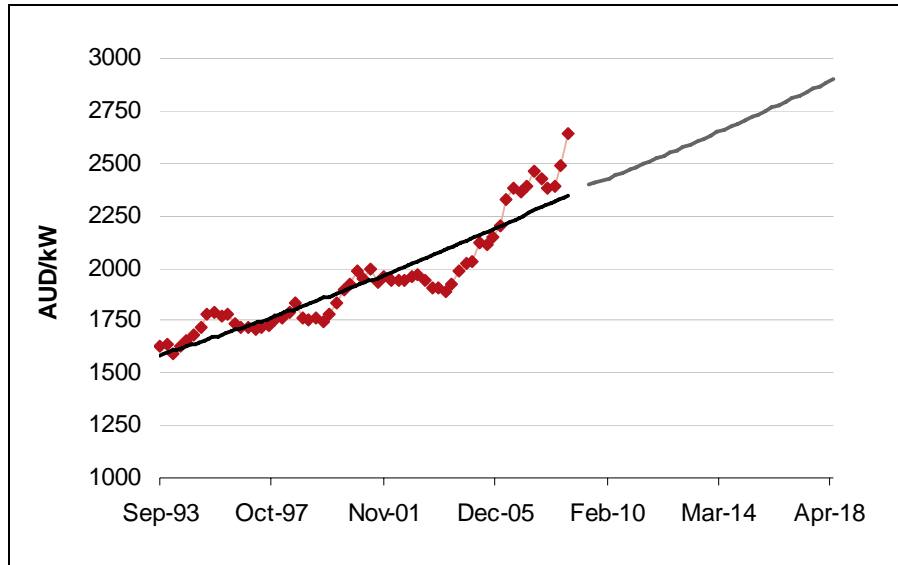
Table 2. Estimated nominal and real black coal power plant costs

Financial year	AUD/kW nominal	AUD/kW \$2009-10
2007-08	2200	2305
2008-09	2221	2257
2009-10	2209	2209
2010-11	2249	2203
2011-12	2298	2195
2012-13	2348	2187
2013-14	2399	2179
2014-15	2451	2171
2015-16	2505	2163
2016-17	2559	2155
2017-18	2615	2147

## 2.5. BROWN COAL POWER PLANTS

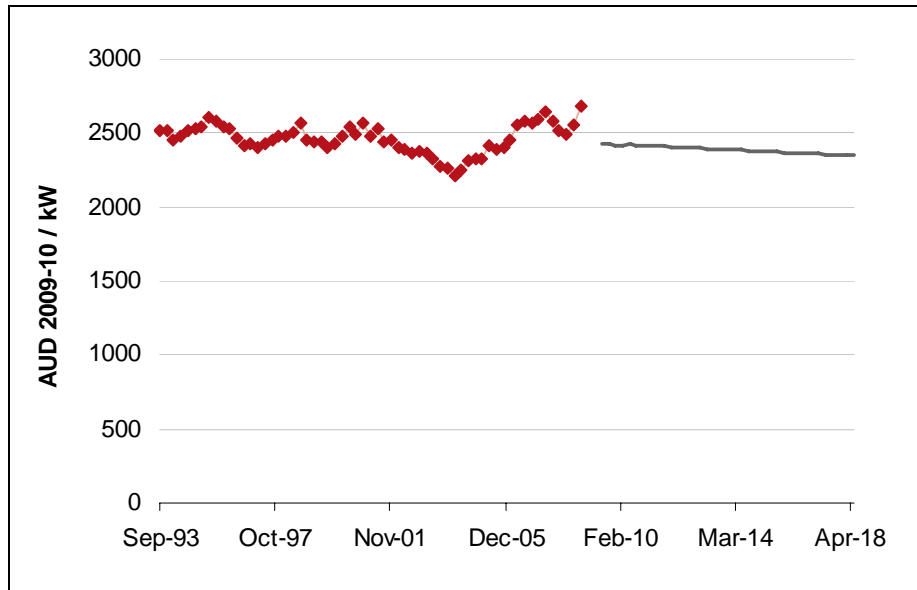
The nominal cost index for brown coal power plants is the same as for black coal power plants. However, the different estimated base year cost of \$2420 per kW for brown coal plants in 2007-08 (based on ACIL Tasman's analysis) leads to a higher nominal projection (Figure 11). By 2017-18, nominal brown coal capital costs are projected to be \$2877 per kW.

Figure 11. Estimated historical and projected nominal brown coal power plant capital costs



Real (\$2009-10) brown coal power plant capital costs are projected to fall by about 7.5 per cent over the forecast horizon from \$2536 per kW in 2007-08 to \$2352 per kW in 2017-18 (Figure 12 and Table 3).

Figure 12. Estimated historical and projected real brown power plant capital costs



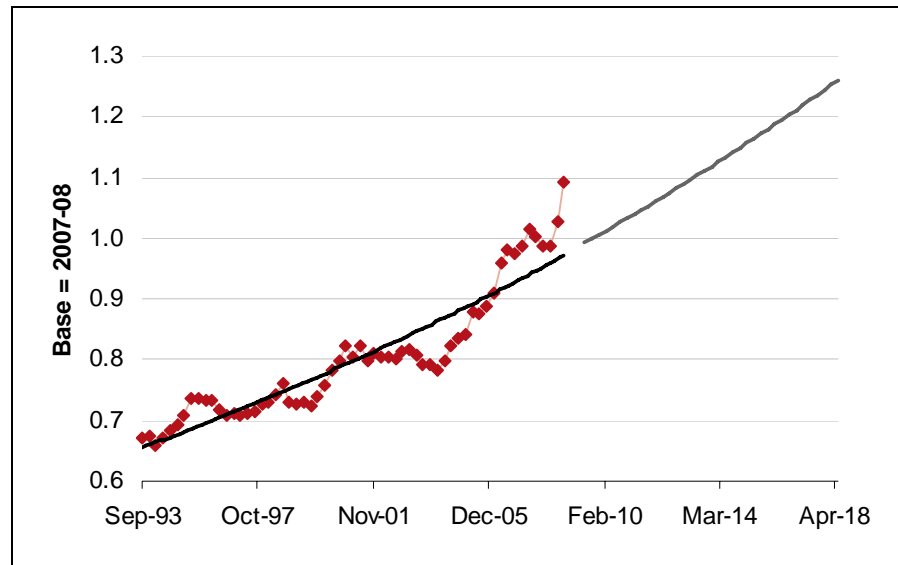
**Table 3. Projected nominal and real brown coal power plant costs**

