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Contents

Benchmarking Hydro Generation Earnings

With the upcoming public float of Snowy Hydro, interest focuses on its prospective earnings. Inevitably assessments of value will be informed by the prices fetched by the sale of assets with similar characteristics. These prices include the $1,425M paid recently by AGL for Southern Hydro and the $800M paid not long before by Industry Funds Management for Pacific Hydro. It has been suggested that these prices reflect the growth potential of both of these businesses, and in the case of Southern Hydro the payment of a substantial “strategic value premium” by the bidder.

In this article we present a simple and insightful formula for decomposing a hydro generator’s electricity spot market revenue. We use this formula to analyse retrospectively Snowy Hydro’s performance in the electricity spot market and undertake limited benchmarking against AGL Hydro Partnership’s principal hydro-electric generation assets.

Decomposition of Spot Market Revenue

A hydro generator’s annual spot market revenue can be usefully represented as

$$R = GC \times VMO \times OCE$$

where

R is annual spot market revenue ($), GC is annual generation capability (MWh), VMO is the value of the market opportunity ($/MWh) and OCE is the opportunity conversion efficiency (%).

It is also useful to define

$$GC = 8760 \times IC \times CF$$

where

IC is installed capacity (MW) and CF is capacity factor (%).

Having defined revenue in this way it is clear that revenue can be grown by any of increasing generation capability (either through more installed capacity or a higher capacity factor – access to more water), being exposed to an increasing value of the market opportunity, and improving the opportunity conversion efficiency[1].

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[1] It should be clear that the factors of the formula are not independent, for example, additional available water would increase the capacity factor but, to the extent to which existing generation is targeted to the highest value opportunities, will also reduce the average value of the market opportunity.

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Generation Capability

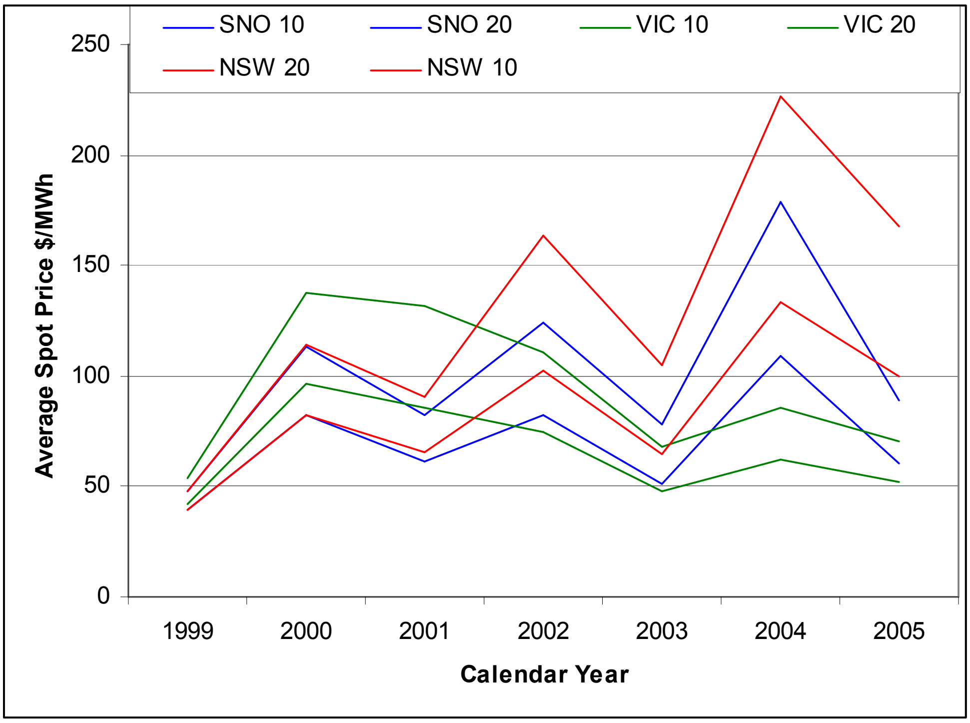
Snowy Hydro has installed capacity of 3,746MW and annual average generation of 4,500GWh (that is, an annual capacity factor of around 14%). For comparison with Southern Hydro we use the 520MW of capacity AGL Hydro Partnership has registered with NEMMCO. We assume average annual generation of 940GWh (that is, an annual capacity factor of around 20%).

Value of the Market Opportunity

We define the market opportunity as the prospective average spot price the generator would earn if able to dispatch its energy into the highest half-hourly prices of any year. For example if a generator has a 10% capacity factor and the highest 10% of spot prices are expected to average $100/MWh, the value of the market opportunity for this generator is $100/MWh.

