PA Consulting Group

Energy Market Authority of Singapore

Review of Vesting Contract level and period weighting factors for 2011 and 2012 - Analysis and Recommendation

Final report

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Executive summary

Introduction

The Singapore electricity market uses the Vesting Contract regime for the mitigation of market power. The long run marginal cost (LRMC) parameters used for setting the Vesting Contract price, Vesting Contract level and period weighting factors under the Vesting Contract regime are scheduled to be 'reset' at two yearly intervals. This is the third such reset, applying to the period commencing on 1st January 2011 and running through until 31st December 2012.

The reset process is managed by the Energy Market Authority of Singapore (EMA), which has engaged PA Consulting Group (PA) to review the recommended level of Vesting Contract cover and period weighting factors to be applied at the next reset. Note that this report does not review the LRMC parameters used for setting the Vesting Contract price[1].

This document sets out PA's analysis and recommendations for the review of the Vesting Contract level and period weighting factors for the period 1 January 2011 to 31 December 2012.

Vesting Contracts and market power

Market power is the ability to profitably move market 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 distinguishable from price and revenue caps in that they promote competition.

The existence of market power can be assessed quantitatively by the use of indices such as the Herfindahl-Herschman 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 effectively for these purposes. We have chosen to use the Cournot model, being aware of the assumptions and limitations of so doing. In particular, the Cournot model presents an upper bound on market power estimation[2].

In seeking to control the exercise of market power in an oligopolistic market, such as the Singapore electricity market, we must choose a target market price. The Vesting Contract level is structured to set the target market price at the Vesting Contract strike price, i.e., based on the LRMC of a theoretical new entrant using the most economic generation technology in Singapore contributing more than 25% of the total demand. This ensures appropriate price signals remain for investors to plant new and efficient generation capacity to meet demand growth, but not excessive returns. It is also important to note that the imposition of Vesting Contracts is not intended to completely eliminate the exercise of market power. Indeed, the Vesting Contract regime anticipates the exercise of some market power in order to produce the target market price. That is, the aim of Vesting Contracts is to allow the average price outcome to be above the average SRMC, and hence permit some residual

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[1] Those parameters are the subject of a separate analysis and consultation process.

[2] In SFE there can be many possible ways a generator can offer its capacity in response to the demand function it faces. One such response is to withhold capacity in the way Cournot assumes. This response is the most aggressive and, if used by the players, will give a solution with as much or more market power than any other available response.

exercise of market power. This is the appropriate outcome since the target market price is sufficient to induce efficient new generation investment, while discouraging the seeking of excessive profits by the incumbent generators.

Historical pool price behaviour

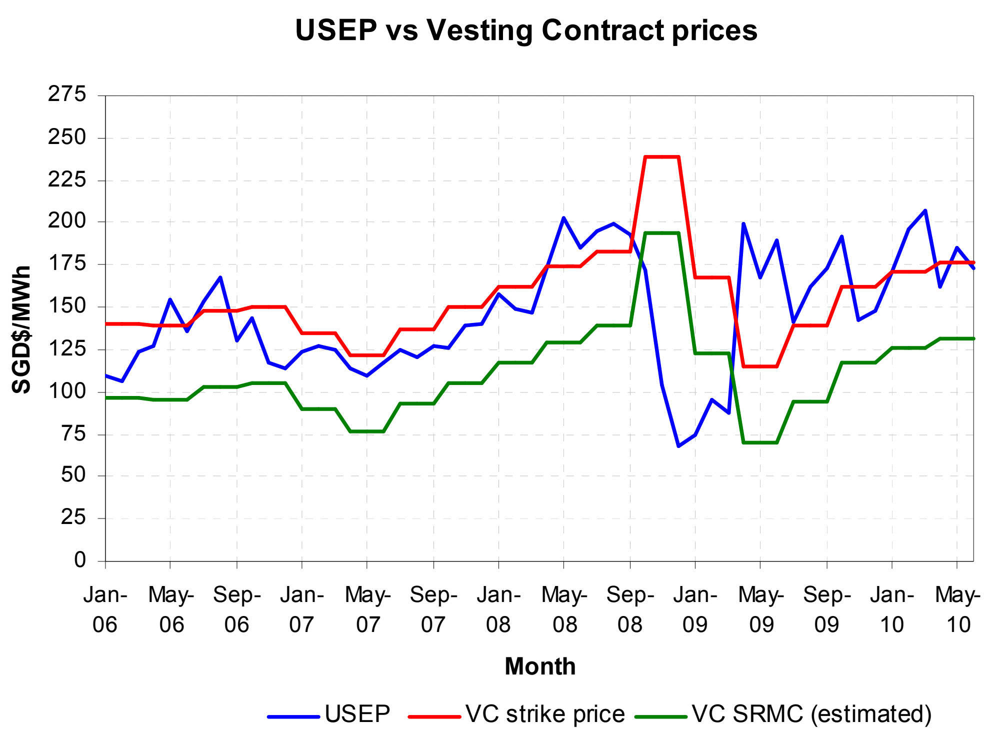
We have examined the outcomes of the wholesale electricity market between January 2006 and June 2010, to assess the adequacy of the Vesting Contract regime in meeting its objectives of market power mitigation.