Financial year	AUD/kW nominal	AUD/kW \$2009-10
2007-08	2420	2536
2008-09	2444	2483
2009-10	2424	2424
2010-11	2473	2417
2011-12	2527	2408
2012-13	2582	2398
2013-14	2639	2389
2014-15	2696	2379
2015-16	2755	2370
2016-17	2815	2361
2017-18	2877	2352

## 2.6. CCGT POWER PLANTS

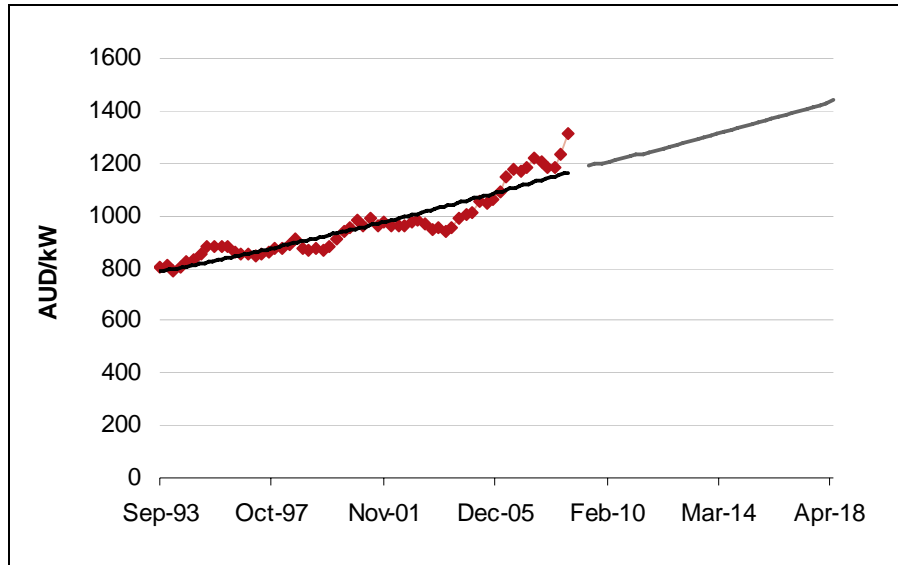
The CCGT power plant cost index differs from the nominal black and brown coal power plant capital indexes because of changes to the share of each input to total costs (see Table 1). Nevertheless, the same overall shape holds (Figure 13).

**Figure 13. Estimated historical and projected nominal CCGT capital cost index**



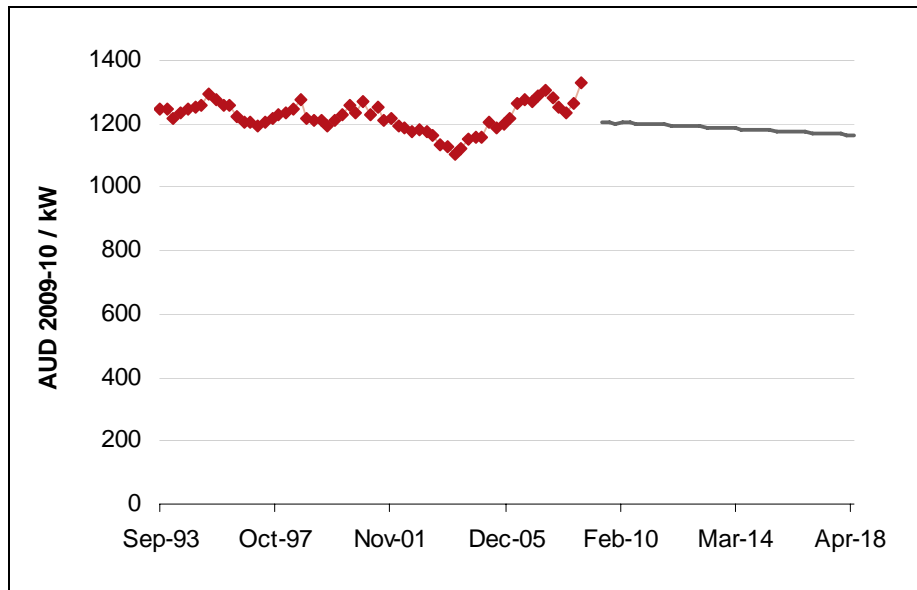
ACIL Tasman cites various ASX announcements and online sources in estimating the construction costs of a CCGT plant in Australia for 2007-08, and Concept Economics found these to conform broadly with other published estimates. A cost of A\$1200 per kW for 2007-08 is used as the basis for converting the index to a price series. Projected nominal CCGT power plant capital costs rise from \$1200 per kW in 2007-08 to \$1427 per kW in 2017-18, an increase of 19 per cent (Figure 14).

Figure 14. Estimated historical and projected nominal CCGT power plant capital costs



Once adjusted for historical and projected inflation, the CCGT capital cost index terms shows the same tendency for real falls in the price of plants prior to the mid-2000s as was observed in the index for coal plants (Figure 15). Real (\$2009-10) CCGT power plant costs fall slightly over the projection period from \$1258 per kW to \$1166 per kW (Table 4).