Figure 1 shows the trends in the averages of the highest 10% and 20% of spot prices by region for the period from 1999 to 2005.

Figure 1 **Value of the Market Opportunity**



Over this period the value of the market opportunity for peaking generators with capacity factors between 10% and 20% has declined in Victoria (VIC) and increased in New South Wales (NSW). The Snowy region (SNO) has followed the New South Wales trend without capturing all of the value.

Opportunity Conversion Efficiency

The value of market opportunity was defined as the maximum value that could be obtained based on the generator achieving a particular capacity factor. The percentage of this maximum value that can be obtained depends in general on the extent to which generation is discretionary (i.e. water can be stored for release at times of high prices) and the ability to identify relatively high prices. In practice the release requirements of other water users, the inability to regulate inflows when storages are full, natural inflow variability, and imperfect spot price forecasts limit the opportunity conversion efficiency that can be attained.

Opportunity conversion efficiency (OCE) is calculated by dividing the dispatch weighted average spot price received by the generator by the average spot price it would have received had it been dispatched into the highest spot prices (measured by the VMO).

Earnings Benchmark

Table 1 uses the generation capability data cited earlier for Snowy Hydro (SN) and Southern Hydro (SH), and period average values of the market opportunity based on Figure 1. Ratios (SN / SH) are also calculated. The Southern Hydro data has been adjusted to conform to long term hydrology. Over the period considered it actually only achieved a 20% capacity factor in one of these years.

Table 1 Snowy Hydro and Southern Hydro – Ratio Analysis

Asset	IC (MW)	CF (%)	VMO ($/MWh)	OCE (%)	Revenue ($M)
SN	3746	14	91	65	272
SH	520	20	66	75	45
SN / SH	7.2	0.7	1.38	0.87	6.02

The results are relevant to a consideration of the spot market revenue multiples of the two assets. While Southern Hydro has a higher capacity factor it has had a lower value of market opportunity. This retrospective analysis suggests that Snowy Hydro has a spot market revenue multiple (to Southern hydro) of close to 6. If it is assumed that operating costs are in the same ratio, the EBITDA ratio will also be 6 suggesting a value of $3,600M for Snowy Hydro on the basis of the $600M paid by Meridian Energy for Southern Hydro in 2003, and more than $6,000M based on the considerably higher and more recent AGL purchase price.[2]

Conclusions

It would seem that key to an assessment of the relative earnings prospects of the two Hydro assets in the longer term is a view around the forward value of the market opportunity in the New South Wales and Victorian regions. Hitherto this value has followed different trajectories in each region.

In relation to Snowy Hydro, a source of value that should not be overlooked is its ability to access value in either of the New South Wales or Victorian regions depending at any time where the greater value lies.

Further, the analysis presented here does not consider the issue of market power and the fact that most generators of any size can have some impact on spot prices. A generator which can influence spot prices may earn higher revenues by

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[2] The AGL purchase price of $1,425M was in respect of a larger asset portfolio than the Victorian hydro-electric stations purchased previously by Meridian Energy and included a number of small hydro stations in New South Wales, the Wattle Point wind farm in South Australia, and a number of development options.

generating in some lower price periods rather than generating only in the highest priced periods and depressing the spot prices in these periods. In this case the generator may seem to have a lower opportunity conversion efficiency than what it could achieve, yet its generation strategy is one which is maximising its profits[3].

Market Opportunity Assessment with PROPHET and GEDIE

IES' market simulation model PROPHET is used to project half-hourly regional spot prices and generator dispatch on the basis of assumed demand growth, investment in new generation and transmission projects, and the behaviour of market participants. It is a suitable tool to study pool strategies in the context of existing and potential inter-regional constraints.

IES' generic dispatch engine, GEDIE, can be used to "re-run" the NEM and determine how prices would have changed with different generator outputs. This information can be combined with an assumed contract profile to determine what were the marginal revenues for a generation portfolio or determine how close the generation portfolio's actual generation was to "optimal".

Do Electricity Contracts Trade at a Premium?

It is sometimes asserted that wholesale electricity contracts trade at a positive premium to the spot market (i.e. expected spot price). According to proponents of this theory, the premium reflects the risk preferences of the natural counterparties to these contracts (i.e. retailers and generators). Briefly, in view of the nature of their exposure, retailers are believed to be keener to hedge than generators and therefore the premium is positive. The alternative theory is that the wholesale contract market is efficient and therefore the premium is zero.

Is there empirical evidence that contracts trade at a premium to expected spot price ? If there is, is this the result of the market attempting to price risk or does the market simply expect spot prices to average more than they do ?