Figure 1 shows a comparison of monthly average Uniform Singapore Energy Price (USEP), Vesting Contract price, and the short run marginal cost (SRMC) portion of the Vesting Contract price for the period January 2006 through to June 2010.

It can be seen from Figure 1 that USEP is usually less than the Vesting Contract price and greater than the SRMC from January 2006 up til the 2nd quarter of 2009. This suggests that the generators have generally not been able to exercise sufficient market power to achieve the Vesting Contract price, on average, during this period.

However, from the 2nd quarter of 2009 onwards, there has been a pattern of sustained periods of high USEP, which significantly exceeded the Vesting Contract price.

Figure 1: Historical USEP and Vesting Contract price



The historical analysis suggests that there has been no excessive exercise of market power up to the 2nd quarter of 2009. Indeed, given that USEP has been below the Vesting Contract price almost all the time over this period until the 2nd quarter of 2009, the Vesting Contract regime may have been seen to over-constrain generator behaviour during this period.

However, a pattern of sustained price spikes has emerged since the 2nd quarter of 2009, with the effect that average USEP has significantly exceeded the Vesting Contract price for 3 of the last 5 quarters up to the 2nd quarter of 2010. This indicates that the Vesting Contract regime is no longer over-constraining generator behaviour, and that an increase in Vesting Contract levels may be necessary until significant new generation capacity enters the market.

Historical Economic Efficiency

In the following respects, the National Electricity Market of Singapore (NEMS), under the Vesting Contracts regime, can be considered successful in promoting competition and economic efficiency:

- 4 new market participants (and 5 small generators as Generation Settlement Facility (GSF)) have entered the market.
- A further 3 new market participants (and a further 5 GSFs) have specific plans to enter the market.
- All new plant built of significant capacity is highly efficient combined cycle gas turbine (CCGT) or cogeneration plant.
- The reserve margin (the gap between total generation capacity and peak load) has dropped from excessive levels over 70% to around 40%.

However, a less favourable aspect of the capacity additions is that capacity added by the incumbent generators has exceeded capacity added by new participants by a significant margin. This factor increases the market power of the incumbents, and this offsets the competitive gains arising from the entry of new participants.

This trend can be expected to reverse in the future, as all 3 large incumbent generators will have reached their regulated maximum capacities with their planed new build in the next 2 years. Any new capacity additions will have to come from other market participants, resulting in real gains in terms of market competition.

Two changes to the Vesting Contract regime have been assessed in terms of their effect on market competition: The Vesting Relief scheme, and Tendering for a Portion of the Non-Contestable Load.

The Vesting Relief scheme is intended to offset the increase in market concentration that occurs when a non-portfolio generator is unable to offer capacity into the market due to the planned maintenance of their power plants. Modelling results indicate that the Vesting Relief scheme provides partial, but not complete, mitigation of market power due to the planned maintenance of the power plants of the non-portfolio generator.

Tendering for a Portion of the Non-Contestable Load is intended to bring some benefits of competitive pricing the non-contestable consumers prior to the introduction of full retail contestability. Modelling results indicate that the scheme can result in an increase in the overall market price, but a decrease in market power for the winning participant. This effect may influence the participants when preparing their tenders under this scheme.

Scenarios for setting the Vesting Contract Level for 2011 and 2012

To explore the range of uncertainty around the appropriate Vesting Contract level for 2011 and 2012, we have examined the following scenarios defined in Table 1.

Table 1: Scenario definitions

Factor	Value	Scenario									
		1	2	3	4	5	6	7	8	9	10
Period weighting factors	Differential	✓		✓		✓		✓			
	Unity		✓		✓		✓		✓		
	Fixed									✓	✓
Senoko Energy Repowering	In 2012	✓	✓			✓	✓			✓	
	After 2012			✓	✓			✓	✓		✓
Tuas Tembusu complex	In 2012	✓	✓	✓	✓					✓	
	After 2012					✓	✓	✓	✓		✓

These scenarios represent the following key factors which could vary in the analysis:

- The relationship between the period weighting factors and the target market price – specifically, whether the period weighting factors should be different, equal or fixed at an intermediate position;
- The commissioning of Senoko Energy's repowered CCGT unit, with a current commercial operation date (COD) of Q3 2012; and
- The commissioning of Tuas Power Generation's Tembusu cogen, with a current COD of 2012.