Figure 15. Estimated historical and projected real CCGT power plant capital costs



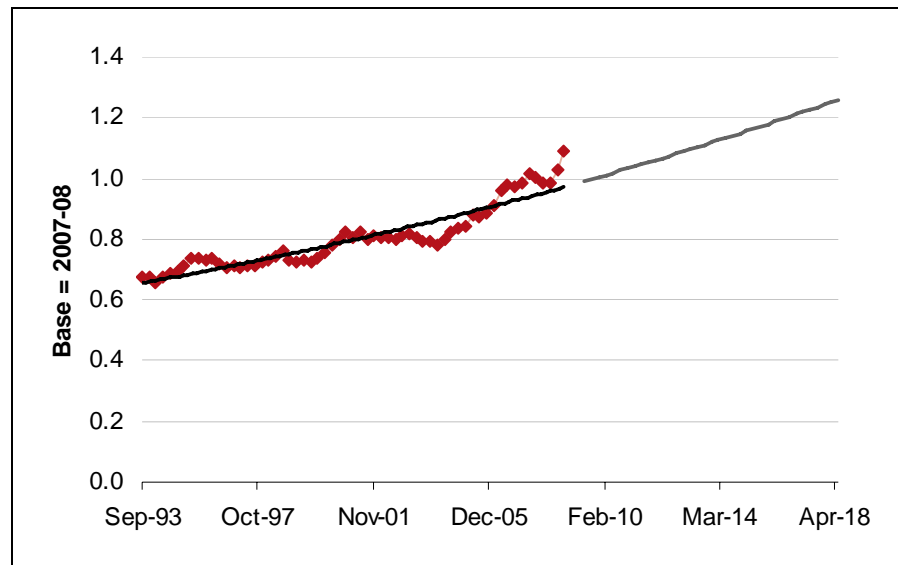
**Table 4. Projected nominal and real CCGT power plant capital costs**

Financial year	AUD/kW nominal	AUD/kW \$2009-10
2007-08	1200	1258
2008-09	1212	1231
2009-10	1202	1202
2010-11	1227	1199
2011-12	1254	1194
2012-13	1281	1189
2013-14	1309	1185
2014-15	1338	1180
2015-16	1367	1175
2016-17	1397	1171
2017-18	1427	1166

## 2.7. OCGT POWER PLANTS

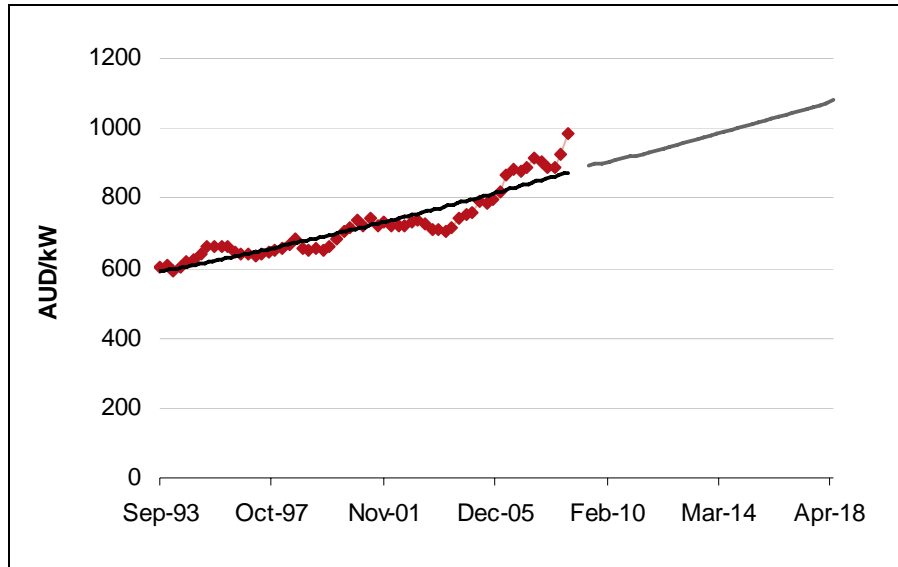
The OCGT power plant construction cost index is similar to those for CCGT and coal power plants (Figure 16). The index rises from 1 in 2007-08 to 1.25 in 2017-18.

**Figure 16. Estimated historical and projected nominal OCGT capital cost index**



After reviewing ACIL Tasman's historical analysis of OCGT power plant construction costs, Concept Economics has adopted ACIL Tasman's estimate of A\$900 per kW in 2007-08. This translates to a nominal cost increase of \$170 per kW to \$1070 per kW by the end of the forecast horizon (Figure 17).

Figure 17. Estimated historical and projected nominal OCGT power plant capital costs



The historical real downward trend in capital costs is projected into the future, with costs falling from \$943 per kW in 2007-08 to \$874 per kW in 2017-18 (Figure 18 and Table 5).