In our investigations we examine the Victorian, New South Wales and Queensland regions of the NEM and are concerned with evidence to support the existence (or non-existence) of apparent contract premiums and the applicability of a particular multi-factor pricing model to explain these premiums where they seem to exist. We notice some alternative explanations of apparent premiums, draw attention to regional differences in the relationship between spot and contract prices, and speculate somewhat as to the reasons for these differences.

Pricing Model

We investigate the applicability of a multi-factor pricing model as follows:

$$P = b_0 + b_1\sigma + b_2\gamma$$

where P is the quoted price of the flat swap contract for the next calendar year and σ and γ are the standard deviation and coefficient of skewness, respectively, of the average monthly spot prices for the twelve month period preceding the quote date

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[3] A generator achieves optimal short term efficiency in the spot market when its marginal revenue (considering all contracts) is equal to its marginal cost for each half-hour.

of the contract. The model assumes that in pricing a wholesale electricity contract, counterparties have regard to the standard deviation and skewness of past spot prices.

The model has the form of a moment preference model and is motivated by the theoretical consideration that *an aversion to standard deviation and preference for positive skewness are general characteristics of all investors having utility functions displaying the desirable behaviouristic attributes of diminishing marginal utility of wealth and non increasing absolute risk aversion*[4].

The model was estimated by regression with the skewness term included (two factor model) and then omitted (single factor model) for each of the Victorian, New South Wales and Queensland regions of the NEM.

Our data set consists of contract prices for the three regions taken at the beginning of each month for the period January 2001 to December 2005. Spot prices for the three regions are from NEMMCO.

Parameter estimates with associated t-scores[5] (in brackets) and overall goodness of model fit (R^2) are set out in Tables 2 and 3.

Table 2 Pricing Model Parameter Estimates – Two Factor Model

Statistic	Victoria	New South Wales	Queensland
b_0	29.68 (30.74)	32.74 (26.53)	37.44 (44.71)
b_1	0.887 (15.31)	0.202 (2.72)	-0.153 (-3.41)
b_2	-2.59 (-4.46)	-0.01 (-0.02)	-1.283 (-2.21)
R^2	81%	12%	31%

Table 3 Pricing Model Parameter Estimates – Single Factor Model

Statistic	Victoria	New South Wales	Queensland
b_0	26.80 (32.40)	32.73 (28.20)	36.35 (44.71)
b_1	0.839 (12.80)	0.202 (2.75)	-0.189 (-4.38)
R^2	74%	12%	25%

The results suggest that while the pricing model has predictive value in Victoria, it largely fails as an explanatory pricing model in New South Wales and Queensland. Later we ask why this might be but first we make some observations on the signs of the estimated parameters.

We expect b_1 to be positive. This is because neither of our natural counterparties wants standard deviation. Supposedly retailers want it least so they pay the generators a premium to take it. We estimate a positive b_1 in Victoria and New South Wales but not in Queensland.

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[4] Kraus and Litzenburger “Skew Preference and the Valuation of Risk Assets”, Journal of Finance 31 1085-1100 (1976) quoted in Brockett and Arven “A Reexamination of the Relationship between Preferences and Moment Orderings by Rational Risk Averse Investors” University of Texas (1993).

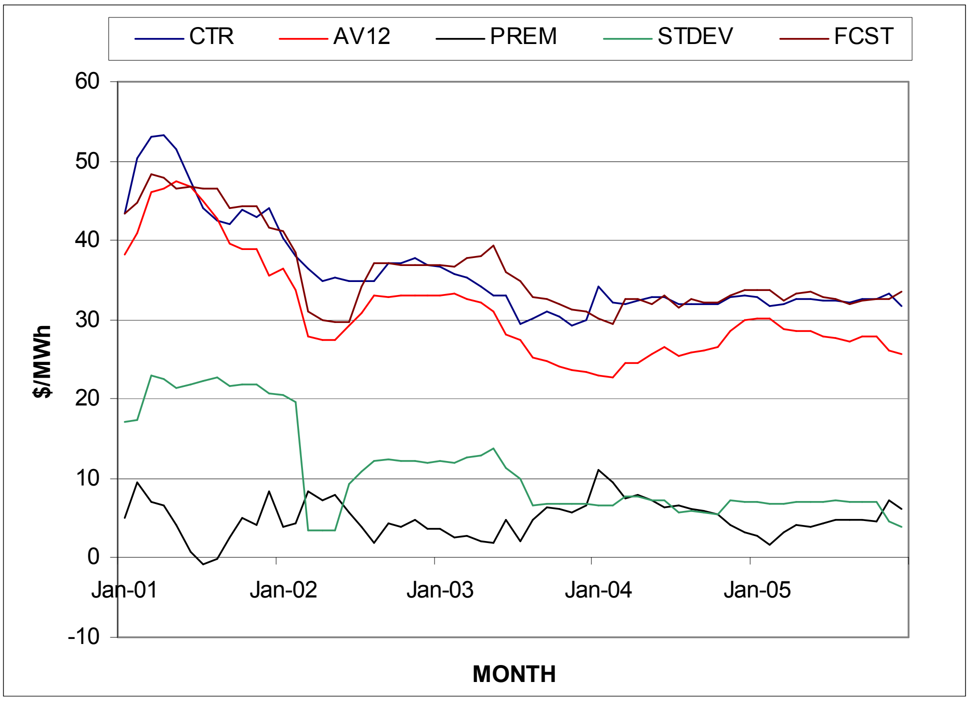
[5] T-scores measure the significance of each regressor variable and are inversely related to the standard error of estimate. As a “rule of thumb”, regressor variables with t-scores greater than 2 (in absolute terms) are regarded as significant.