Scenario results

The results of these scenarios are summarised in Table 2.

Table 2: Summary of scenario results

Year			Scenario									
			1	2	3	4	5	6	7	8	9	10
2011	Vesting Contract Level		67.8%	64.5%	67.8%	64.5%	67.8%	64.5%	67.8%	64.5%	61.9%	61.9%
	Weight-ing factor	Peak	1.13	1.00	1.13	1.00	1.13	1.00	1.13	1.00	1.10	1.10
		Shoulder	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Off-Peak	0.83	1.00	0.83	1.00	0.83	1.00	0.83	1.00	0.87	0.87
	Target price ($/MWh)	Peak	192.91	207.96	192.85	207.96	192.85	207.96	192.85	207.96	203.32	203.38
		Shoulder	192.87	195.61	192.87	195.61	192.87	195.61	192.87	195.61	197.39	197.39
		Off-Peak	173.28	170.46	173.3	170.46	173.3	170.46	173.28	170.46	174.24	174.24
2012	Vesting Contract Level		40.4%	48.5%	50.9%	54.0%	45.6%	50.6%	59.8%	57.5%	46.3%	55.2%
	Weight-ing factor	Peak	1.71	1.00	1.38	1.00	1.52	1.00	1.18	1.00	1.10	1.10
		Shoulder	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Off-Peak	0.05	1.00	0.49	1.00	0.30	1.00	0.76	1.00	0.87	0.87
	Target price ($/MWh)	Peak	192.92	221.82	192.92	213.72	192.92	218.9	192.86	209.36	217.68	205.28
		Shoulder	192.9	185.93	192.94	190.26	192.9	188.62	192.94	194.51	187.82	196.15
		Off-Peak	181.85	164.04	179.53	169.32	176.86	164.72	174.18	169.96	167.07	173.27

Recommended Vesting Contract level for 2011 and 2012

Table 3 shows the recommended Vesting Contract levels for 2011 and 2012. This recommendation is based on Scenario 9:

Table 3: Recommended Vesting Contract levels

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	61.9%	1.10	1.00	0.87	203.32	197.39	174.24
2012	46.3%	1.10	1.00	0.87	217.68	187.82	167.07

PA's recommendation that the Vesting Contract level be increased for 2011 to around 62% reflects the following changed market conditions:

- A decrease in the reserve margin, greater potential for market power to be exercised in a supply constrained environment if left unchecked;
- An increase in the Vesting Contract level for 2011 is also supported by the pattern of high market prices in excess of the LRMC seen in 2009 and early 2010

- These factors are partially offset by the commissioning of new CCGT capacity introduced since the previous reset. This will have moderated the effect of the other factors listed above, i.e. the recommended Vesting Contract level would have been even higher without them.

With the addition of new capacity of both Senoko Energy's repowered CCGT and Tuas Power Generation's Tembusu cogen in 2012, Vesting Contract levels could reduce to 46%.

Contents

1 Introduction

1.1 Structure of this report

This report sets out PA Consulting Group's analysis of the Vesting Contract level and period weighting factors for the Singapore electricity market for the period 1 January 2011 to 31 December 2012, pursuant to the scheduled review by the Energy Market Authority.

This report is structured as follows:

- Section 2 presents a theoretical overview of Vesting Contracts and market power.
- Section 3 presents an analysis of historical market power from January 2006 through to early 2010.
- Section 4 presents an analysis of historical economic efficiency since the start of the Vesting Contract regime.
- Section 5 presents our analysis and conclusions with respect to the Vesting Contract level and period weighting factors for the period 1 January 2011 to 31 December 2012.
- Section 6 presents sensitivity analysis of key modelling assumptions.
- Section 7 presents our recommendations.
- The appendices contain additional information, including detailed assumptions.

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 is not necessarily associated with a single market participant. It is possible for several participants in a market to collectively possess market power. For purposes of this discussion, we focus on tacit market power in which market participants behave independently rather than on situations in which market participants act collusively.

2.1.2 Exercise of market power

Whereas 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, there is usually significant uncertainty on the part of regulators regarding production costs. Consequently, a certain level of mark-up[4], while arguably the result of the exercise of market power, is considered acceptable in order to achieve a commercially viable level of profitability. In addition, it is almost inevitable in electricity markets that market power exists and is exercised – if only in peak demand periods.

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:

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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.

- Indices
- Market power models

Indices

Indices provide a "rule of thumb" basis for testing for the existence of market power. The most commonly-used index is the Herfindahl-Hirschman 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:

$$HHI = (S1)^2 + (S2)^2 + (S3)^2 + (S4)^2 + \ldots$$

where S_j is the % market share of the jth 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 of the HHI given in Table 4.

