APPENDIX

Energy Market Authority of Singapore

Review of vesting contract level and peak weighting factors

22 May 2006

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EXECUTIVE SUMMARY

The Singapore electricity market uses a vesting contract regime for the mitigation of market power. The vesting contract strike price, vesting level and peak weighting factor under the vesting regime are scheduled to be 'reset' at two yearly intervals. This is the second such reset, applying to the period commencing on 1st January 2007 and running through until 31st December 2008.

The 'reset' process is managed by the Energy Market Authority of Singapore (EMA), which has engaged PA Consulting Group to review the recommended level of vesting contract cover and peak weighting factor to be applied at the next reset[1]. This document sets out PA's analysis in this respect.

Vesting Contracts and Market Power

Market power is the ability to profitably move prices away from the competitive level. The *possession* of market power, which is principally a structural phenomenon, is distinct from the *exercise* of market power, which is a behaviour and creates effects in terms of market clearing prices and quantities, social net benefit and distribution of wealth. Market power can be mitigated through market design to promote competition and/or through a variety of other mechanisms, including enforcement, price and revenue caps, and vesting contracts. Vesting contracts are preferable to price and revenue caps in that they promote competition.

The purpose for the introduction of vesting contracts in Singapore was the mitigation of market power. Coincidentally, vesting contracts provide a degree of consumer price protection as well as providing support for generator revenue. While these effects are not the purpose for vesting contracts in Singapore their existence and repercussions cannot be ignored.

The existence of market power can be determined quantitatively by the use of indices such as the Herfindahl-Hershman Index (HHI), or by modelling using one of several game-theoretic modelling approaches to supplier behaviour. The Cournot Game and Supply Function Equilibrium (SFE) are two models that can be used for these purposes. While it might be possible to apply SFE to the vesting contract analysis, the most robust approach would be to apply assumptions that approximate a Cournot response function. In order to avoid the limitations of SFE, we prefer to apply the Cournot model directly.

In seeking to control the exercise of market power is an oligopolistic market, such as the Singapore electricity market, the desirable average market price is equal to the LRMC of most efficient generator as determined by EMA – hence that is the average market price we target in setting the vesting contract quantities. It is also important to note that this price level does not completely eliminate the exercise of market power. The average price outcome is above the average SRMC, and hence there remains some residual exercise of market power. However, this is the appropriate outcome since the market price is sufficient to induce efficient new generation investment, yet it does not provide excessive profits to the generators.

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1 This report does not review the value of vesting contract strike price or long-run marginal cost.

Pool price behaviour in 2004 and 2005

Table 1 shows a comparison between the average Vesting Contract (VC) strike price (LRMC of the most efficient generator), the GWA pool price, and the average market SRMC in 2004 and 2005.

Table 1: Comparison of LRMC, GWA pool price, and SRMC for 2004-2005

Price ($/MWh)	2004	2005
VC Strike Price	96.95	110.94
GWA pool price	81.48	108.72
Average Market SRMC	N/A	85.07

Examining the quarterly data we see that:

- The 2004 prices were low in comparison to the vesting contract strike price, which could be attributed to a transition period. We would expect this transition period as the market adapts after the introduction of a new regulatory framework.
- The 2005 prices are much closer to vesting contract strike price, with the average price only $2.22/MWh lower than the average vesting contract strike price.

When we examine the 2005 outcomes we see that the actual GWA is greater than the average market SRMC but less than vesting contract strike price[2]:

- Comparing the SRMC with the GWA market price gives an overall margin of $23/MWh. These results, where GWA is greater than SRMC indicate that market power was used to some extent in the market.
- The fact that the GWA Prices are below LRMC indicates that the generation companies have not exercised an excessive degree of market power since vesting contracts were introduced to the market on January 1st 2004.

These results are consistent with the interpretation that vesting contracts have achieved the intention set out for them of mitigating market power:

- Market power exists and the generation companies exercised some market power by obtaining a market price above SRMC.
- In 2005 the GWA Market Price was very similar to LRMC, with only a $2.22/MWh difference.

We are reluctant to claim a precise causal relationship between vesting contracts and the resulting average market price. While we had expected that the vesting contracts would force prices down to near LRMC we are somewhat surprised that the outcome was so close. We must allow that other explanations (eg, good luck, setting a price that just avoids investigation by the EMA) are possible and each one would need to be examined in detail before we say for certain that the generation companies were running a profit maximising strategy.

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[2] Prices are produced by running the calibrated model for 2005 with 100% contracting. This gives approximately the perfectly competitive or SRMC market price.

Vesting Contract Levels in Singapore

Our review of vesting contract level and peak weighting factors considered five scenarios. Each scenario represents a different build schedule for new power stations by Keppel and Island Power:

- Scenario 1 (the "Base Case") includes 500MW of new generation from Keppel in 2007 and 800MW of new generation from Island Power in 2008.
- Scenario 2 includes 500MW of new generation from Keppel in 2008 and 800MW of new generation from Island Power in 2008.
- Scenario 3 includes 500MW of new generation from Keppel in 2008, but excludes any new generation from Island Power in 2007-08.
- Scenario 4 excludes any new generation from Keppel in 2007-08, but includes 800MW of new generation from Island Power in 2008.
- Scenario 5 excludes any new generation from Keppel or Island Power in 2007-08.

A summary of our suggested vesting contract levels and weighting factors for the five scenarios is shown in Table 2.

Table 2: Recommended Vesting Contract Levels and Weighting Factors

	Year	Scenario				
		1	2	3	4	5
VC Level	2007	56%	63%	63%	63%	63%
Peak	2007	1.22	1.20	1.20	1.20	1.20
Shoulder	2007	1.00	1.00	1.00	1.00	1.00
Off-Peak	2007	0.71	0.74	0.74	0.74	0.74
VC Level	2008	52%	52%	58%	57%	65%
Peak	2008	1.25	1.25	1.22	1.23	1.17
Shoulder	2008	1.00	1.00	1.00	1.00	1.00
Off-Peak	2008	0.68	0.68	0.71	0.71	0.78

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1. INTRODUCTION

This report sets out PA Consulting Group's analysis of the vesting contract levels and peak weighting factors for the Singapore electricity market for 2007 and 2008, pursuant to the scheduled review of those parameters by the Energy Market Authority. It includes analysis of the success (or otherwise) of vesting contracts in curbing market power in the two years since their introduction. It also reiterates the theoretical basis for the use of vesting contracts to address market power issues.

In **Section 2** we present a **theoretical overview of vesting contracts and market power**:

- Sections 2.1 and 2.2 consider the origins, exercise, effects and mitigation of market power
- Section 2.3 considers the uses of vesting contracts, both generically and in Singapore.

In **Section 3** we present **analysis of the level of market power in Singapore since the introduction of vesting contracts**:

- Section 3.1 analyses market power comparing market prices to LRMC
- Section 3.2 presents a recent analysis of market power in Singapore by Youngho Chang
- Section 3.3 presents our conclusions.

In **Section 4** we present our **analysis and conclusions with respect to the vesting contract level and peak weighting factors in Singapore**:

- Section 4.1 introduces the vesting contract modelling
- Section 4.2 sets out the key assumptions that underpin our analysis
- Section 4.3 summarises the different scenarios used for modelling purposes
- Section 4.4 summarises the different sensitivity analyses used
- Section 4.5 sets out the results of our different scenarios
- Section 4.6 sets out the results of our different sensitivities
- Section 4.7 presents our conclusions and recommendations.

The appendices set out our modelling work in more detail.

2. *THEORETICAL OVERVIEW OF VESTING CONTRACTS AND MARKET POWER*

2.1 MARKET POWER

2.1.1 Basics

Market power is the ability to profitably move prices away from the competitive level. In a theoretical, perfectly competitive market, no participant would be able to affect the market price through its behaviour, and market power can thus be thought of as being associated with imperfect competition.

Market power should not be confused with market dominance, which is a different concept and is associated with a single market participant. One or several participants may possess market power.

For purposes of this discussion, we do not concentrate on games where players are acting collusively.

2.1.2 Exercise of market power

Market power is an *ability* and is principally a structural phenomenon. A participant can possess market power without exercising it. The *exercise* of market power is a *behaviour*.

Market power is exercised by withholding capacity from the market, either physically (by declining to offer some or all of the participant's capacity) or financially (by offering capacity at an increased price). In most cases the two methods of exercising market power are equivalent.