We expect b_2 to be positive also. This is because positive skewness of spot prices, while good for generators, translates into negatively skewed retail margins. Retailers will be keen to get rid of this and again should pay a premium to the generators for this to happen. The skewness coefficient has no statistical significance in New South Wales and for Victoria and Queensland the negative signs of the parameter estimates do not accord with expectation.

Victoria

In Figure 2 we show the quoted contract price (CTR) and the predicted contract price calculated using the estimated two factor model (FCST). We also show the average spot price for the twelve month period up to the contract quote date (AV12), the standard deviation of the twelve monthly average spot prices (STDEV) and the difference between CTR and AV12 which we define as the contract premium (PREM).

Figure 2 **Contract Price Analysis - Victoria**



This analysis suggests an apparent premium of contract price to current spot price of around \$4.90/MWh[6]. Take any quote date over the period analysed, and on average the quoted price of the contract for the next full calendar year is \$4.90/MWh higher than the spot price average taken over the preceding twelve months.

Explanation 1 – There is no premium. The apparent premium calculated in this way is simply indicative of an expectation of tightening supply and is the expected increase in spot price.

Explanation 2 – There is no premium. The apparent premium is the market's recognition of the potential high skewness of the annual spot price distribution.

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[6] Please note that we have not adjusted the data for CPI.

Perhaps every ten years or so (who knows?) we can expect a very high annual average spot price. For example if the annual spot price distribution is conceived as a mixture distribution where there is 90% chance that the outcome is sampled from a distribution with mean \$30/MWh and 10% chance that the outcome is sampled from a distribution with mean \$80/MWh then the fair price (to those in the know!) is 0.9x\$30 + 0.1x\$80 = \$35/MWh. However, until the process samples from the distribution with the higher mean, available sample information will suggest a mean of \$30/MWh.

Explanation 3 – There is a premium and it is related to the risk preferences of natural counterparties and their views (grounded to some extent in history) of the volatility of spot prices.

From Table 2 the Victorian two factor model is

$$P = 29.68 + 0.887\sigma - 2.59\gamma$$

Noting that the average standard deviation was 11.06 and average coefficient of skewness 1.314, we can rearrange this to give

$$P = 36.08 + 0.887\,(\sigma - 11.06) - 2.59\,(\gamma - 1.314)$$

That is to say a mean and standard deviation consistent with the period average will give a predicted contract price of around \$36/MWh. An increase of standard deviation by \$10/MWh (as experienced in 2001) gives a predicted contract price of nearly \$45/MWh.

The prediction seems satisfactory but we retain some reservations about the estimation of this model. The first is that parameter estimates need correcting for autocorrelation in the residuals. This creates the potential for incorrect inference but is not fatal[7]. The second is more serious and is that the standard deviation (STDEV) is in fact highly correlated with the average spot price of the preceding twelve months (AV12). This means that an alternative predictive model can be based on AV12 alone.

The apparently reasonable predictive value of the two factor model is not a sure indication that the model is correctly specified or indeed that standard deviation and skew have anything to do with the contract premium. Nothing is proved for sure!