Table 4: Interpretation of HHI

Index	Competitiveness
HHI < 1,000	Competitive
1000 <= HHI < 1,800	Moderately concentrated
1800 <= HHI < 10,000	Highly concentrated
HHI = 10,000	Monopoly

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

The definition of "market share" is controversial. It can be the actual output of the plant or its potential (i.e. its registered capacity). In Singapore, we have tried several definitions of market share relative to available capacity. For 2010 the HHI index has a score of 2,462 – 2500 (depending on the metric used)[5]. From the interpretation in Table 4, this suggests that the Singapore electricity spot market is highly concentrated. On that basis, it would fail the test of being a competitive market structure.

Models

Oligopolistic behaviour can also be modelled using game theory. Different models 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 with the competitive price. Three well-known models are:

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[5] Detailed calculations are given in Section A.1.

- 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; and
- Supply Function Equilibrium, wherein participants construct supply functions (offer curves) to find an equilibrium set of profit-maximising supply functions for the participants.

Models used to evaluate market power in electricity markets are discussed in Section 2.3.

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 have large plant size relative to the size of the market, and formerly regulated sectors in transition to competition, market power is a reality. Often pre-reform there is one vertically integrated player that controls the transmission grid, makes the dispatch decisions, operates nearly all the generation capacity and perhaps also services nearly all of the retail load. In many instances, for political reasons, this player is not broken up or privatised but it is left intact or separated into only two or three semi-independent generation companies. This situation leaves unresolved two types of issues:

- Commercial issue – the potential for market dominance that allows the player to dictate price and dispatch; and
- Perception issue – a concern among independent generators and retailers that there is a lack of impartiality in both long-term and operational decision-making.

So, if a genuine separation of the old corporation into its constituent parts is not possible, measures are needed that will dampen the effects of the power of the incumbent(s). This can be done either:

- Directly – by mechanisms like "regulated bidding". Here the regulator decides the maximum offer price that a participant can offer (either individually, in the case of dominant player(s) or collectively when the whole market has market power). Bids in excess of this bid cap are rejected; or
- Indirectly – by mechanisms like financial contracts (CfD – contracts for differences). The use of contracts for this purpose is discussed in Section 2.2.

The Singapore industry has gone a long way into organisational re-structuring, particularly with the current generation sale process. Nonetheless, the question remains whether the smallness of both the country and electricity industry has left open the possibility of the existence of market power.

2.2 Contracting

The wholesale market for electricity is a combination of spot market transactions, explicit contracting and implicit contracting via vertical integration leading to retail sales. When discussing

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

market power there is a risk of concentrating solely on the spot market. In fact, there is a strong inter-relationship between a firm's contractual position both for the sale of power and the buying of fuel, even at the day-to-day operational level.

Contracting is usually a risk management instrument used to give certainty of price and volume, or at least bounding the risk to limit exposure to price fluctuations.

A firm's contract position affects the spot market bidding strategy in two important ways:

- A good short-term bidding strategy is to cover the volume of contracts – either fuel supply or energy sales:
  - For a fuel supply take-or-pay (ToP) contract this means offering volume into the market at "zero" because the effective marginal cost of fuel is zero until the ToP volume is reached[7].
  - For energy contracts the strategy is to offer the contract volume into the spot market at the SRMC of the plant. Then, if the marginal plant is cheaper than one's own plant at the margin, it is cheaper to buy from the market to cover the contract than to generate using one's own plant.
  - If the market is heavily contracted the spot price will tend to be more competitive and the market will tend to clear at around the SRMC of the marginal plant.
- In the longer term the price of a contract will be driven by the historical and projected spot market prices. It is therefore to the generators' advantage to keep the spot price up in order to signal the contract price. This will lead to generators acting as if they are less heavily contracted than they really are.

With one trend encouraging the price down and the other encouraging the price up it is unclear what the overall effect of a contract on the spot market would be. These influences on the spot market will be present for each of the modelling variants discussed in Section 2.3.

2.2.1 Retail load

The contract level is both a significant influence and a risk barometer. In many cases a company seeks to cover its retail load by its generation. This may or may not be a good strategy depending on the nature of the cover.

We do not treat a generator's retail load as 100% contract cover because:

- The effect of "churn"[8] is that only a portion of a retailer's load is secure.
- The spot price heavily influences the contract target price for participant-to-participant contracts.
- Our experience suggests that retailers treat 50%[9] of their own retail load as if it were equivalent to fixed contracts. This becomes their effective contract level.

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[7] In fact, there are also some minor VOM costs that make the SRMC slightly above zero.