The exercise of market power results in changes to the market clearing price and quantity that are advantageous to the party exercising market power (and possibly to others) and that have a negative net social benefit. When suppliers exercise market power, the effect is to reduce the cleared quantity and increase the cleared price[3]. In electricity markets, where demand may be, or may be modelled as, inelastic, the effects on price can be dramatic.

Practically speaking, there is usually sufficient uncertainty on the part of regulators regarding production costs, that a certain level of mark-up[4], while arguably the result of the exercise of market power, is considered tolerable.

2.1.3 Tests for the existence of market power

There are several indices and models that can be used to quantitatively test for the existence of market power. Quantitative tests fall into two categories:

- Indices
- Market power models

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[3] In the case where the price elasticity of demand is zero, the quantity distortion from the exercise of market power is zero and there is no loss of social net benefit. There is, however, a wealth transfer from consumers to producers.

[4] Mark-up is commonly measured by the Lerner Index, which is the price-cost margin as a fraction of price.

A. INDICES

Indices provide a "rule of thumb" basis for testing the existence of market power. The most commonly-used index is the Hirfindahl-Hirshman Index (HHI).

The HHI is a measure of market concentration used by the US Department of Justice (DOJ). It takes into account the relative size and distribution of the firms in a market. The index is defined as:

$$HHI = (S_1)^2 + (S_2)^2 + (S_3)^2 + (S_4)^2 + \ldots\ldots$$

where S_j is the % market share of the j^{th} market player.

HHI approaches zero when a market consists of a large number of firms of relatively equal size and increases as the number of players in the market decreases and as the disparity in size between those firms increases. A market with 1 player has an HHI of 10,000. The DOJ suggests the interpretation given in Table 3.

Table 3: Interpretation of HHI

Index	Competitiveness
HHI <1000	Competitive
1000 < HHI < 1800	Moderately concentrated
1800 < HHI <10000	Highly concentrated
HHI = 10000	Monopoly

Source: *http://www.usdoj.gov/atr/public/testimony/hhi.htm*

In Singapore for 2005 the HHI index has a score of over 2700. Compared to a trigger point of 1800 this suggests that the market is highly concentrated. On that basis it would fail the test of being a competitive market structure.

The HHI has a theoretical link to the Cournot Game: the average mark-up[5] in a Cournot oligopoly is equal to the HHI divided by the price elasticity of demand.

B. MODELS

Oligopolistic behaviour can also be modelled using game theory. Different models exist that make different assumptions about the way participants interact with the market, and can be used to test for the existence of market power by comparing the price predicted by the model to the competitive price. Three well-known models are:

- The Bertrand game, which assumes participants bid up to the SRMC of the next more costly plant owned by a competitor[6];
- The Cournot game, wherein each participant withholds capacity in order to maximise profit on the assumption that all other participants hold their output constant; and
- Supply Function Equilibrium, wherein participants construct supply functions (offer curves) iteratively that converge to an equilibrium set of profit-maximising supply functions for the participants.

Models used to evaluate market power in electricity markets are discussed in Section 2.2.

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[5] The average mark-up is the Lerner Index for each supplier, weighted by market share.

[6] For example, a marginal CCGT can bid up to the SRMC of an oil plant and an oil plant to a GT.

2.1.4 Methods for Mitigating Market Power

Ideally, mitigation of market power would not be necessary and competitive prices would prevail. The ideal market from this point of view would have many, diverse participants, with few barriers to entry, elastic demand, good access to information and deep, liquid forward markets. Taking measures that promote the creation of such a market would be the first and best step toward controlling market power.

However, particularly in sectors of small economies that lack depth, and formerly regulated sectors in transition to competition, market power is a reality. By mandating that participants with market power hold supply contracts with particular features, regulators can reduce the incentives for market participants with market power to exercise it. The use of contracts for this purpose is discussed in Section 2.3.

2.2 ECONOMIC MODELS OF MARKET POWER

2.2.1 Bertrand Game

The Bertrand game is best illustrated in a market simulation model by bidding up the SRMC of each player to the next highest SRMC of a competitor. The impact of this is most dramatic for plant at the top of the merit order of one category (say the most expensive steam turbine) being able to bid to the SRMC of the next category (say the cheapest gas turbine).

Bertrand gaming is not taken further in this analysis for two reasons:

- While it is useful in illustrating some forms of bidding behaviour it is not suitable for assessing contract positions, since Bertrand Gaming takes no account of contract positions, and
- It is a much milder form of gaming behaviour than normally experienced in electricity markets, because the generators are seeking only to capture the available price increment to the next most expensive generator rather than to take maximum advantage of their market power[7], and so underestimates market power potential.

2.2.2 Cournot Gaming

Cournot gaming is a theoretically rigorous analysis of oligopoly market behaviour. It recognises the incentives on each player in a competitive market and it considers the interactions between those players. If market power is absent the Cournot solution becomes the perfect competition solution.

Specifically, Cournot gaming assumes that:

- Players seek to maximise their profit (market price less marginal cost, taking into account contract commitments).
- Each player alters the quantity it offers in the wholesale market from each of its stations to move along their "residual demand curve" (the change in demand they see) to maximise its profit, assuming the other players have fixed outputs.
- Other players similarly react to their "residual demand curve" in an iterative fashion.

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7 In a merit order graph this can be seen as each generator pushing their price to just below the next step in the supply curve.

- Simultaneously, demand responds to changes in the wholesale market spot price, according to a defined demand curve.
- The process stops when all players reach Nash equilibrium (no player can move from its position without making itself worse off).

The Cournot analysis does not assume collusion – each player operates independently. The Cournot analysis establishes equilibrium market share. Any move away from the Cournot equilibrium is unstable.

More detail of this method is given in Appendix B.

2.2.3 Supply Function Equilibrium

Supply function equilibrium (SFE) models are a credible alternative to Cournot. Like Cournot they seek profit maximising market equilibrium but using a different dynamic.

This approach assumes that the demand is uncertain and that each player specifies a supply function. These supply functions are modified as they interact with other players. The modified supply functions iterate until they converge to a set of equilibrium supply functions that specify an equilibrium market price that maximises its return while facing demand uncertainty.

The focus of the SFE approach is that it attempts to mimic the participant behaviour in a “bid-based-pool” like Singapore in that players are assumed to respond by altering both price and quantity. It focuses on modelling the shape of supply functions in the face of uncertain demand. In so doing it aims at giving insight into how to devise a consistent offer curve that is appropriate over multiple period when demand is not known with certainty. While an interesting problem, this is not the focus of the vesting contract study[8] so the model is not directly applicable to the problem we are solving.

There are some significant limiting assumptions usually made for the sake of tractability:

- Consistent bidding across multiple pricing periods,
- Linear cost, supply and demand functions, and
- A well-defined response mechanism (e.g. an optimal response) by players to the supply functions of their competitors.

Without making some severely limiting assumptions (one of the most useful being to assume Cournot-like behaviour), the model does not guarantee that the model results in consistent and unique equilibria.

Consequently, while significant strides are being made in the solution of the SFE models, under many realistic assumptions these models are difficult to solve and may have multiple solutions. For further details we refer to an article by Ross Baldick[9].

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8 We are interested in determining appropriate contract levels to control market power without reference to uncertain demand, since the effect of uncertain demand from half hour to half hour is not a significant feature over the course of an annual vesting contract period.

9 See Ross Baldick, “Electricity market equilibrium models: the effect of paramatization”, http://www.ece.utexas.edu/~baldick/papers/parametrization.pdf. Also Aleksandr Rudkevich, “Supply Function Equilibrium: Theory and Applications”, Proceedings of the 36th Hawaii Conference on System Science, (HICSS’03), 2002.

2.2.4 Comparison of Cournot and SFE

Choosing a modelling methodology is a balance between suitability to the problem, theoretical robustness and computational tractability. No model is perfect and each represents a compromise in some ways.

Cournot is particularly suited to the problem at hand in that contract cover is a direct driver of the model and its solution. It relies on a few key assumptions that to a large extend can be tested against and calibrated to the real market[10].

The SFE model is focussed on a rather different problem to the Cournot model – developing an offer curve under uncertain demand rather than deriving a price/quantity solution. The focus of the current study is significantly different from the modelling emphasis of SFE.

The Cournot model has the advantage of being theoretically robust (its theoretical assumptions are well-understood), it is computationally simple and allows, if necessary, for different definitions of the demand function[11].