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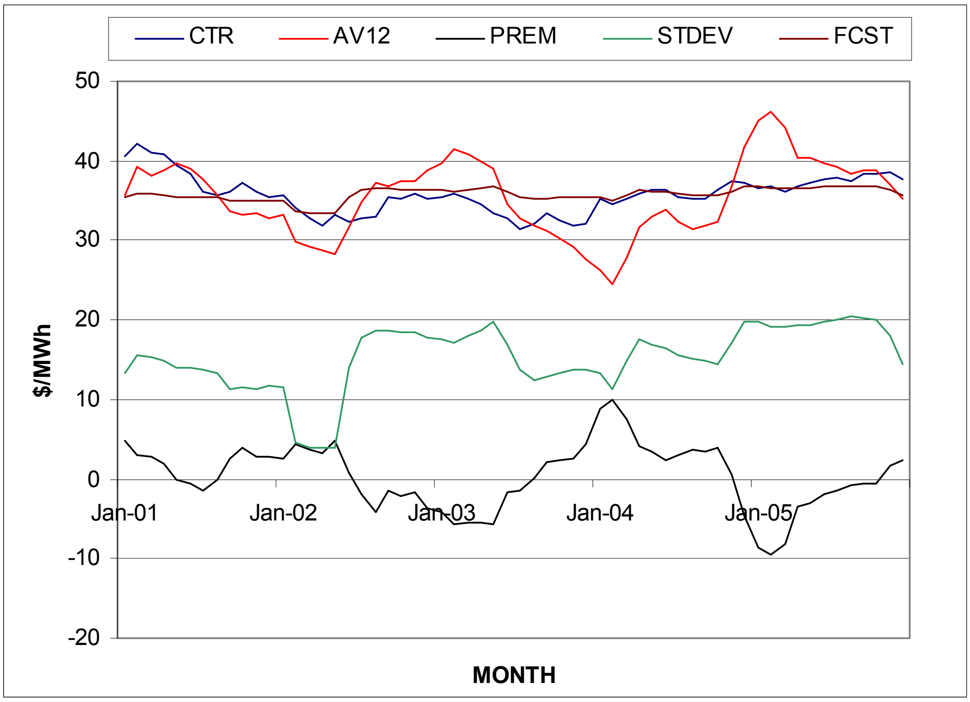
[7] The first order autocorrelation coefficient (ρ) of the residuals of the uncorrected model is around 0.7. Parameter estimates corrected for autocorrelation are obtained by regressing $P_t - \rho P_{t-1}$ on $\sigma_t - \rho\sigma_{t-1}$ and $\gamma_t - \rho\gamma_{t-1}$. The corrected model is $31.55 + 0.6\sigma - 1.79\gamma$ with t-scores 26.36, 5.93 and -3.09 respectively. The R^2 value is 39%.

New South Wales

Figure 3 shows the contract price analysis repeated for New South Wales. In contrast with Victoria, the premium (PREM) averages only $0.40/MWh. Further, notwithstanding fluctuations in antecedent spot price averages (which presumably should be relevant), the contract price is largely invariant over time.

For Victoria the contract price series (CTR) has a standard deviation of 5.9 and the spot price series (AV12) 6.5. For New South Wales CTR has a standard deviation of just 2.4 and AV12 4.75. This suggests that compared with Victoria, the contract prices in New South Wales are less responsive to movements in spot prices. The contract price dynamic appears to be less affected by the spot market and presumably has to do more with common ownership of generation portfolios and retail businesses and the stabilising effect of ETEF.

Figure 3 **Contract Price Analysis - New South Wales**



Queensland

Figure 4 shows the contract price analysis for Queensland. Again Queensland exhibits reasonably stable contract prices. The contract price series (CTR) has a standard deviation of 2.4 (similar to New South Wales) but the spot price series (AV12) has a standard deviation of 7.30 (higher than both New South Wales and Victoria). The average premium (PREM) in Queensland for the period studied is actually negative (-$1.38/MWh) although it has been positive since December 2003. Queensland also shows contract prices since 2004 steadily increasing notwithstanding a decline in the level and volatility of antecedent spot prices. However, in recent times, the contract price has experienced some softening.