[8] "Churn" refers to retail customers switching from one energy retailer to another. Most retail customers can switch to another retailer with short notice, so such customers do not represent a secure load for their current retailer.

[9] The basis for this figure is discussed further in Section 2.2.4.

2.2.2 Effective contract level

We define the "effective contract level" as a measure of the level of contracting and other methods of mitigation of market power on a generator. In a gaming model the level of mitigation is usually modelled as a long-term two-way CfD hedge struck against the spot market price at a specified node. A high effective contract level implies that generators receive (or act as if they receive) a substantial proportion of their revenue on a fixed basis, and therefore gain less from gaming the spot price.

Contracts impact on a generator's behaviour 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 target price, then the generator is paid (by the other party to the contract) the difference between the spot and the target price, for the quantity specified in the contract. If the spot price is greater than the contract target price, then the generator pays the difference between the spot and the target 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, or act as if they 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.

2.2.3 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 will buy direct from the spot market. The generator will lose the difference between the 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. These conditions do not often occur in practice.

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 less relevant as the retailer gains the same revenue from those customers regardless of spot market prices. These customers want the hedge against volatile prices and may even be willing to pay a premium over average spot prices in return for price-certainty.

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 can change retailer at very short notice. So they are of indeterminable duration, at worst they are equivalent to a very short term contract although possibly they may be very long term.
- 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). Although the reason for there being an agent between the spot market and the retail customer is precisely for this reason – to insulate the customer from spot market price volatility.
- 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. In addition, retail prices are public while contract terms are usually hidden behind confidentiality.
- 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.

2.2.4 Behavioural modifiers

In addition to actual contracts, there are other factors that can modify the behaviour of an individual generation company.

There are political and strategic reasons for a company to act either more or less contracted than they technically are. Out of fear of Government or regulatory intervention, public outcry, or just for "social good", a generator may act to stabilise the spot price or indeed act to suppress it[10]. An interpretation of this behaviour is that the company appears to have a CfD with the Government. State-owned enterprises face this pressure.

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[10] Market power may manifest in terms of reducing the market price to drive competitors out of the market – a behaviour called "predatory pricing".

Conversely, a company may act intentionally or otherwise as if it is uncontracted or contracted at much lower levels than in actuality. It may reduce generation beyond that suggested by sticky retail load in order to increase spot price (and retail prices in the long term). In such a situation, it 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 trade-off is made between short-term and long-term profitability.

The final result of these issues is to treat retail load as less firm than a CfD contract. Allowing for churn, uncertainty of customer volume, and spot price support for increasing retail tariffs, typically we find it appropriate to treat retail load as 50% of the actual customer demand.

2.3 Economic models of market power

2.3.1 Bertrand Game

The Bertrand game is best illustrated in a market simulation model by bidding up the SRMC of each player to the SRMC of the next highest competitor. The impact of this behaviour 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, primarily because it is a much milder form of gaming behaviour than normally experienced in electricity markets, with the generators seeking only to capture the available price increment to the next most expensive generator rather than to take maximum advantage of their market power[11], and so underestimates market power potential.

2.3.2 Cournot Gaming

Cournot Gaming[12], like the other models, 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.
- Simultaneously, demand responds to changes in the wholesale market spot price, according to a defined demand curve.

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[11] 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.

[12] More detail on Cournot Gaming is given in Appendix B.

- The process stops when all players reach Nash equilibrium (no player can move from its position without making itself worse off).

It is important to note that Cournot Gaming does not assume collusion – each player operates independently. The Cournot Game establishes equilibrium market share, such that any move away from the equilibrium is unstable and hence unlikely to persist for long.

2.3.3 Supply Function Equilibrium

Supply Function Equilibrium (SFE) models are a recent theory in the economic tool kit and present a credible alternative to Cournot. Like Cournot they seek profit maximising market equilibrium but using a different dynamic both in theory and in application. Cournot Gaming and SFR are equally rigorous models of market power.

In this approach 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 a demand response.

The focus of the SFE approach is that it attempts to mimic the participant's bidding 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 as they react to a residual demand function or set of functions[13]. In so doing it aims at giving insight into how to devise a consistent offer curve that is appropriate over multiple periods. This is an interesting approach even if, on the face of it, this is not quite the focus of the Vesting Contract study[14].

As with all modelling approaches, 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 and carefully defined response mechanism (e.g. an optimal response) by players to the supply functions of their competitors.

The method is more a modelling approach than a specific gaming behaviour. Thus it can mimic a number of gaming behaviours, including Bertrand and Cournot Gaming.

Being quite general in structure, it is not surprising that under some sets of assumptions it cannot be guaranteed that the SFE model is tractable and hence it may not result in a unique equilibrium[15]. Significant strides are being made in the solution of SFE models, but 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[16].