From a theoretical standpoint SFE is more general than Cournot within the confines of its focus, in that it allows for a range of generator response functions, whereas Cournot Gaming involves only a single response (withholding generation capacity from the market) in order to maximise profit. The supply curve that approximates the Cournot outcome can be developed as a particular case of SFE. Within the SFE construct the Cournot-like assumptions gives more conservative (higher price) outcomes than some of the alternative SFE parameterisations.

In terms of computational tractability Cournot stands out. The solution methodology is well understood, it is straightforward to solve and give reliable and consistent solutions. Cournot modelling is fundamentally a well-understood and robust methodology that has been widely applied to electricity market modelling for gaming behaviour.

By contrast SFE results depend on the modeller's assumptions about competitive behaviour based on their specification of various parameters. Under many parameter settings the model does not reach consistent and unique equilibria. The most reliable parameter settings closely resemble the Cournot game. Recent developments, still in the academic domain, use Conjectured Supply Functions. This may have overcome some of SFE's computational deficiencies, but have yet to be widely applied in practice[12].

While it might be possible to apply SFE to the vesting contract analysis, the most robust approach would be to apply assumptions that approximate a Cournot response function. In order to avoid the limitations of SFE, we prefer to apply the Cournot model directly.

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[10] Where there is doubt we can check parameter robustness by sensitivity analysis, experience in other markets and reference to the academic literature.

[11] Note: our application of Cournot as a medium-term or long-term predictor of market behaviour negates the weakness that Cournot cannot deal with a fully inelastic demand function.

[12] Christopher J Day, Benjamin F Hobbs and Jong-Shi Pang, "Oligopolistic Competition in Power Networks: A Conjectural Supply function Approach, IEEE Transactions on Power Systems, 17, No. 3, p597-606, 2002.

2.3 VESTING CONTRACTS

A vesting contract is a supply contract imposed ('vested') on market participants. In Singapore, vesting contracts are of the form of Contracts for Differences (CfDs), in keeping with the 'gross pool' design of the spot market.

2.3.1 Market power mitigation

A supplier that holds contracts faces a reduced incentive to exercise market power, since the costs of withholding capacity are the same as if it were uncontracted, but the benefits are less. Vesting contracts can therefore be applied to reduce the incentive to exercise market power.

Vesting contracts differ in two important respects from freely-entered CfDs and other hedging arrangements that suppliers may undertake of their own accord:

- They have a longer term than typical supply contracts. This fact is important because shorter-term contract prices tend to reflect recent observed spot prices rather than long-run costs. If contract terms are short, then suppliers have an incentive to exercise market power to raise spot prices in the expectation that those prices will be reflected in any contracts they negotiate in the future.
- They are priced at a benchmark level. The benchmark typically reflects both the long-run economics of the market and Government policy regarding stranded asset cost recovery: if stranded asset costs are determined to be recoverable, then the benchmark may be set above the long-run marginal cost of a the most efficient generator. By contrast, the price of a commercial CfD contract is a matter for negotiation.

2.3.2 Objectives of the vesting contract regime in Singapore

The vesting contract regime in Singapore is targeted at mitigation of market power. The regime achieves this objective by assigning a quantity of vesting contracts to the generators.

In setting the vesting contract volume levels for an oligopoly market, a key decision is "what spot price outcome is appropriate"?

To answer this question, we discuss the two extreme opposite competitive positions, perfect competition and monopoly, and then look at an oligopoly market outcome.

In a perfectly competitive market, each of the generators will offer their capacity into the market at their SRMC. The market pool price each half hour will be the SRMC of the most expensive generator needed to meet demand (and other requirements, such as reserve). The resulting pool price over a year will be a generation-weighted average of those SRMCs.

The problem with this outcome is that the generators would generally have received only sufficient revenue to cover their short-run variable costs. In the long run, this level of market prices would be insufficient to cover the generators' fixed costs. If generators do not expect to cover the fixed costs of new generation, then they will not make further generation investments, which will eventually lead to a shortage of generation capacity in the market. This would be an undesirable outcome.

The reason this happens is that perfect competition is a model that exists only in economic theory and assumes free entry into the market. This assumption is not valid for generators, whose investment represents a significant fixed entry cost.

The opposite extreme to perfect competition is a market in which all generation capacity is owned by a monopoly. In this case, an unfettered monopoly will exercise market power to the extent that average spot prices are above the LRMC of the most efficient generator. This would also be an undesirable, and inefficient, outcome.

Therefore, neither perfect competition nor monopoly would provide appropriate market outcomes. So, what should we do in an oligopolistic market, such as Singapore?

To enable the generators to earn sufficient revenue to cover their long run fixed and variable costs, and hence to induce further generation investment, the market needs to deliver an adequate average price. That adequate price is the LRMC of an efficient new generator. Therefore, in seeking to control the exercise of market power in an oligopolistic market, the desirable average market price is equal to the LRMC of the most efficient generator – hence that is the average market price we target in setting the vesting contract quantities.

Note that the LRMC of an efficient new generator does not necessarily deliver sufficient revenue to existing generators – but it is not the intent of the policy to provide revenue (or valuation) support for incumbent generators.

It is also important to note that the oligopolistic market outcome, in which the average market price is equal to the LRMC of an efficient new generator, does not completely eliminate the exercise of market power. The average price outcome is above the average SRMC solution described above, and hence there remains some residual exercise of market power. However, this is the appropriate outcome since the market price is sufficient to induce efficient new generation investment, yet it does not provide excessive profits to the generators.

3. *ANALYSIS OF THE LEVEL OF MARKET POWER IN SINGAPORE SINCE THE INTRODUCTION OF VESTING CONTRACTS*

3.1 GWA PRICE LEVELS IN 2004/2005

Whether the generation companies have exercised market power, and the extent of the exercise of market power, can be gauged by comparing the Generation Weighted Average (GWA) pool price with the perfectly competitive solution and the LRMC solution. That is:

- GWA pool price: represents the generation weighted average price observed in the wholesale market.
- Average Market SRMC[13]: the average price resulting from a perfectly competitive market in which all generation stations offer into the market at their SRMC[14].
- VC Strike Price: We expect the GWA pool price to approximately equal the VC Strike Price, where the vesting contract strike price is the LRMC of the next efficient new generation station.

Table 4 shows a comparison between the average Vesting Contract strike price (LRMC), the GWA pool price, and the average market SRMC in 2004 and 2005.

Table 4: Comparison of VC strike price, GWA Price, and SRMC for 2004-2005

Price ($/MWh)	2004	2005
VC Strike Price	96.95	110.94
GWA pool price	81.48	108.72
Average Market SRMC	N/A[15]	85.07

Table 5 shows quarterly price results for 2004 and 2005.

Table 5: 2004-2005 Results by quarter for VC strike price and GWA Price

Price	2004				2005			
($/MWh)	1	2	3	4	1	2	3	4
VC Strike Price	94.24	96.25	95.73	101.56	101.29	96.35	117.38	128.39
GWA Market Price	68.86	82.78	82.06	92.11	85.84	107.90	116.22	124.42

Examining the quarterly data we see that:

- The 2004 prices were low in comparison with the VC strike price, particularly early in the first quarter of the year, which could be attributed to a transition period as the new

13 Running the calibrated Cournot model for 2005 with 100% contracting produces these market prices. Using 100% contracting gives approximately the perfectly competitive or SRMC market price.

14 This is not to be confused with the SRMC of the next new build generator, which will usually (though not always) be lower than the average market SRMC. The average market SRMC is the perfectly competitive market price that results from all plant offering into the market at their SRMC.

15 The generators' 2004 SRMC data, required to calculate the average market SRMC by running the model with 100% contracting, was not available.

market became established. We would expect this transition period as the market adapts after the introduction of a new regulatory framework.

- The 2005 prices are much closer to LRMC, with the average price only $2.22/MWh lower than the average LRMC. We see some variation in each quarter, which could be due to several factors (e.g. market volatility, fuel-price volatility, fuel hedging).

Table 6 compares the average market SRMC with the actual market in 2005.

Table 6: SRMC vs. Market Price by Load Block

Price ($/MWh)	Load Block			GWA
	Peak	Shoulder	Off-Peak	
Average Market SRMC	84.37	84.68	86.43	85.07
Actual Market Price	111.46	110.73	103.99	108.72

When we examine the 2005 outcomes we see that the actual GWA is greater than the average market SRMC, but less than LRMC (vesting contract strike price)[16]:

- Comparing the SRMC with the GWA market price gives an overall margin of $23/MWh, ranging from $17/MWh (off-peak) to $27/MWh (peak). These results, where GWA is greater than SRMC indicate that market power was used to some extent in the market.
- The fact that the GWA prices are below LRMC indicates that the generation companies have not exercised an excessive degree of market power since vesting contracts were introduced to the market on January 1st 2004.