Figure 18. Estimated historical and projected real OCGT power plant capital costs

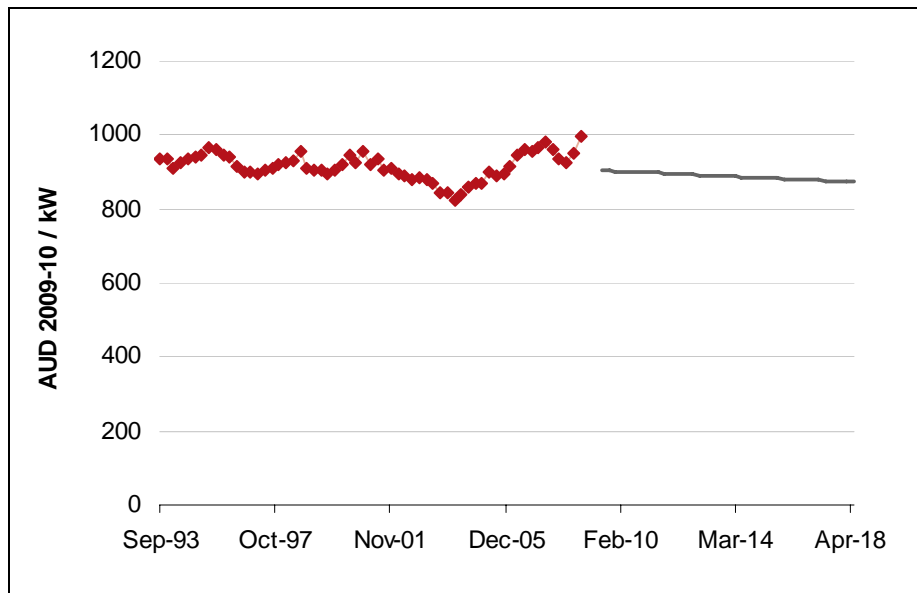


Table 5. Projected nominal and real OCGT power plant costs

Financial year	AUD/kW nominal	AUD/kW \$2009-10
2007-08	900	943
2008-09	909	924
2009-10	902	902
2010-11	920	899
2011-12	940	895
2012-13	961	892
2013-14	982	888
2014-15	1003	885
2015-16	1025	881
2016-17	1047	878
2017-18	1070	874

2.8. RENEWABLES

2.8.1. Wind

After reviewing various sources, Concept Economics has adopted ACIL Tasman’s estimates of \$2300 per kW for wind power in 2007-08. Nominal wind power plant capital costs rise from \$2300 per kW in 2007-08 to \$2519 per kW in 2017-18 (Figure 19). Real prices fall to \$2058 per kW (Figure 20).

Figure 19. Estimated historical and projected nominal wind power plant capital costs

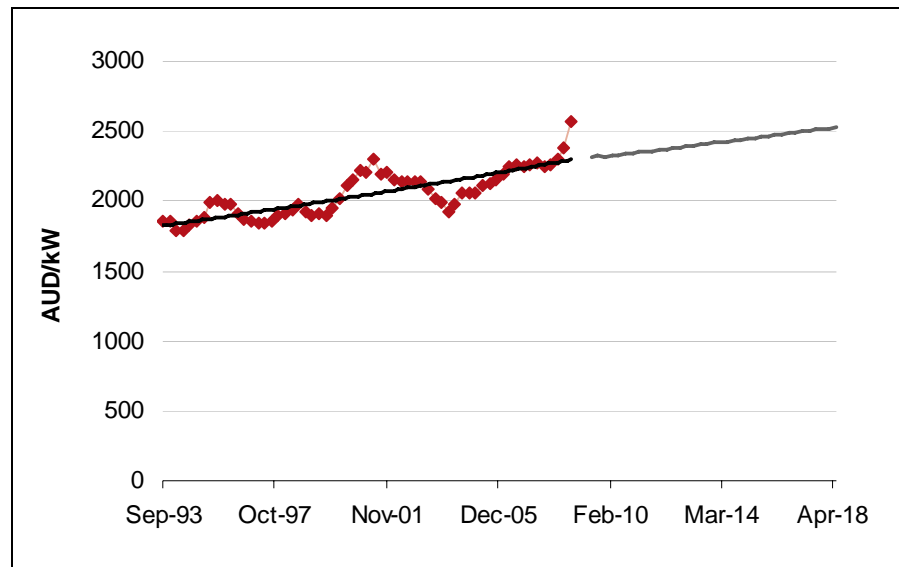
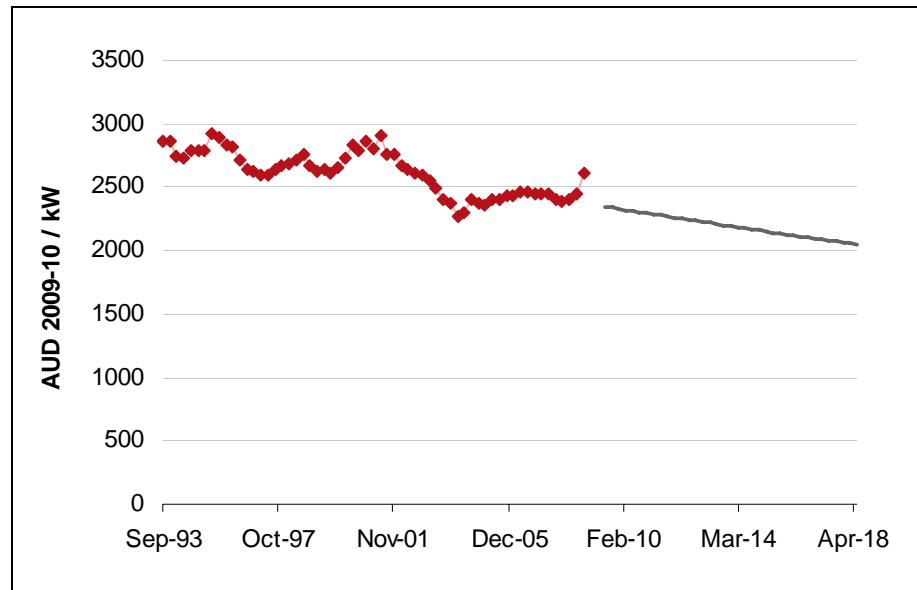


Figure 20. Estimated historical and projected real wind power plant capital costs



### 2.8.2. Geothermal

Concept Economics has adopted ACIL Tasman's estimate for geothermal power plant capital costs of \$5000 per kW in 2007-08 in the absence of large-scale Australian geothermal power plants. Geothermal power plants costs are projected to increase to \$5947 per kW in nominal terms, and to fall in real terms to \$4859 per kW in real terms (Table 6).