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[13] A key drawback of the SFE approach is that, in many applications, these functions are not known with certainty.

[14] 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.

[15] Interestingly the Cournot response function can be one of the more tractable alternatives.

[16] See Ross Baldick, "Electricity market equilibrium models: the effect of paramatization", http://www.ece.utexas.edu/~baldick/papers/parametrization.pdf. Also see Aleksandr Rudkevich, "Supply Function

2.4 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.

2.4.1 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 can be seen as hedge instruments but 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 the most efficient generator. By contrast, the price of a commercial CfD contract is a matter for negotiation.

2.4.2 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 the level of market power that is acceptable, that 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.

Perfect competition

In a perfectly competitive market, all of the generators would 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.

Equilibrium: Theory and Applications", Proceedings of the 36th Hawaii Conference on System Science, (HICSS'03), 2002.

The problem with this outcome is that the generators would generally have received only sufficient revenue to cover the short-run variable costs of their mid-merit and peaking plant. 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 that is more of a worry to regulators than a small degree of market power.

The reason this happens is that perfect competition is a model that exists only in economic theory and assumes free entry into the market. It is a norm against which to compare real markets, rather than an expectation of actual market outcomes. The assumption of free entry is not valid for electricity generators, whose investment represents a significant fixed entry cost.

Monopoly

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.

Oligopolistic market

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 this 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 in Singapore 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 in the context of perfect competition above, and hence there remains some residual and acceptable 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 historical market power

3.1 Basis for historical market power analysis

The extent to which the generation companies have exercised market power can be gauged by comparing the Uniform Singapore Energy Price (USEP) pool price with the Vesting Contract prices over that time period.

This section presents the results of such an analysis. Specifically, we examine the market outcomes for the years 2006 to 2009, along with the part of the 2010 year for which data is currently available.

The market outcomes that form the basis for assessing historical market power are:

- USEP: This is the weighted average wholesale electricity price at the withdrawal nodes, which we use to represent an average market spot price.
- Vesting Contract target price: We expect the average market price to approximately equal the Vesting Contract target price, where the Vesting Contract target price is the LRMC of a theoretical new entrant using the most economic generation technology in Singapore contributing more than 25% of the total demand as defined by EMA.
- Vesting Contract SRMC: This is an approximation of the SRMC underlying the Vesting Contract target price. In this analysis we have assumed a gap of $43.78/MWh between the Vesting Contract target price and the Vesting Contract SRMC[17].

Ideally, analysis of historical market power would adjust the historical data for changes in fuel prices over time, so that the market behaviour could be separated from changes in underlying costs. However, such an adjustment is problematic because:

- Firstly, it is not possible to know with assurance the fuel price paid by each of the generators. In particular, fuel purchases are likely to be a combination of fuel spot market trading and forward contracts of various durations and quantities. The actual terms of those purchases arrangements are not known to us; and
- Secondly, the wholesale spot price is set by the bid price of the marginal generator in each market clearing period. This may move from plant to plant depending on the fuel price and plant efficiency of each generating unit, as well as due to changes in demand, transmission configuration (including capacity constraints), and other factors in the real time spot market.

Consequently, we do not have an appropriate historical fuel price data series with which to adjust the market data. While an approximate assessment of the historical fuel price adjustments could be made, their inherent uncertainty would be unlikely to bring any further clarity to the analysis. Therefore, we have not adjusted the market data for changes in underlying fuel costs in this analysis.