These results are consistent with the interpretation that vesting contracts have achieved the intention set out for them of mitigating market power:

- Market power exists and the generation companies exercised some market power by obtaining a market price above SRMC.
- In 2005 the GWA Market Price was very similar to LRMC, with only a $2.22/MWh difference.

We are reluctant to claim a precise causal relationship between vesting contracts and the resulting average market price. While we had expected that the vesting contracts would force prices down to near LRMC we are somewhat surprised that the outcome was so close. We must allow that other explanations (eg, good luck, setting a price that just avoids investigation by the EMA) are possible and each one would need to be examined in detail before we say for certain that the generation companies were running a profit maximising bidding strategy that exactly matched the vesting contract market power mitigation[17].

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[16] Prices are produced by running the calibrated model for 2005 with 100% contracting. This gives approximately the perfectly competitive or SRMC market price.

[17] The price duration curve, while quite flat by international standards, still had a number of very high periods and a number of very low price periods that would have a strong effect on the GWA market price.

3.2 AN INDEPENDENT STUDY OF MARKET POWER IN SINGAPORE

A recent study by Youngho Chang (“*Pricing Behaviour, Market Power and Vesting Contracts in a Deregulated Electricity Market”,* National University of Singapore, December 2005) of the New Electricity Market of Singapore (NEMS) looked at the effect vesting contracts had on the newly deregulated market. Chang conducted both a theoretical forecast of the effects, using the supply function equilibrium (SFE) model, and an analysis of empirical evidence, using observed USEP from 1 January 2003 to 31 October 2004[18].

3.2.1 Supply Function Equilibrium

Chang constructed a theoretical SFE model to predict the effect that vesting contracts would have on prices in an electricity spot market. He showed mathematically that the supply function under vesting contracts has a flatter slope than compared with a case with no vesting contracts, i.e. supply is more elastic. It was also found that the supply function is, in theory, lower with vesting contracts than without, resulting in a lower equilibrium spot price. Chang concludes that the electricity spot market under vesting contracts will be more competitive than in a market without vesting contracts, due to the fact that generation companies are forced to reduce their prices.

3.2.2 Analysis of Actual Pricing Behaviour

In the numerical analysis to confirm his theoretical findings, Chang measured market power using the price-cost margin index (PCMI). PCMI is defined as ‘the ratio of difference between the actual price and the competitive benchmark price (CBP) calculated from the marginal generator’s cost of supply at total demand equating total licensed capacity less planned outage level’.

Chang compared PCMI’s from 2003, before vesting contracts were introduced, with PCMI’s (adjusted for oil-prices) from 2004. The average monthly PCMI’s for 2003 were $34.95/MWh and $30.87/MWh, for low and high infra marginal costs respectively, while the oil-price adjusted PCMI’s for 2004 were $4.85/MWh and $3.95/MWh. This indicates that much lower market power existed in 2004 than 2003.

Chang concluded ‘…it becomes obvious how vesting contracts helped to curb the exercise of market power in the electricity spot market’, and ‘[The results] impl[y] that the electricity market is more competitive in 2004 where vesting contracts are present than in 2003 when vesting contracts are not yet introduced’.

3.3 CONCLUSIONS

From the 2005 results market power appears to have been controlled to an appropriate level. They have produced GWA prices that are in line with the expected LRMC (VC strike price) values.

Control of market power is an inexact process, and so it is pleasing to achieve outcomes as close as they were in 2005, with GWA price only $2.22/MWh different from the average LRMC. However we are reluctant to attribute these successful results solely to the Vesting Contracts regime without further examination.

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[18] Note that Chang’s analysis only covered 2004; it did not include 2005.

3. Analysis of the level of market power in Singapore since the introduction of vesting contracts…

The independent study presented adds further weight to our analysis that vesting contracts have been successful in curbing market power. It shows that market prices decreased in 2004 from their pre-VC levels, and that the theory indicates this should be expected under vesting contracts.

4. REVIEW OF VESTING CONTRACT LEVEL AND PEAK WEIGHTING FACTORS IN SINGAPORE FOR 2007 AND 2008

4.1 INTRODUCTION

Section 4.2 covers the basic input assumptions made to create the Cournot gaming model of the Singapore electricity market.

Sections 4.3 and 4.4 define the scenarios and sensitivities respectively. Scenario results are presented in Section 4.5, followed by sensitivity results in Section 4.6.

Conclusions and recommendations about the level of vesting contracts and peak weighting factors required to mitigate generator market power for 2007 and 2008 are presented in Section 4.7.

4.2 REVIEW OF ASSUMPTIONS

The data assumptions for the modelling have been thoroughly updated from the previous review:

- The model has been calibrated to the historic market data for 2005 prices, outputs and contract positions.
- Plant build, repowering and decommissioning schedules have been reviewed and revised in the light of best current information. In particular, we consider scenarios around the commissioning date of the Keppel and Island Power generators.
- Long run marginal cost of the most efficient generator was supplied by the EMA as $119/MWh. This is for a new CCGT plant and includes an SRMC of $91/MWh. This SRMC is based on the 2005 average spot HSFO price of US$40.87/bbl.

Appendix A contains the detailed model assumptions.

4.3 DETERMINATION OF SCENARIOS

Five scenarios have been run:

- Scenario 1 includes 500MW of new generation from Keppel in 2007 and 800MW of new generation from Island Power in 2008.
- Scenario 2 includes 500MW of new generation from Keppel in 2008 and 800MW of new generation from Island Power in 2008.
- Scenario 3 includes 500MW of new generation from Keppel in 2008, but excludes any new generation from Island Power in 2007-08.
- Scenario 4 excludes any new generation from Keppel in 2007-08, but includes 800MW of new generation from Island Power in 2008.
- Scenario 5 excludes any new generation from Keppel or Island Power in 2007-08.

Note that the Keppel and Island Power generation stations are assumed to be operational for the entire year in which they are commissioned. If a station were to be commissioned part way through a year, then the appropriate vesting contract level would be a combination of the scenarios listed above. For example, if Keppel were to be commissioned in the middle of 2007 and Island Power commissioned in 2008, then for the first half of 2007 Scenario 2 results would apply and for the second half of 2007 Scenario 1 results would apply.

4.4 DETERMINATION OF SENSITIVITIES

Three sensitivity analyses have been carried out for:

- Change in forecasted total load growth
- Change in the fixed component of LRMC (i.e. the difference between LRMC and SRMC)
- Change in the SRMC.

4.5 SCENARIO RESULTS

4.5.1 Scenario 1 – Keppel in 2007, Island Power in 2008

To achieve the target forecast price of LRMC of the most efficient generator (i.e. $119 / MWh) in 2007 and 2008 a modelled vesting contract level of **56%** was required in 2007 and **52%** in 2008.

The peak weighting factors shown in Table 7 are required to reflect competitiveness across each load block.

Table 7: Scenario 1 results

Year	VC Level	Load Block Weighting Factors		
		Peak	Shoulder	Off-Peak
2007	56	1.22	1.00	0.71
2008	52	1.25	1.00	0.68

4.5.2 Scenario 2 – Keppel in 2008, Island Power in 2008

To achieve the target forecast price of LRMC of the most efficient generator (i.e. $119 / MWh) in 2007 and 2008 a modelled vesting contract level of **63%** was required in 2007 and **52%** in 2008. The increase in the 2007 contract level of 7% compared with Scenario 1 is due to the absence of Keppel, leaving less competition in the market and hence greater market power. The higher contract level is required to curb this extra market power.

The peak weighting factors shown in Table 8 are required to reflect competitiveness across each load block.

Table 8: Scenario 2 results

Year	VC Level	Load Block Weighting Factors		
		Peak	Shoulder	Off-Peak
2007	63	1.20	1.00	0.74
2008	52	1.25	1.00	0.68

4.5.3 Scenario 3 – Keppel in 2008, No Island Power

To achieve the target forecast price of LRMC of the most efficient generator (i.e. $119 / MWh) in 2007 and 2008 a modelled vesting contract level of **63%** was required in 2007 and **58%** in 2008. The increase of 6% in the 2008 contract level compared with the first two scenarios show the effect of the removal of Island Power's new plant in this scenario. Its absence means there is less competition in 2008, more market power and the higher contract level is required to curb this market power.