### 2.8.3. Biomass

Concept Economics estimates the capital cost of biomass generating capacity at \$5000 per kW, based on a 10MW stoker-boiler plant. It should be noted that the per-kW capital cost of biomass plants falls significantly as power increases, making the selection of power plant capacity important (as it is for the other plant types also). The estimate is based on an analysis undertaken by CRA International for Cairns Water in March 2008 (CRA International 2008). Biomass capital costs fall by about 7.5 per cent in real terms from 2007-08 to 2017-18, from \$5240 per kW to \$4856 per kW.

### 2.8.4. Hydro

Concept Economics adopts the capital cost used in CRA International's draft first report of \$2705 per kW in the absence of information specific to Australia.

Table 6. Projected power plant capital costs for wind, geothermal and biomass technologies

Year	Wind		Geothermal		Biomass		Hydro	
	AUD/kW nominal	AUD/kW \$2009-10	AUD/kW nominal	AUD/kW \$2009-10	AUD/kW nominal	AUD/kW \$2009-10	AUD/kW nominal	AUD/kW \$2009-10
2007-08	2300	2410	5000	5240	5000	5240	2581	2705
2008-09	2369	2407	5061	5141	5049	5129	2663	2705
2009-10	2323	2323	5022	5022	5006	5006	2705	2705
2010-11	2345	2291	5125	5007	5111	4992	2768	2705
2011-12	2369	2256	5235	4985	5222	4973	2839	2705
2012-13	2393	2222	5348	4964	5336	4953	2913	2705
2013-14	2418	2188	5462	4943	5452	4934	2988	2705
2014-15	2443	2155	5580	4921	5571	4914	3065	2705
2015-16	2468	2122	5699	4900	5693	4895	3144	2705
2016-17	2493	2090	5822	4880	5817	4876	3225	2705
2017-18	2519	2058	5947	4859	5944	4856	3309	2705

### 3. FUEL INPUT COSTS

Concept Economics' view is that energy prices internationally are likely to increase in real terms over the next ten years. China and India are projected to resume their high rates of growth within the next 18 to 24 months, and the worst of the real economic effects of the recent problems in the US credit markets will have dissipated for the rest of the world. A return to historical average rates of growth will apply similar pressures to world energy markets as were felt leading up to the recent downturn.

Concept Economics projects that world oil prices (as measured by the price for West Texas Intermediate crude) will grow from US\$72.0 a barrel in 2009-10 to over US\$105 a barrel in 2017-18 (in 2009-10 dollars), a real increase of about 46 per cent (Table 7). In Australian dollar terms, this translates to an increase from A\$109.2 a barrel in 2009-10 to A\$148.0 a barrel in 2017-18 (in 2009-10 dollars). The oil price projection serves as the basis for projections of the world prices of natural gas and coal.

**Table 7. World energy price projections, 2009-10 to 2017-18**

	Oil (West Texas Intermediate)		Gas (Aus. unit export)	Coal (Aus. unit export)	
	\$2009-10 USD per barrel	\$2009-10 AUD per barrel	\$2009-10 AUD per GJ	\$2009-10 USD per tonne	\$2009-10 AUD tonne
2009-10	72.0	109.2	8.1	68.0	103.1
2010-11	88.0	131.0	9.8	83.1	123.7
2011-12	93.6	136.2	10.2	88.4	128.7
2012-13	97.6	138.7	10.3	92.2	131.0
2013-14	100.0	140.3	10.5	94.4	132.5
2014-15	102.0	143.2	10.7	96.3	135.3
2015-16	103.0	144.7	10.8	97.3	136.7
2016-17	104.0	146.3	10.9	98.2	138.1
2017-18	105.1	148.0	11.0	99.3	139.8

Note that the Australian dollar oil price is influenced by projections of US and Australian inflation rates and the projected nominal USD/AUD exchange rate. Concept Economics' projections of real exchange rates and Australian dollar inflation rates are shown in Table 8. In the December 2008 quarter, prices (as measured by the Consumer Price Index) actually fell by -0.3 per cent driven largely by falls in the cost of transport following the decline in the price of oil. Other components of the index remained relatively strong however and in March 2009 inflation increased to 0.1 per cent. Concept Economics does not expect further quarters of price deflation. Inflation for 2008-09 is projected to be 1.5 per cent. Inflation in the longer term is projected to be about 2.6 per cent as banks begin to convert their current holdings of liquid assets into longer term claims, resulting in expansion of the money supply through the credit creation process.

**Table 8 Real exchange rate and Australian inflation projections**

Financial year	Real USD/AUD exchange rate		AUD price level
	\$2009-10	Base = 2009-10	Annual inflation (%)
2009-10	0.65	1.00	2.0
2010-11	0.67	1.02	2.6
2011-12	0.68	1.05	2.6
2012-13	0.70	1.07	2.6
2013-14	0.71	1.10	2.6
2014-15	0.71	1.13	2.6
2015-16	0.71	1.16	2.6
2016-17	0.71	1.19	2.6
2017-18	0.71	1.22	2.6

International gas prices (as measured by the Australian dollar unit export price) are projected to grow at the same rates of growth as Australian dollar oil prices. This implies that real prices are projected to grow by 36 per cent from 2009-10 to 2017-18, from A\$8.1 to A\$11.0 per GJ (Table 7).