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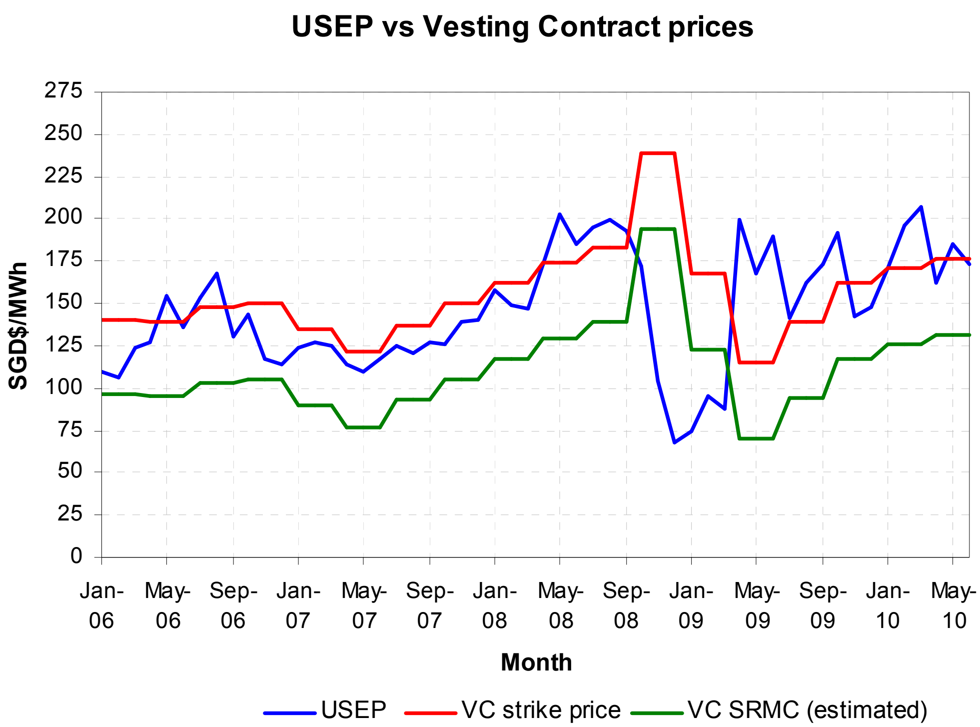
[17] The LRMC-SRMC gap is the difference between the LRMC and SRMC that result from the parameter values determined by the separate Vesting Contracts price parameters review.

3.2 Comparison of USEP and Vesting Contract price

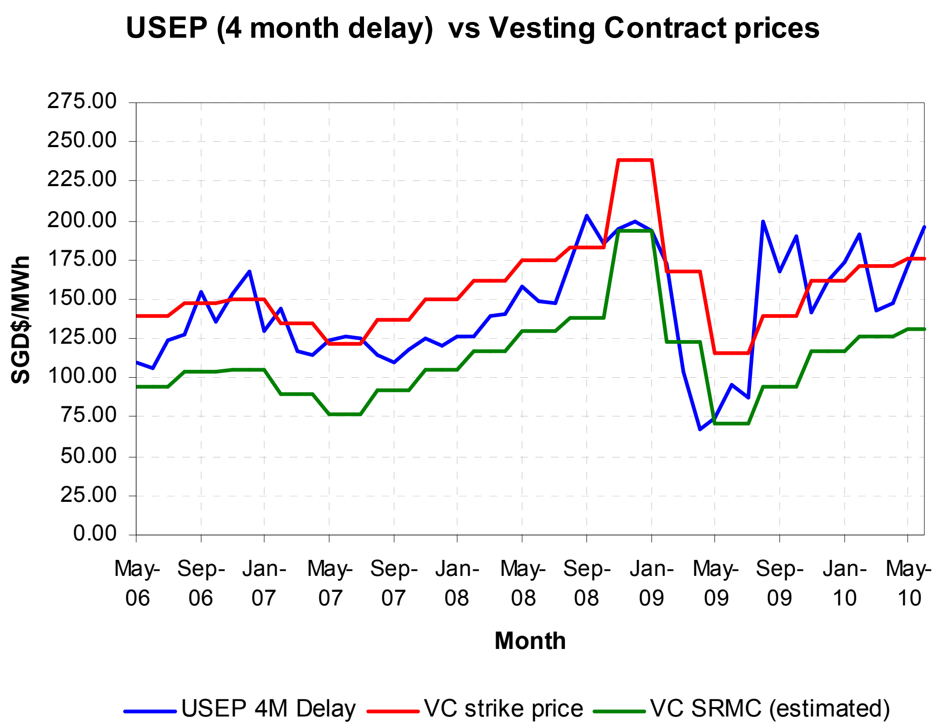
Figure 2 shows a comparison of monthly average USEP, Vesting Contract price, and the Vesting Contract SRMC for the period January 2006 through to June 2010.

Figure 2: Historical USEP and Vesting Contract price



It is evident from Figure 2 that there is a delay between the fluctuations in fuel prices that give rise to fluctuations in market prices, and the corresponding adjustments to the Vesting Contract price. If the USEP data is delayed by 4 months, a much better fit is observed, as shown in Figure 3:

Figure 3: USEP, with a 4-month delay, compared with Vesting Contract price



It can be seen from Figure 2 and 3 that USEP is usually less the Vesting Contract price and greater than the Vesting Contract SRMC up to the 2nd quarter of 2009. This suggests that the generators have generally not been able to exercise sufficient market power to achieve the Vesting Contract price, on average.

However, in 2009 there were two sustained periods of monthly average USEP exceeding the Vesting Contract price:

- April - June 2009
- September - October 2009

These periods of high USEP were investigated by the Market Surveillance & Compliance Panel (MSCP). In general, contributing factors to these high USEP were found to be a combination of units out for maintenance, unplanned outages, and high demand. However, for the April incidence, it was also found that "Lower volume of low-priced offers also contributed to the price spikes"[18], indicating a possible exercise of market power to raise prices. With the information available, it is not possible to determine the exact cause of these low volumes.