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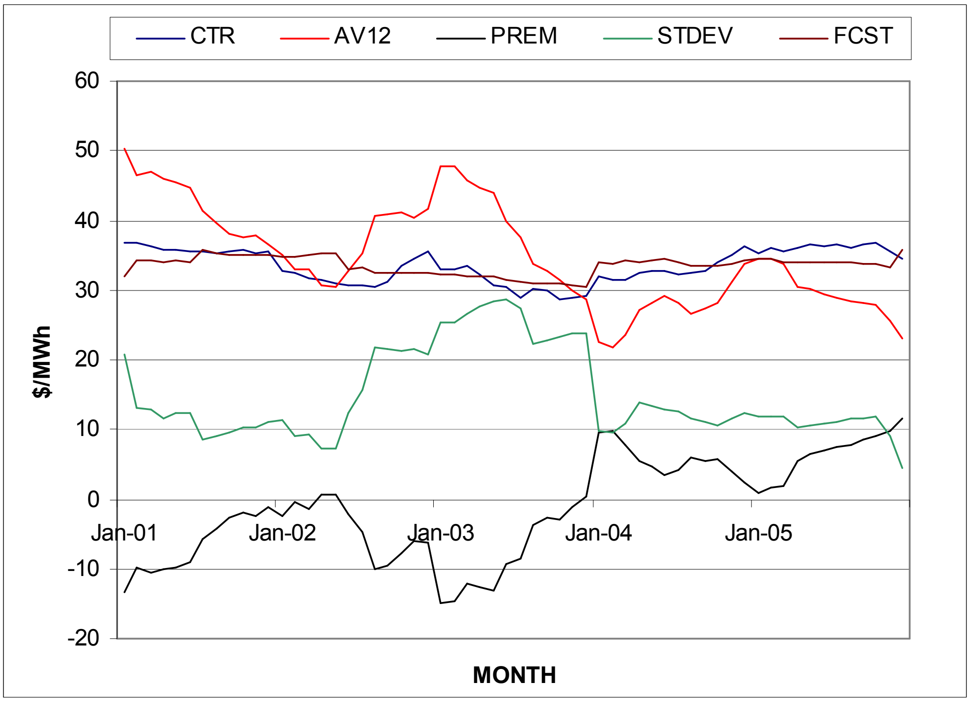
Figure 4 **Contract Price Analysis- Queensland**



Conclusion

The Victorian region of the NEM appears to exhibit a strong relationship between quoted contract prices and antecedent spot price behaviour – whether in terms of spot price averages or standard deviation.

There appears to be little evidence for such a relationship in New South Wales and Queensland. This lack of relationship might have something to do with common State government ownership of much of the retail and generation sector in those States, and the existence of market distorting arrangements (ETEF in New South Wales and LEP in Queensland). Perhaps the Victorian region provides some clues as to how the relationship between spot and contract prices in the other regions might change when these arrangements are dismantled.

Finally we point out that this analysis has not directly addressed the question of whether the forward prices are unbiased estimates of future spot prices. Instead we have looked at whether the current spot prices influence the current forward prices for settlement at a future date. Contracts and the efficient market hypothesis is a subject we are planning to take up in a future edition of Insider.

Using NEO to Analyse Contract and Spot Prices

The IES analysis tool NEO brings spot prices and contract data together facilitating insightful analysis of relationships.

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Estimating the Value of Energy in Storage

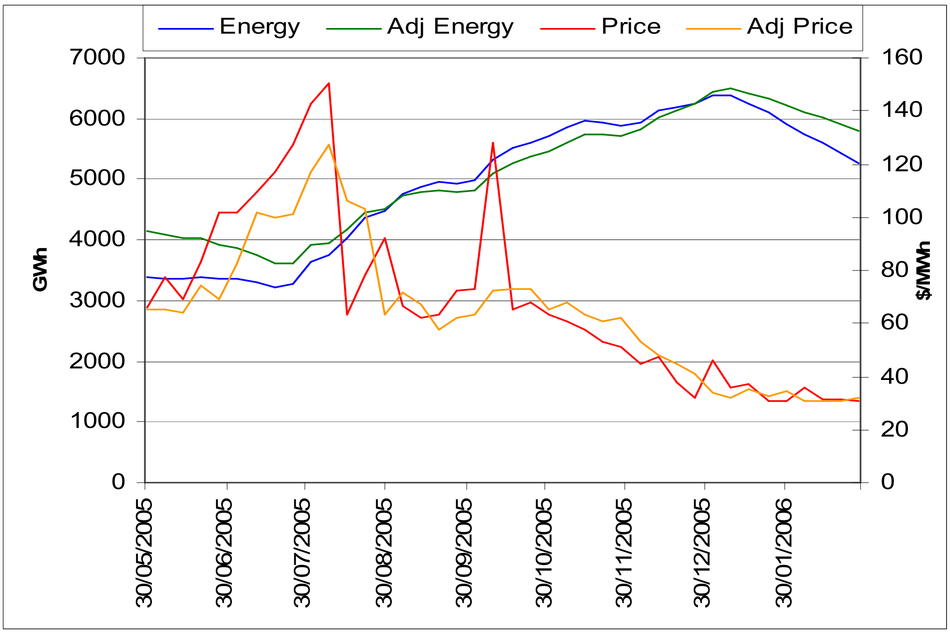
Tasmania entered the National Electricity Market in May 2005 ahead of physical interconnection. Presently Basslink is undergoing final testing and is expected to enter commercial operation at the end of April 2006. When this occurs the Victorian region will be subject to a new spot pricing dynamic. While it is well understood that at times of high Victorian spot prices, Hydro Tasmania will “appear” in Victoria as a 600MW peaker, it is harder to form a view on the direction and quantum of the net flow of energy between the Tasmanian and Victorian regions.