Record coal prices in both US and Australian dollars were reached in 2008-09, but these are highly unlikely to be sustained. Some coal contracts for Japan's next financial year have already been signed, with some Japanese buyers achieving at least a 45 per cent discount on the JFY 2008-09 price. Chambers (2008) reports that Xstrata Coal signed at \$US80 per tonne for the 2009 calendar year in late 2008, which is barely 50 per cent the price locked in for the Japanese year starting April 2008. Concept Economics projects that coal prices in 2009-10 will average US\$68.0 a tonne (in 2009-10 dollars), rising to US\$99.3 a tonne by the end of the forecast horizon. In Australian dollar terms, this is an increase from A\$103.1 a tonne to just over A\$139.8 a tonne (Table 7).

### 3.1. REGIONAL GAS PRICES

Historically, gas prices in the eastern states have been approximately half those in Western Australia, where the gas price is, to a large extent, internationalised by the existence of large LNG export facilities. However, the identification of very large coal seam methane gas reserves in Queensland's Surat and Bowen Basins, and the development of new technology, has brought forth a number of investment proposals for the construction of LNG export facilities on the east coast, particularly at Gladstone. For example, Santos and Petronas plan to make a final decision on a 3 to 4 mtpa (170 to 220PJ pa) project at the end of 2009 to allow first shipments in early 2014 (Santos 2009). Another, larger project of up to 12 mtpa is being considered by QCG and BG Group for export in 2013.

Concept Economics considers it unlikely that the construction of these (and various other) east coast gas projects will lead to a complete internationalisation of east coast gas market prices in the next ten years, principally because the new projects are drawing on previously untapped CSG deposits rather than existing exploited fields. Concept Economics agrees with ACIL Tasman that although not all the projects are likely to proceed, they still offer a 'credible

alternative market pathway for local gas suppliers' (p. 81). Therefore, east coast gas market internationalisation is highly likely in the longer term.

Concept Economics projects that gas prices will *begin* to approach netback parity prices in 2010-11 as construction of the currently proposed projects begins. Ultimately, prices are projected to rise to about 70 to 80 per cent of international prices by 2017-18, up from projected 2009-10 levels of about 50 per cent. Real international energy prices are projected to be rising simultaneously as the real effects of the US credit crisis abate and historical average economic growth resumes. To serve as a base for the projections, Concept Economics has adopted the domestic gas prices reported in ACIL (2007) for each state, and inflated them to 2009-10 dollars. These show slight differences in natural gas prices across states partly because of transport costs, and these differences are retained over the projection horizon in real terms. In South Australia, real gas prices are projected to increase from A\$4.1 a GJ in 2009-10 to A\$8.5 a GJ in 2017-18; in Tasmania from A\$4.5 to A\$8.8 a GJ; in Victoria from A\$3.5 a GJ to A\$7.9 a GJ; in NSW from A\$3.9 a GJ to A\$8.3 a GJ; and in Queensland from A\$3.6 a GJ to A\$8.0 a GJ (Table 9).

**Table 9. Projected nominal and real gas prices, by region**

	QLD		NSW		VIC		SA		TAS	
	\$/GJ nominal	\$/GJ \$2009-10	\$/GJ nominal	\$/GJ \$2009-10	\$/GJ nominal	\$/GJ \$2009-10	\$/GJ nominal	\$/GJ \$2009-10	\$/GJ nominal	\$/GJ \$2009-10
2009-10	3.64	3.64	3.87	3.87	3.51	3.51	4.10	4.10	4.45	4.45
2010-11	3.99	3.89	4.22	4.11	3.86	3.76	4.46	4.35	4.82	4.70
2011-12	4.49	4.27	4.72	4.49	4.35	4.14	4.97	4.73	5.34	5.07
2012-13	5.13	4.75	5.37	4.97	4.99	4.62	5.63	5.21	6.00	5.56
2013-14	5.90	5.32	6.14	5.55	5.75	5.19	6.41	5.78	6.79	6.13
2014-15	6.78	5.97	7.03	6.19	6.63	5.84	7.30	6.43	7.70	6.78
2015-16	7.74	6.64	8.00	6.87	7.59	6.52	8.28	7.11	8.69	7.45
2016-17	8.76	7.33	9.03	7.55	8.61	7.20	9.31	7.79	9.73	8.14
2017-18	9.81	8.00	10.08	8.22	9.65	7.87	10.37	8.46	10.80	8.80

Concept Economics notes that ACIL Tasman provides a schedule of prices whereby greater levels of adoption of gas-fired generation (from 0 to 90 per cent) are associated with higher gas prices. In Queensland for example, prices under a scenario of 90 per cent gas-fired generation are 71 per cent higher in 2017-18 than under a scenario of 0 per cent gas-fired generation. Certainly, gas prices would be affected by the demand associated with each scenario of gas-fired power shares.

Concept Economics has provided a single price series for each region on the grounds that this is consistent with ACIL Tasman's and Concept Economics' treatments of capital costs in which no account is taken of the fact that rebuilding the entire generation portfolio is likely to lead to substantial increases in capital costs.

The hypothetical nature of the 'greenfields' approach may even mean that the LRMC model's potential switch to gas-fired generation will demand more gas than the eastern Australian network can currently supply. For example, ACIL Tasman brings forward the first gas from the joint venture Kipper project off Victoria to 2009, although the project is more likely to

supply its first gas in 2011 (ABARE 2008). It may be that this is the only way that sufficient supply can be made available in ACIL Tasman's model for projected gas consumption to be met.

It should also be noted that Australian Government Treasury modelling assumptions for gas penetration in the future generation portfolio is low relative to some of the scenarios considered by ACIL Tasman's methodology. This is almost certainly because the 'greenfields' generation assumption forces ACIL Tasman to consider high adoption rates for gas-fired power.

Peaking open cycle gas turbines will usually pay more for gas than CCGT plants which will often be on long term contracts. ACIL Tasman's uplift estimate of 50 per cent is adopted.