The peak weighting factors shown in Table 9 are required to reflect competitiveness across each load block.

Table 9: Scenario 3 results

Year	VC Level	Load Block Weighting Factors		
		Peak	Shoulder	Off-Peak
2007	63	1.20	1.00	0.74
2008	58	1.22	1.00	0.71

4.5.4 Scenario 4 – No Keppel, Island Power in 2008

To achieve the target forecast price of LRMC of the most efficient generator (i.e. $119 / MWh) in 2007 and 2008 a modelled vesting contract level of **63%** was required in 2007 and **57%** in 2008.

The 2008 contract level shows an increase of 5% from Scenarios 1 and 2, due to the absence of Keppel's new plant in 2008. However the contract level is 1% lower than in Scenario 3 where only Island Power's new plant is absent. This is because Keppel's new plant is smaller, at 500MW, than Island Power's at 800MW, so in Scenario 4 we are effectively adding 300MW onto Scenario 3 in 2008. This increases competition, decreases market power and the lower contract level is needed.

The peak weighting factors shown in Table 10 are required to reflect competitiveness across each load block.

Table 10: Scenario 4 results

Year	VC Level	Load Block Weighting Factors		
		Peak	Shoulder	Off-Peak
2007	63	1.20	1.00	0.74
2008	57	1.23	1.00	0.71

4.5.5 Scenario 5 – No Keppel, No Island Power

To achieve the target forecast price of LRMC of the most efficient generator (i.e. $119 / MWh) in 2007 and 2008 a modelled vesting contract level of **63%** was required in 2007 and **65%** in 2008.

This is the only case where a higher contract level is required in 2008 than in 2007, with the level increasing 2%. This is because under this scenario no new plant is planned to come online in 2008, so the only change is a rise in demand. With all else remaining equal, a rise in demand equates to a decrease in competition in the market and an increase in market power. Therefore an increase in the contract level is required.

The peak weighting factors shown in Table 11 are required to reflect competitiveness across each load block.

Table 11: Scenario 5 results

Year	VC Level	Load Block Weighting Factors		
		Peak	Shoulder	Off-Peak
2007	63	1.20	1.00	0.74
2008	65	1.17	1.00	0.78

4.6 SENSITIVITY RESULTS

4.6.1 Sensitivity of Model Results to Load Growth

The model results are not particularly sensitive to the total load growth forecast, as can be seen from the following sensitivity analysis.

Table 12 shows the effect that a decrease/increase in the annual load growth rate forecast for 2006-08 has on the 2007-08 VC Levels under Scenario 1. There is very little change in any of the Vesting Contract levels.

Table 12: Sensitivity results for demand variations under Scenario 1

Year	Change in demand growth forecast from Base case						
	-3%	-2%	-1%	0%	1%	2%	3%
2007	-0.3%	-0.3%	0.0%	0.0%	+0.5%	+1.3%	+2.0%
2008	-0.5%	-0.5%	-0.3%	0.0%	+0.3%	+0.5%	+0.8%

4.6.2 Sensitivity to fixed component of LRMC

The recommended contract cover increases as the fixed component of LRMC (LRMC less SRMC) decreases in order to control incentives to bid up the price. A higher gap between LRMC and SRMC indicates a greater tolerance for the exercise of market power so a lesser requirement to mitigate it by the imposition of contracts.

The Cournot game is maximising generator profit, where profit is defined in terms of market price less SRMC (in this case the target average market price is the LRMC of an efficient new generator). Therefore, the gap between LRMC and SRMC is the important factor in determining profit maximising behaviour, rather than LRMC itself.

Table 13 shows the sensitivity of the results to changes in the fixed component of LRMC. That is, we re-run each scenario with the same SRMC of $91/MWh, but varying the LRMC to have values of $114/MWh, $119/MWh and $124/MWh. This is equivalent to having a fixed LRMC component of $23/MWh, $28/MWh and $33/MWh respectively.

Table 13: Sensitivity results for fixed component of LRMC Variations

Year	SRMC to LRMC gap $/MWh	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
2007	23	60%	66%	66%	66%	66%
2007	28	56%	63%	63%	63%	63%
2007	33	52%	60%	60%	60%	60%
2008	23	57%	57%	62%	61%	68%
2008	28	52%	52%	58%	57%	65%
2008	33	48%	48%	54%	53%	61%

4.6.3 Sensitivity to SRMC

Table 14 shows that for SRMCs of $5/MWh below and above our base case (as used in all sensitivity scenarios) for the most efficient generator SRMC of $91/MWh, there is no change in the recommendation for the 2007 and 2008 vesting contract coverage levels (except for small rounding differences). It is important to note that the fixed component of LRMC in this case is being held constant at $28/MWh.

Table 14: Sensitivity Results for SRMC

Year	SRMC $/MWh	LRMC $/MWh	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
2007	86	114	56%	63%	63%	63%	63%
2007	91	119	56%	63%	63%	63%	63%
2007	96	124	56%	63%	63%	63%	63%
2008	86	114	52%	52%	58%	57%	64%
2008	91	119	52%	52%	58%	57%	65%
2008	96	124	52%	52%	58%	57%	65%

4.7 CONCLUSIONS AND RECOMMENDATIONS

Under the base case (Scenario 1), where Keppel's new generation facility is commissioned in 2007 and Island Power is commissioned in 2008, it is recommended that vesting contract levels be set at **56% in 2007** and **52% in 2008**. This is for the most efficient generator's SRMC of $91/MWh and an LRMC of $119/MWh, but is also applicable for other SRMC and LRMC levels where the difference between the two remains constant at $28/MWh.

If Keppel's new generation facility is not commissioned in 2007, it is recommended that vesting contract levels be decreased only slightly from the current level of 65% to **63%.** This contract level is 7% higher than in Scenario 1 and reflects the significant effect the Keppel plant has in increasing competition and reducing market power.

For 2008, with Keppel the only new plant commissioned, we recommend a vesting contract level of **58%,** and with Island Power the only new plant we recommend a level of **57%**. The slight difference is due to the Island Power new plant contributing an extra 800MW of competition compared with Keppel's 500MW.

With neither Keppel nor Island Power commissioning new plant in 2008 we recommend a contract level of **65%**, which indicates a slight increase of 2% from the recommended level in 2007, due to the increased demand reducing competition in the market.

Table 15 summarises the recommended vesting contract levels and peak weighting factors under each scenario.

Table 15: Recommended Vesting Contract Levels and Weighting Factors

	Year	Scenario				
		1	2	3	4	5
VC Level	2007	56%	63%	63%	63%	63%
Peak	2007	1.22	1.20	1.20	1.20	1.20
Shoulder	2007	1.00	1.00	1.00	1.00	1.00
Off-Peak	2007	0.71	0.74	0.74	0.74	0.74
VC Level	2008	52%	52%	58%	57%	65%
Peak	2008	1.25	1.25	1.22	1.23	1.17
Shoulder	2008	1.00	1.00	1.00	1.00	1.00
Off-Peak	2008	0.68	0.68	0.71	0.71	0.78

A.1 NUMBER OF GENERATION UNITS AND GROSS UNIT CAPACITY

Table 16: Generation station capacity

Station Name	Number of Generation Units[19]			Gross Unit Capacity[20]		
	2005-06	2007	2008	2005-06	2007	2008
SenokoCCP12	2	2	2	425.0	425.0	425.0
SenokoCCP345	3	3	3	365.0	365.0	365.0
SenokoG45678	5	5	5	250.0	250.0	250.0
PPBGT1	1	1	1	105.0	105.0	105.0
SerayaG123	3	3	3	250.0	250.0	250.0
SerayaG456	3	3	3	245.0	245.0	245.0
SerayaG789	3	3	3	235.0	235.0	235.0
JURGT12	2	2	2	91.0	91.0	91.0
SerayaCCP12	2	2	2	364.0	364.0	364.0
TuasUnit12	2	2	2	600.0	600.0	600.0
TuasCCP12	2	2	2	367.5	367.5	367.5
TuasCCP34	2	2	2	367.5	367.5	367.5
SembCorpCCP12	2	2	2	392.5	392.5	392.5
IslandPower12	0	0	2	0.0	0.0	400.0
Keppel12	0	2	2	0.0	250.0	250.0
UluPandanIncineration	1	1	1	16.0	16.0	16.0
TuasIncineration	1	1	1	47.8	47.8	47.8
SenokoIncineration	1	1	1	55.4	55.4	55.4
TuasSthIncineration	1	1	1	132.0	132.0	132.0

[19] Source: EMA Generation Planting Schedule.