As Tasmania’s hydro-electric generation system has a very large storage capacity (14,435GWh), the net energy flow between regions will be largely governed by the level of stored (potential) energy reserves, or more precisely the marginal value associated with this energy in storage. Hydro Tasmania can be expected to assess this value based on its view of future opportunities to trade this energy. Other things being equal, the value will be high at relatively low levels of stored energy and low at relatively high levels of stored energy. We analyse the Tasmanian regional reference (spot) prices published by NEMMCO together with the stored energy level advised by Hydro Tasmania each week on its website[8] for the period 1 June 2005 to 28 February 2006.

Stored Energy and Price Data

Figure 5 compares the stored energy available at the start of a week with the average spot price for that week. From July to December 2005 the stored energy has increased from less than 4,000GWh to nearly 6,500GWh. This has been accompanied by a decrease in the average level of spot prices from around $140/MWh (unadjusted) to around $30/MWh.

Figure 5 **Tasmania Stored Energy and Price**



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[8] http://www.hydro.com.au//Storages/Storage%20Summary.xls

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Adjusting Price and Stored Energy Data

Identification of the underlying relationship between price and storage level necessitates two adjustments. First, the stored energy data needs to be adjusted for seasonality of inflows. Second, the price data needs to be adjusted by removing any large price spikes unrelated to the stored energy situation. The price data is adjusted simply by truncating price spikes at $200/MWh. A more elaborate adjustment is made to stored energy data and there is some error in this adjustment arising from not having available the actual seasonal profile of expected storage inflows, not correcting for seasonality of demand (this could be done), and not correcting for any imbalance between expected storage inflows and expected hydro-electric generation.

However, to illustrate, we effect a seasonal adjustment to stored energy by scaling the monthly rainfall pattern for Queenstown in Western Tasmania[9] to an assumed annual expected storage inflow of 10,000GWh.

The storage adjustment at the start of any month is the expected movement in storage relative to the beginning of the year (or any arbitrary reference point) assuming a constant outflow (hydro generation) each month and expected inflows.

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[9] Source – Bureau of Meteorology.

The calculation of the storage adjustment is set out in Table 4.

Table 4 Calculation of Storage Adjustment

Month	Rain (mm)	Percent	Inflow GWh	Surplus / Deficit	Storage Adjustment
1	149.9	6.2%	619	-214	0
2	98.8	4.1%	408	-425	-214
3	147.2	6.1%	608	-225	-640
4	211.3	8.7%	873	39	-865
5	248.5	10.3%	1,026	193	-826
6	219.7	9.1%	907	74	-633
7	268.6	11.1%	1,109	276	-559
8	267.5	11.0%	1,105	271	-284
9	248.5	10.3%	1,026	193	-12
10	209.9	8.7%	867	33	181
11	183.7	7.6%	759	-75	214
12	168.1	6.9%	694	-139	139
Total	**2,421.7**	**100.0%**	**10,000**	**0**	**0**

We estimate a seasonal adjustment function SA(t) by fitting a sine curve to the storage adjustment. The fit is shown in Figure 6.

$SA(t) = C + A \, SIN(\varphi + \pi t/6)$

Where C is an offset, A is the amplitude and φ is the phase.

We estimate: C = -292, A = 535, and $\varphi = 2.13$.

This allows us to interpolate the seasonal storage adjustment to apply to the stored energy at any time in the year (in this case the start of each week).

For example if the level of stored energy is 5,000GWh at the beginning of January, we would expect it to have fallen to 5,000 – 865 = 4,135GWh by the start of April (the low point) and to have risen to 5,000 + 214 = 5,214GWh at the start of November (the high point). We seasonally adjust reported stored energy values to the January reference point by subtracting the storage adjustment i.e.