### 3.2. REGIONAL COAL PRICES

In the event of the existing portfolio of coal-fired generation being theoretically rebuilt under a greenfields approach, it is very likely that the rebuilding would take place in the locations where coal-fired generating capacity currently exists. At present, power plants are located with simple access to thermal coal deposits and close to water sources, whether man-made or otherwise.

It follows that current estimated power plant coal costs are a useful base for projecting future coal power plants fuel costs, and so — as is the case for regional natural gas prices — Concept Economics has adopted base year coal prices from ACIL (2007). From these, a modification to the outlook for world coal prices is applied for the forecast horizon for each state. In New South Wales, fuel costs are assumed to be partly exposed to world movements in coal prices because many of the mines supplying thermal coal to domestic power plants in that state also supply the export market (although it is noted that the energy content of exported coal is likely to be higher than that used for domestic power). The situation in Queensland is reasonably similar to the overall picture for New South Wales: there are transport links from many of the major thermal coal mines to coal loaders at the ports of either Abbott Point, Dalrymple Bay, Hay Point, Gladstone or Brisbane. Therefore, coal prices in Queensland are also assumed to be partly influenced by movements in world coal prices. Brown coal in Victoria is assumed to be isolated from world markets given its low energy content. Concept Economics considers that giving consideration to existing long-term contracts as inconsistent with the greenfields approach.

Real Queensland coal prices are projected to increase from A\$1.24 per GJ to A\$1.35 per GJ from 2009-10 to 2017-18 (in 2009-10 dollars) as world energy prices increase (Table 10). In New South Wales, real coal prices are projected to rise eight per cent from A\$1.47 per GJ to A\$1.59 per GJ. Victorian brown coal prices are projected to remain unchanged in real terms at A\$0.595 per GJ.

Table 10. Projected nominal and real coal prices, by region

	QLD		NSW		VIC	
	A\$/GJ	A\$/GJ	A\$/GJ	A\$/GJ	A\$/GJ	A\$/GJ
	Nominal	\$2009-10	Nominal	\$2009-10	Nominal	\$2009-10
2009-10	1.244	1.244	1.465	1.465	0.595	0.595
2010-11	1.340	1.307	1.578	1.538	0.610	0.595
2011-12	1.389	1.320	1.635	1.553	0.626	0.595
2012-13	1.431	1.326	1.684	1.560	0.642	0.595
2013-14	1.472	1.330	1.733	1.565	0.659	0.595
2014-15	1.518	1.336	1.787	1.573	0.676	0.595
2015-16	1.562	1.340	1.838	1.577	0.693	0.595
2016-17	1.606	1.344	1.891	1.581	0.711	0.595
2017-18	1.653	1.347	1.945	1.586	0.729	0.595

### 3.3. BIOMASS COST

MMA (2006) reports biomass fuel costs in the range \$10 to 20 per MWh which at reasonable heat rates implies an energy price of about \$1.5 per GJ. In 2009-10 dollars, this is equivalent to \$1.7 per GJ.

## **4. OTHER PARAMETERS**

This chapter discusses Concept Economics' assumptions regarding weighted average cost of capital, carbon permit prices, plant auxiliary use, plant life, operating and maintenance costs, plant availabilities and thermal efficiencies.

### **4.1. WEIGHTED AVERAGE COST OF CAPITAL**

ACIL Tasman estimates a post tax, real weighted average cost of capital (WACC) of 6.81 per cent. Concept Economics has reviewed the parameters used in ACIL Tasman's analysis and recommends that they be adopted with a modification to the long-run inflation rate from 2.5 per cent to 2.6 per cent. The result is a change in the WACC to 6.71 per cent (Table 11).

Given the long term nature of investments in electricity generation, Concept Economics does not recommend revisions in light of recent events in financial markets. Recent reductions in the current risk free rate of lending (at December 2008, Australian government 10 year bonds were yielding 3.99 per cent per year) and an increase in the debt basis point premium for many companies (bond yield spreads for A-rated companies increased from 265 basis points in June 2008 to about 470 basis points in April 2009) are largely offsetting in terms of WACC estimation. The risk-free rate has fallen, but risk and debt premiums have increased. More importantly, these are short term effects relating to the current economic conditions. To argue that these changes are long-term it would have to be assumed that there has been a long term change in the balance of consumer expenditure and savings and of perceptions of financial risk. Given the current, short-term uncertainty it is difficult to ascertain whether this has occurred.

If there were any longer term impacts on the parameters of the WACC, these would most likely be realised through an increase in the relative returns to equity versus debt. Where debt is considered to be a promise to pay obligation, equity is considered to be a share of residual resources. If the current climate increases the risk aversion of investors, this would result in an increase in the market risk premium required to induce investors into equity markets rather than investing in corporate bonds. The impact that such an increase would have is to raise the required return on equity, and hence the cost of equity, resulting in an increase in the WACC. However, it is too soon to say whether there has been a long-term change in the relative returns of equity and debt.

**Table 11. Parameters for weighted average cost of capital calculation**

<b>Variable</b>	<b>Value</b>
Liabilities	100%
Debt	60%
Equity	40%
Risk free RoR	6%
Market risk premium	6%
Market ROR	12%
Corporate tax rate	30%
Effective tax rate	22.50%
Imputation adjusted tax	15%
Debt basis point premium	200
Cost of debt	8.0%
Gamma	0.50
Asset beta	0.80
Debt beta	0.16
Equity beta	1.744
Required return on equity	16.5%
Inflation	2.6%
Post tax real WACC	6.71%

## 4.2. CARBON PERMIT PRICES

Concept Economics' projections of likely future carbon permit prices are higher than those arising from the Australian Government Treasury's modelling out to 2020 under a 5 per cent trajectory (Table 12). The differences in the projections are not marked in the case of the 5 per cent reduction by 2020 trajectory but are more stark in the case of the 15 per cent reduction trajectory. The differences mainly reflect differences in the estimates of the marginal cost of abatement and assumptions about the availability and price of international permits.