[20] Source: EMA Registered Generation.

A.2 RESERVE, AUXILIARY AND COGENERATION USAGE

Table 17: Generation station reserve, auxiliary usage, and cogen

Station Name	Reserve Usage[21] (MW)	Auxiliary Usage[22] (MW)	Cogen Usage[23] (MW)
SenokoCCP12	51.39	0.00	0.00
SenokoCCP345	37.31	0.00	0.00
SenokoG45678	9.81	0.00	0.00
PPBGT1	0.04	0.00	0.00
SerayaG123	0.70	0.00	0.00
SerayaG456	10.07	0.00	0.00
SerayaG789	10.47	0.00	0.00
JURGT12	0.22	0.00	0.00
SerayaCCP12	10.79	0.00	0.00
TuasUnit12	22.81	0.00	0.00
TuasCCP12	21.27	0.00	0.00
TuasCCP34	15.98	0.00	0.00
SembCorpCCP12	62.02	0.00	0.00
IslandPower12	34.14	0.00	0.00
Keppel12	19.43	0.00	0.00
UluPandanIncineration	0.00	0.00	0.00
TuasIncineration	0.00	0.00	0.00
SenokoIncineration	0.00	0.00	0.00
TuasSthIncineration	0.00	0.00	0.00

[21] Source: EMA Market Data 2005.

[22] Source: EMA – station (auxiliary) use is included in demand figures.

[23] Source: EMA – cogen use is included in demand figures.

A.3 SCHEDULED OUTAGE, FORCED OUTAGE AND OTHER DE-RATING

The following Scheduled and Forced Outage data has been based on an average of the outage data for 2003. No other de-rating has been assumed because any small changes in capacity have been accounted for in the Gross Unit Capacity values.

Table 18: Generation outage rates

Station Name	Scheduled Outage[24] (%)	Forced Outage[25] (%)	Other De-rating (%)
SenokoCCP12	6.83%	0.04%	0%
SenokoCCP345	6.83%	0.07%	0%
SenokoG45678	10.84%	0.04%	0%
PPBGT1	10.84%	0.00%	0%
SerayaG123	10.84%	0.03%	0%
SerayaG456	10.84%	0.02%	0%
SerayaG789	10.84%	0.02%	0%
JURGT12	3.63%	0.00%	0%
SerayaCCP12	6.83%	0.04%	0%
TuasUnit12	10.84%	0.00%	0%
TuasCCP12	6.83%	0.01%	0%
TuasCCP34	6.83%	0.09%	0%
SembCorpCCP12	6.83%	0.13%	0%
IslandPower12	6.83%	0.06%	0%
Keppel12	6.83%	0.06%	0%
UluPandanIncineration	4.21%	0.04%	0%
TuasIncineration	4.21%	0.04%	0%
SenokoIncineration	4.21%	0.01%	0%
TuasSthIncineration	4.21%	0.00%	0%

[24] Source: EMA - Scheduled Maintenance 2004-05.

[25] Source: EMA - Failure Probabilities Oct 2004 to Mar 2006.

A.4 NET GENERATION CAPACITY

The net capacity of each generator is calculated using the following formula:

Net Capacity = N x [G – C – R – (A + S + F + O) x G]

Where:

N = ‘Number of Units’: The number of identical units in the station.

G = ‘Gross Unit Capacity’: The rated maximum capacity of each identical unit in the station, expressed in MW.

C = ‘Cogeneration Use’: The average amount of cogeneration usage, in MW, from each unit.

A = ‘Auxiliary Usage Rate’: The average amount of auxiliary usage, as a percentage of the ‘Gross Unit Capacity’, for each unit.

R = ‘Reserve’: The average amount of reserve usage, in MW, for each unit.

S = ‘Schedule Outage’: The expected amount of scheduled outage, as a percentage of the ‘Gross Unit Capacity’, for each unit.

F = ‘Forced Outage’: The expected amount of forced outage, as a percentage of the ‘Gross Unit Capacity’, for each unit.

O = ‘Other De-Rating’. Any other de-rating of capacity from its gross value that impacts the station’s net capacity, as a percentage of the ‘Gross Unit Capacity’.

Only the net capacity is used in the model, not the building blocks used to derive it.

Table 19: Net generation capacity

Station Name	2005	2006	2007	2008
SenokoCCP12	688.79	688.79	688.79	688.79
SenokoCCP345	907.56	907.56	907.56	907.56
SenokoG45678	1,064.98	1,064.98	1,064.98	1,064.98
PPBGT1	93.58	93.58	93.58	93.58
SerayaG123	666.41	666.41	666.41	666.41
SerayaG456	625.00	625.00	625.00	625.00
SerayaG789	597.07	597.07	597.07	597.07
JURGT12	174.96	174.96	174.96	174.96
SerayaCCP12	656.41	656.41	656.41	656.41
TuasUnit12	1,024.27	1,024.27	1,024.27	1,024.27
TuasCCP12	642.20	642.20	642.20	642.20
TuasCCP34	652.19	652.19	652.19	652.19
SembCorpCCP12	606.31	606.31	606.31	606.31
IslandPower12				676.57
Keppel12			426.67	426.67
UluPandanIncineration	15.32	15.32	15.32	15.32
TuasIncineration	45.77	45.77	45.77	45.77
SenokoIncineration	53.06	53.06	53.06	53.06
TuasSthIncineration	126.44	126.44	126.44	126.44

A.5 LONG RUN MARGINAL COST OF THE MOST EFFICIENT GENERATOR

The most efficient generator inthe Singapore electricity market would take the form of a CCGT plant. Based on the average spot HSFO fuel price from 2005 (US$40.87/bbl) the LRMC of such a plant would be $119 / MWh[26].

A.6 SHORT RUN MARGINAL COSTS

Table 20: SRMC of each generator

Station Name	Short Run Marginal Cost[27]			
	2005	2006	2007	2008
SenokoCCP12	$91.00	$91.00	$91.00	$91.00
SenokoCCP345	$91.00	$91.00	$91.00	$91.00
SenokoG45678	$107.00	$107.00	$107.00	$107.00
PPBGT1	$263.00	$263.00	$263.00	$263.00
SerayaG123	$91.00	$91.00	$91.00	$91.00
SerayaG456	$107.00	$107.00	$107.00	$107.00
SerayaG789	$107.00	$107.00	$107.00	$107.00
JURGT12	$263.00	$263.00	$263.00	$263.00
SerayaCCP12	$91.00	$91.00	$91.00	$91.00
TuasUnit12	$107.00	$107.00	$107.00	$107.00
TuasCCP12	$91.00	$91.00	$91.00	$91.00
TuasCCP34	$91.00	$91.00	$91.00	$91.00
SembCorpCCP12	$91.00	$91.00	$91.00	$91.00
IslandPower12	$91.00	$91.00	$91.00	$91.00
Keppel12	$91.00	$91.00	$91.00	$91.00
UluPandanIncineration	$0.00	$0.00	$0.00	$0.00
TuasIncineration	$0.00	$0.00	$0.00	$0.00
SenokoIncineration	$0.00	$0.00	$0.00	$0.00
TuasSthIncineration	$0.00	$0.00	$0.00	$0.00

A.7 PEAK LOAD FORECAST

The peak load forecast, supplied by the EMA, is shown in Table 21.

Table 21: Peak load forecast

Year	2006	2007	2008
Peak Load (MW)	5,859	6,115	6,381

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26 Source: Provided by EMA – based on 2005 average spot HSFO price of US$40.87/bbl.

27 Source: Provided by EMA – based on 2005 average spot HSFO price of US$40.87/bbl and 2005 average diesel price of US$64/bbl.

A.8 TOTAL LOAD FORECAST

The total load forecast, supplied by the EMA, is shown in Table 22.

Table 22: Total load forecast

Year	2006	2007	2008
Total Load (GWh)	40,030	41,782	43,599

B.1 BASIC COURNOT ASSUMPTIONS

Cournot gaming is theoretically rigorous analysis of oligopoly market behaviour. It recognises the incentives on each player in a competitive market and it considers the interactions between those players. Specifically, Cournot gaming assumes that:

- Players seek to maximise their profit (market price less marginal cost, taking into account contract commitments).
- Each player alters the quantity it offers in the wholesale market from each of its stations to move along their "residual demand curve" (the change in demand they see) to maximise their profit, assuming the other players have fixed outputs.
- Other players similarly react to their "residual demand curve".
- Simultaneously, demand responds to changes in the wholesale market spot price, according to a defined demand curve.
- The process stops when all players reach a Nash equilibrium.