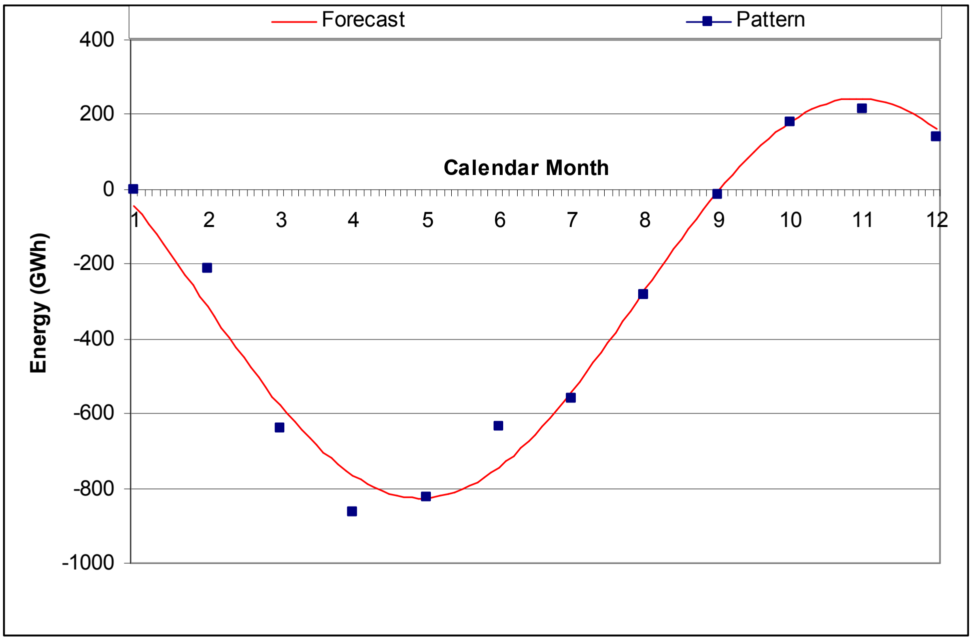
$AS(t) = S(t) - SA(t)$

where S(t) is the reported energy in storage, and

AS(t) is the adjusted energy in storage.

For example, if the reported stored energy in April was 5,000GWh we would adjust it to 5,865GWh.

Figure 6 **Seasonal Storage Adjustment**



Specifying and Estimating Alternative Stored Energy Valuation Models

The adjusted price and adjusted storage data are shown as a scatterplot with superimposed trend curves (see Figure 7).

We estimated parameters for three alternative model specifications as follows:

- Linear: AP = 178 – 22 AS
- Inverse: AP = 524/AS – 41
- Power: AP = 1042 $AS^{-1.77}$

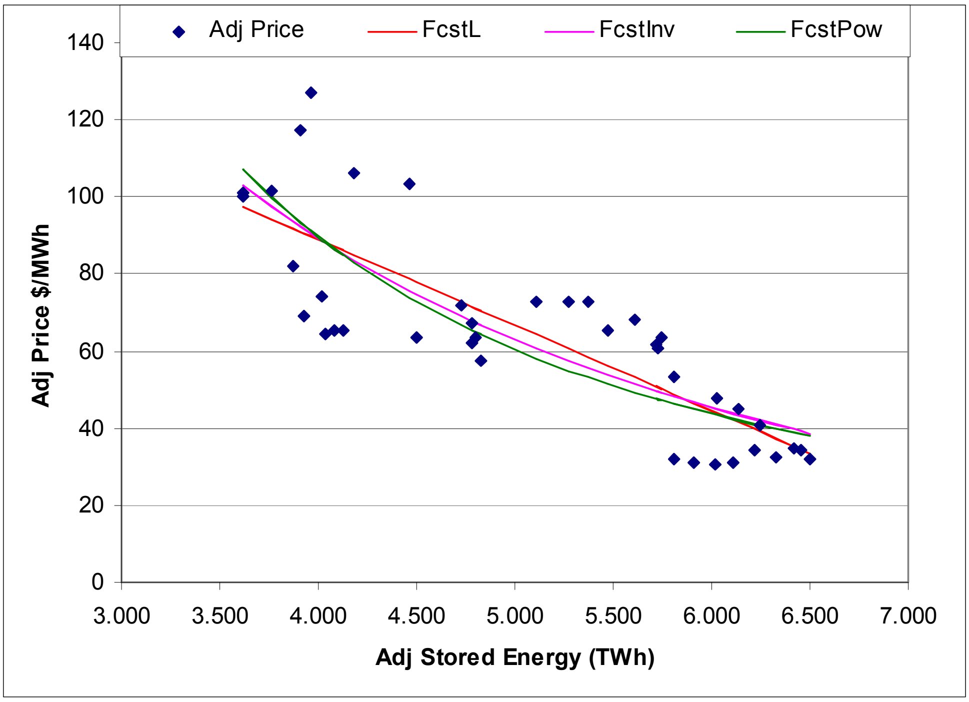
where

AP is the adjusted price ($/MWh), and

AS is the adjusted energy in storage (TWh).

Based on the adjusted data there does not appear to be a strong reason to prefer any one of these functional specifications above another.

Figure 7 Estimated relationship between price and energy in storage



Using PROPHET to Model Hydro-Electric Storage Generators

The IES market simulation program PROPHET provides for the specification of energy and water valuation functions for hydro-electric storage generators. A number of model specifications are supported. In market simulations, PROPHET effects storage accounting and adjusts hydro-electric generator bids dynamically based on storage.

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