**Table 12. Projected carbon permit prices under different emissions reductions trajectories (\$2010/tCO<sub>2</sub>-e)**

Year	Treasury		Concept Economics	
	CPRS-5 <sup>a</sup>	CPRS-15 <sup>a</sup>	Trajectory 5% by 2020 <sup>b</sup>	Trajectory 15% by 2020 <sup>b</sup>
2010	24	33	na	na
2011	25	34	9.8	9.8
2012	27	37	27	44
2013	29	40	29	46
2014	31	43	30	49
2015	33	47	32	51
2016	35	49	34	67
2017	36	52	36	71
2018	38	54	38	75
2019	40	56	41	79
2020	41	59	43	84
2021	43	62	46	89
2022	45	64	48	95
2023	47	66	51	100
2024	49	69	54	106
2025	50	71	58	113
2026	52	74	61	119
2027	54	77	65	127
2028	57	80	69	134
2029	59	82	73	142
2030	61	86	77	151

**a** Treasury prices in the White Paper are in 2005 dollars. Historical and projected inflation rates are used to convert these to 2010 dollars for comparison with Concept Economics' estimates.

**b** All permit prices are projected on the basis of emission reduction trajectories consistent with a 60 per cent reduction in Australian emissions (compared to 2000 levels) by 2050. Consistent with the White Paper it is assumed that the permit price is capped at \$40 (with an escalator of 5 per cent real) for the first five years of the scheme. Following the government announcement on 4 May 2009 it is assumed that the scheme will commence on 1 July 2011 with a one-year price cap of \$10. The cap of \$10 is \$9.8 when presented in 2010 dollars.

### 4.3. PLANT AUXILIARIES

Assumed plant auxiliaries are shown in Table 13. Concept Economics has reviewed and adopts ACIL Tasman's estimates.

**Table 13. Assumed auxiliary usage**

<b>Plant type</b>	<b>Auxiliaries</b>
Supercritical black coal	7.50%
Supercritical brown coal	9.50%
CCGT	2.40%
OCGT	2.00%
Wind	0%
Hydro	0%
Geothermal	0%
Biomass	0%

#### 4.4. PLANT LIFE

A plant life of 30 years is assumed.

#### 4.5. FIXED AND VARIABLE OPERATING AND MAINTENANCE COSTS

Concept Economics notes that ACIL Tasman's estimates of operating and maintenance (O&M) costs are drawn from a range of sources including company annual reports and are subject to review by many clients. Concept Economics adopts the fixed and variable O&M costs proposed in ACIL Tasman (2007) for coal and gas technologies. ACIL Tasman's costs relate to 2007-08 so were inflated to 2009-10 dollars (Table 14). Geothermal and hydro variable and fixed O&M costs are due to CRA (2006) (inflated to 2009-10). Fixed costs for biomass are also from CRA (2006) but variable costs are due to CRA's second final report to QCA. Fixed O&M for wind generation are Concept Economics' estimates based on CRA analysis in the 2008 Business Council of Australia report titled "Modelling Success: Designing an ETS That Works".

**Table 14. Fixed and variable operating and maintenance costs, by technology**

<b>Technology</b>	<b>Variable O&amp;M costs</b>	<b>Fixed O&amp;M costs</b>
	\$/MWh	\$/MWh/year
	\$2009-10	\$2009-10
Black coal	1.25	41,819
Brown coal	1.25	41,819
CCGT	5.07	13,382
OCGT	7.84	7,841
Wind	0.00	46,018
Geothermal	0.00	78,411
Hydro	7.32	52,274
Biomass	4.81	50,769

#### 4.6. THERMAL EFFICIENCIES AND PLANT AVAILABILITIES

Assumed thermal efficiencies and plant availabilities are shown in Table 15. Availabilities for all technologies (including wind and hydro generation) refer to technical availabilities rather than capacity factors.

**Table 15. Assumed thermal efficiencies and availabilities**

<b>Technology</b>	<b>Thermal Efficiency (%)</b>	<b>Availability (%)</b>
Black coal	42.0	90.0
Brown coal	33.0	90.0
CCGT	52.0	92.0
OCGT	31.0	97.0
Wind	n/a	93.4
Geothermal	10	90.0
Hydro	n/a	92.2
Biomass	30	85.0

## 5. REGRESSION RESULTS

This section contains detailed results of the log-linear regressions that test for structural breaks in the capital cost series for coal and CCGT power plants. In the case of CCGT plant capital costs, the null hypothesis of no structural break in the series is rejected at the 5 per cent significance level (Table 16). In the case of coal power plant capital costs, the null hypothesis of no structural break cannot be rejected at the same significance level.

**Table 16 Regression results for combined cycle gas technology capital costs**

Adjusted R-squared	0.333		
P-value of break	0.0347		
	<b>Coefficients</b>	<b>Standard error</b>	<b>P-value</b>
Constant	6.6749	0.0927	0.0000
Year	0.0018	0.0189	0.9238
Step	0.1170	0.0815	0.1577
Slope	0.1198	0.2069	0.5653

**Table 17 Regression results for coal power plant capital costs**

Adjusted R-squared	0.588		
P-value of break	0.1273		
	<b>Coefficients</b>	<b>Standard error</b>	<b>P-value</b>
Constant	7.1878	0.0906	0.0000
Year	0.0047	0.0173	0.7872
Step	0.1734	0.2052	0.4106
Slope	0.0897	0.0671	0.1996

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