The Cournot analysis does not assume collusion – each player operates independently. The Cournot analysis establishes equilibrium market share. Any move away from the Cournot equilibrium is unstable.

B.2 COURNOT MARKET BEHAVIOURS

There are several behaviours seen in a Cournot game that reflect behaviours observed in real wholesale electricity markets. Specifically, the types of behaviour observed under Cournot market assumptions include:

- Demand, particularly in the long term, will vary as market price goes up or down, due to the price elasticity of demand. The lower the elasticity of demand, the greater the scope for generators with market power to increase market prices by withholding generation capacity.
- Contracts mitigate market power, leading to much less bullish behaviour because generators are playing in the net market – leaving them with less room for benefiting from using market power.
- Players protect their contract position – generating sufficient volume to at least meet their contract volumes if their SRMC is less than the spot price.
- A player's risk attitude will modify the actual CfD and retail book position that they seek to hold.

In this context, "contract position" represents the degree of risk aversion that each player has, including their portfolio of CfDs, retail customers that are sticky, and general attitude to risk.

The Cournot framework does not explicitly account for long-run revenue maximisation behaviours that may conflict with short-run incentives although these may be reflected in their effective contract positions. However, given the short-run incentives faced by generators in a wholesale spot market, it is arguable that a different outcome can be achieved without collusion.

B.3 EXAMPLE OF COURNOT GAME WITHOUT CONTRACTS

An oligopoly market has the feature that a player can influence the price unilaterally by altering its offering to the market in response to other players positions and the demand curve. In so doing they can increase their net revenue.

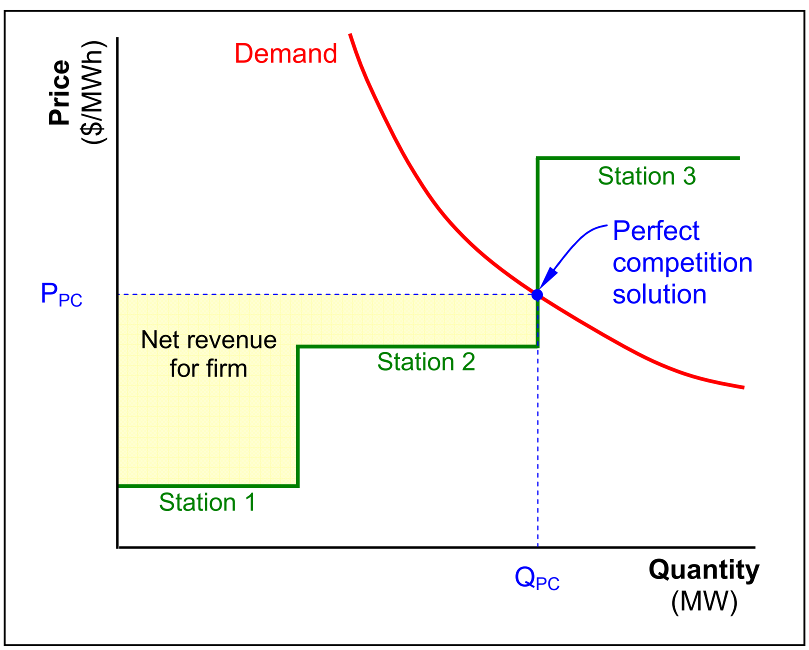
Beginning with the generation quantities produced by the cost minimisation modelling approach, we assume that an elastic demand curve passes through the perfect competition demand level. However, these generation levels may not produce the maximum trading net revenues for the individual firms. If a firm holds a significant proportion of generation in the market – that is, it has some market power – it has an incentive to reduce generation volume.

A generation company may reduce generation volume by withholding some of its capacity. As a consequence, the market price will rise. The net revenue for that firm may increase if the loss in revenue due to a reduction in quantity sold is more than offset by the higher prices and reduced costs from its remaining generation. In this case it is in the interest of that firm to reduce its generation. Each generator faces the same incentive.

The extent to which it is profitable for firms to reduce their production depends on the shape of the supply curve and the degree of demand response to the resulting higher generation prices.

To illustrate the process, Figure 1 shows the perfect competition solution for a firm facing the residual demand curve as shown. The firm has three generation stations available: Station 1 has a low SRMC, Station 2 has a moderate SRMC, and Station 3 has a high SRMC. Stations 1 and 2 are operating at full capacity and Station 3 is off. The demand curve intersects a vertical section of the supply curve, implying that a demand bid is effectively marginal. The firm receives net revenue equal to the shaded area – representing the difference between its revenue (Q_{PC} x P_{PC}) and its SRMC costs (the area under the supply curve).

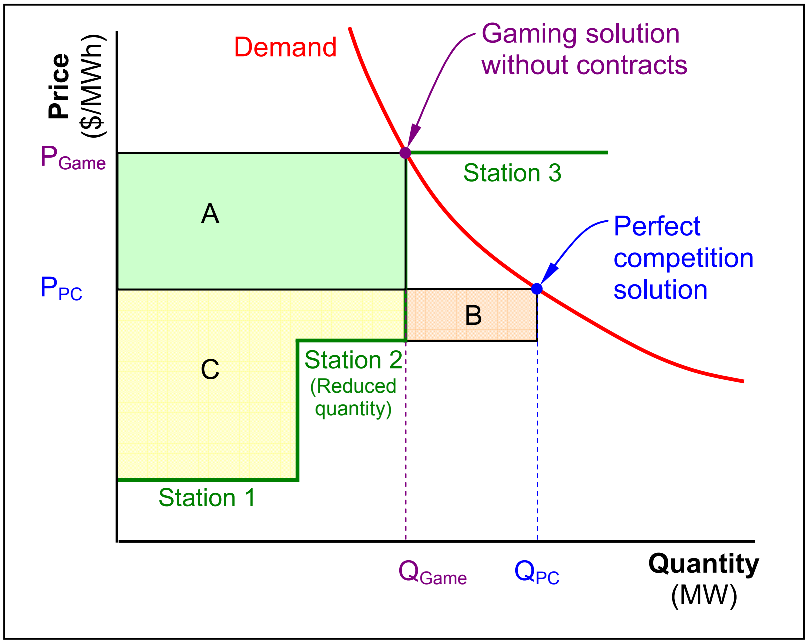
Figure 1: First step of Cournot game – perfect competition solution



But suppose that the firm has some market power. Given the situation shown in Figure 1, the firm says to itself: "If I withhold some of Station 2's capacity, I could make Station 3 marginal and hence receive a higher price".

The result of withholding some of Station 2's capacity is shown in Figure 2. The quantity offered by Station 2 has reduced, and now Station 3 is setting the market price P_{Game}. Overall, total market quantity is reduced and the spot price has risen. This particular firm has forgone net revenue equal to area B, but gained net revenue equal to area A (with area C representing net revenue it was already receiving). Provided area A is larger than area B, the firm is receiving higher net revenue in total.

Figure 2: Second step of Cournot game – without contracts



Each firm faces similar incentives to withhold some of their capacity and hence increase the market price. The Cournot framework assumes that each firm makes their decision in isolation from all other firms, but the process is effectively iterative. The firms take turns to decide their offers until no firm can improve on its position given the responses of all other firms and the consumers (via the demand curve). At that point, the game has reached equilibrium.

B.4 EXAMPLE OF COURNOT GAME WITH CONTRACTS

The strength of a company's incentive to extract price benefits in such a market depends on its exposure to the spot market price. This incentive can be weakened in two ways:

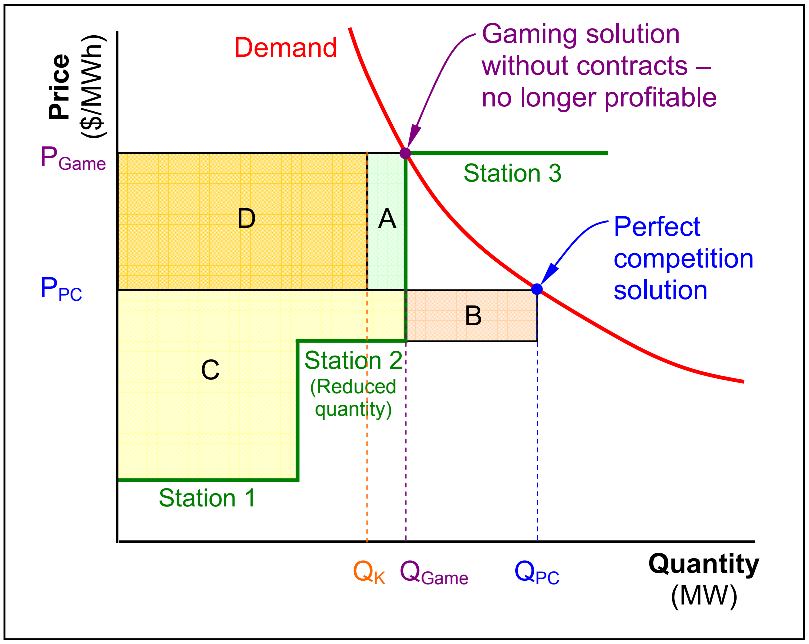
1. Either the company's market share must be reduced, and/or

2. A proportion of its output should be pre-sold in the form of long-term, fixed price hedge contracts.

By reducing market share, we are moving towards a closer approximation of perfect competition with many small competitors each with little influence on market price.

Long-term hedge contracts reduce the incentive to manipulate price, as a quantity of electricity is pre-sold at a fixed price. As illustrated in Figure 3, with quantity Q_K of hedge contracts, the size of area A is reduced by area D – because Q_K is fixed via the hedge contract. Therefore, the firm only gets the benefit on the reduced area A less area B. In this example, the value gained due to price increasing (area A) is less than the value lost due to withholding quantity (area B), and so this degree of gaming is no longer profitable. Consequently, the firm would not withhold so much of Station 2's capacity, and hence the solution would move back towards the Perfect Competition solution.

Figure 3: Third step of Cournot game – with contracts



Clearly, the incentive to offer reduced quantities in the market is weakened when the generation companies have contracts. As the contract quantity Q_K increases, incentives are weakened further until the perfect competition level Q_{PC} is reached where there is no more incentive to "game" the market. Increasing Q_K beyond Q_{PC} reverses the incentives and the generators increase the quantity on the market in order to push the price down. Depending on how the total long-term contract quantity is divided between generators, the incentives to vary the capacity offered can differ between generators.

B.5 EFFECTIVE CONTRACT LEVEL

We define the "effective contract level" as a measure of the level of mitigation of market power on a generator. In a Cournot game, the level of mitigation is modelled as a long-term two-way CfD hedge contract struck against the spot market price at a specified node. A high effective contract level implies that generators receive substantial proportions of their revenue on a fixed basis, and therefore gain less from gaming the spot price.

This is because the generator's revenue with no contracts is simply the spot price times the generator's quantity. If a proportion of that output is contracted with a two-way CfD held with another party, then the effective revenue changes. If the spot price is less than the contract strike price, then the generator is paid (by the other party to the contract) the difference between the spot and the strike price, for the quantity specified in the contract. If the spot price is greater than the contract strike price, then the generator pays the difference between the spot and the strike price, for the quantity specified in the contract. The net effect is to make the generator receive the same fixed revenue for output up to the contract quantity. Generation beyond that quantity receives the spot price.

A low effective contract level implies that generators receive low proportions of their revenue from fixed price contracts and more on the spot market, thus having greater incentive to "game up" the spot price, as explained in the previous section.

Two considerations for effective contract position are how "sticky" contracted customers are and the market "behaviour" of each generating company.

B.6 THE "STICKINESS" FACTOR

Consider the case of a combined generator and retailer with a reliable consumer base absorbing some proportion of their total output at a particular price level. If spot prices fall, then some proportion of customers will observe the lower spot market price, will note that they pay the standard retail price rate, and will either look for other suppliers with better prices, or buy direct from the spot market. The generator will lose the difference between spot and retail prices on the volume of customers lost. Generators therefore have an incentive to exercise market power to raise the spot price, balanced against the loss of spot market volume. This incentive is no different from being uncontracted, provided the customers are very responsive to price and there are alternative suppliers with competitive prices.

Therefore, for the generator, customers with a high propensity to switch, which we regard as "non-sticky" customers, are equivalent to being exposed to the spot market.

Other customers may not have the necessary information to decide on a change, or if they do, may not have the inclination or perceive sufficient value to change and hence we regard them as "sticky". For sticky customers, the spot market price is less relevant. For the retailers, the spot market price is also irrelevant as the retailer gains the same revenue from those customers regardless of spot market prices.

Therefore, for the generator, sticky customers mimic a two-way CfD. In fact, sticky customers may be more valuable than a CfD, given there may be some opportunity to increase retail prices.

In reality, the degree of stickiness (or the propensity of customers to switch) will be difficult to determine accurately, and is likely to be the subject of much commercial activity. It is unlikely that all customers will exhibit the same amount of stickiness, and one would presume that larger differences between retail prices and spot prices would encourage more customers to switch.

In the long run, new entry provides a cap on both spot and contract prices. Subject to sites, consents, fuel, and transmission connections, new generation can be built relatively inexpensively and quickly. Thus, neither contracted end use consumers nor spot purchasers would pay, on average, above the new entry price for energy in the long run.

As previously discussed, for a vertically integrated business, supply obligations to a group of electricity customers can produce similar effects as a contract, with sales to the customers at a fixed price. However, there are some differences between customers and contracts. The main differences are:

- Customers generally have little incentive to respond to wholesale price signals, possibly resulting in lower demand elasticity compared with a retailer (although even retailers, while facing incentives to reduce demand, may not be able to take any action).

- Customer demand is variable compared with the fixed quantities in most contracts.
- The price offered to a customer may follow competitor offers and spot price trends more closely than fixed term Contracts for Differences, as otherwise customers would switch to lower priced competing suppliers.
- Generators who own retail customers have an incentive to keep the spot price high so that they can increase their customer price.

Even long-term contracts often contain escalators related to the spot market price, effectively giving the generation company an incentive to raise the price.

B.6.1 Behavioural modifiers

So far we have discussed the effective contract level in relation to actual contracts. However, an important consideration is the behavioural aspect of the individual generation company.

There are political and strategic reasons for a company to act either more or less contracted than they technically are. In fear of Government intervention or just for "social good" a generator may act to stabilise the spot price or indeed act to suppress it. An interpretation of this behaviour is that the company appears to have a CfD with the Government.

Conversely, a company may act intentionally or otherwise as if it is uncontracted or contracted at much lower levels than in actuality:

- Backing-off generation beyond that suggested by sticky retail load in order to increase spot price (and retail prices) is behaving as if some proportion of the retail load is not considered to be a fixed price hedge.
- Similarly, behaving at a lower effective contract level may occur in order to push up the spot price so as to influence the contract price in the long-term. A short-term trade-off is made for long term profitability.

B.7 USING COURNOT GAMING FOR SETTING VESTING CONTRACT QUANTITIES IN SINGAPORE

The methodology for setting the Vesting Contract Level is the converse of the earlier argument in that we modify the behaviour of the market by imposing a quantity of contracts so as to increase the degree of competition at the margin. In determining the level of Vesting Contract cover a target price is set outside the model, e.g., an estimate of LRMC. Then the model is used to find the contract quantity that will lead the market, under the Cournot assumptions, to experience the target price.

The model is initially calibrated, in this case using 2005 data, with historic prices, loads, and effective contract levels in order to find demand elasticity values for each block (peak, shoulder and off-peak). Ideally, we would have several years of data against which we would calibrate the model. However, the current market only commenced in 2004, and the market underwent a transition from the old arrangement to the new arrangement over the 2004 year, so the 2005 data is the best available for calibrating the model.

Demand elasticity is a central component of the Cournot model, as it represents the consumers' response to attempts by generators to exercise market power. The greater the consumer response, the less ability generators will have to exercise market power. However, demand elasticity cannot be calculated directly – it must be inferred from observation of actual market behaviour. Therefore, we tune the Cournot model to estimate the elasticity values in each of the demand blocks (peak, shoulder, and off-peak). These elasticity values are then used to determine the future contract quantities, with a given target price, as described above.

Table 23: Calibrated demand elasticities

Calibration using 2005 historic data	Demand Block		
	Peak	Shoulder	Off-Peak
Demand elasticity	-0.13	-0.17	-0.36

The market is solved in these three blocks (peak, shoulder and off-peak), essentially as three separate markets and the vesting contract quantity determined for each. The weighting factors used in the Singapore market reflect the results for each of the different blocks. The shoulder block weighting is always set to 1.0, as outlined by the rules, i.e. the VC level for the shoulder period is equal to the generation weighted average over all three blocks.