Furthermore, a further period of high USEP has occurred in January – February 2010, indicating the emergence of a pattern of these high price periods.

[18] Market Surveillance & Compliance Panel Annual Report 2009, page 12

It is out of concern of the increase in market concentration during periods of outages of the non-portfolio generators that the Vesting Relief scheme has been implemented. This is discussed further in section 4.3.1.

Table 5 shows the historical data averaged over each quarter. The effect of the price spikes discussed above is that USEP has significantly exceeded the VC strike price for 3 of the last 5 quarters.

Table 5: Historical data by quarter

Quarter	Platts Oil Price ($SGD/bbl)	USEP (SGD$/ MWh)	Vesting Contract Price (SGD$/ MWh)	Vesting Contract SRMC (estimated) (SGD$/MWh)
2006 Q1	78.92	113.81	140.70	96.92
2006 Q2	81.37	139.65	139.44	95.66
2006 Q3	76.72	150.73	147.90	104.12
2006 Q4	64.71	125.16	150.20	106.42
2007 Q1	67.64	125.05	134.66	90.88
2007 Q2	79.28	113.80	121.14	77.36
2007 Q3	87.40	123.99	137.25	93.47
2007 Q4	101.92	135.33	150.04	106.26
2008 Q1	100.88	151.50	161.80	118.02
2008 Q2	122.22	187.21	174.44	130.66
2008 Q3	138.93	195.98	183.25	139.47
2008 Q4	64.47	114.48	238.64	194.86
2009 Q1	60.48	85.30	167.14	123.36
2009 Q2	78.64	185.19	115.26	71.48
2009 Q3	91.65	158.59	138.92	95.14
2009 Q4	99.84	160.95	161.70	117.92
2010 Q1	103.14	191.31	171.05	127.27
2010 Q2	100.33	173.68	176.10	132.32

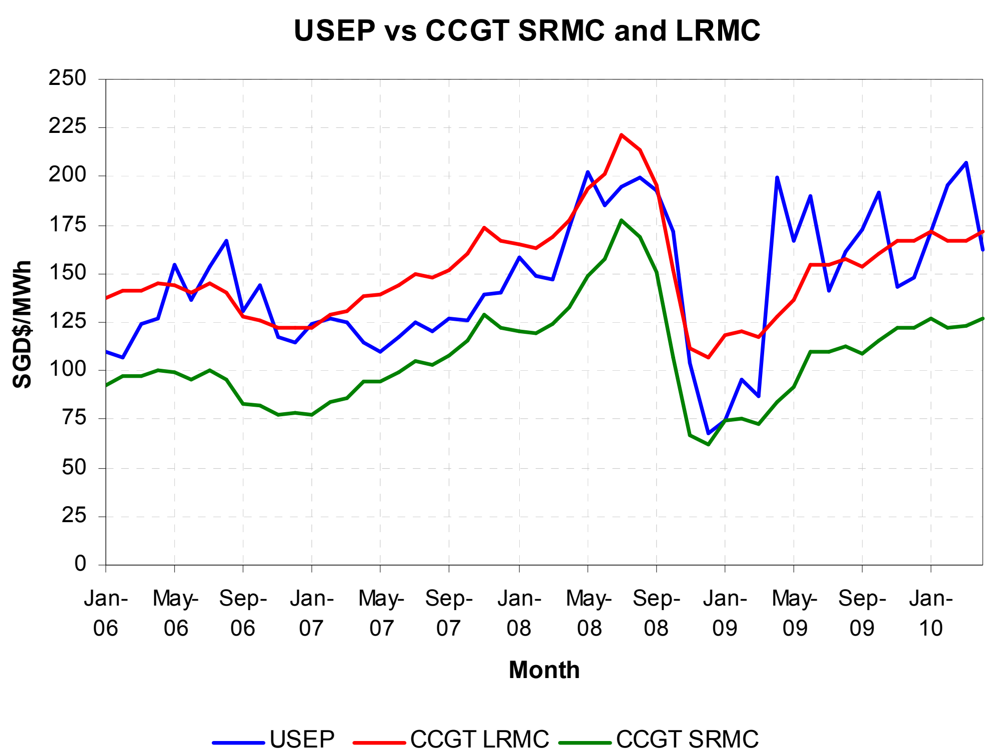
Source: Platts Oil Price – Opec Monthly Oil Reports; USEP and Vesting Contract price provided by EMA; SRMC estimated by PA.

3.3 Possible Contributing Factors to High Prices

Other factors were also considered in turn in relation to the high prices observed in 2009-2010.

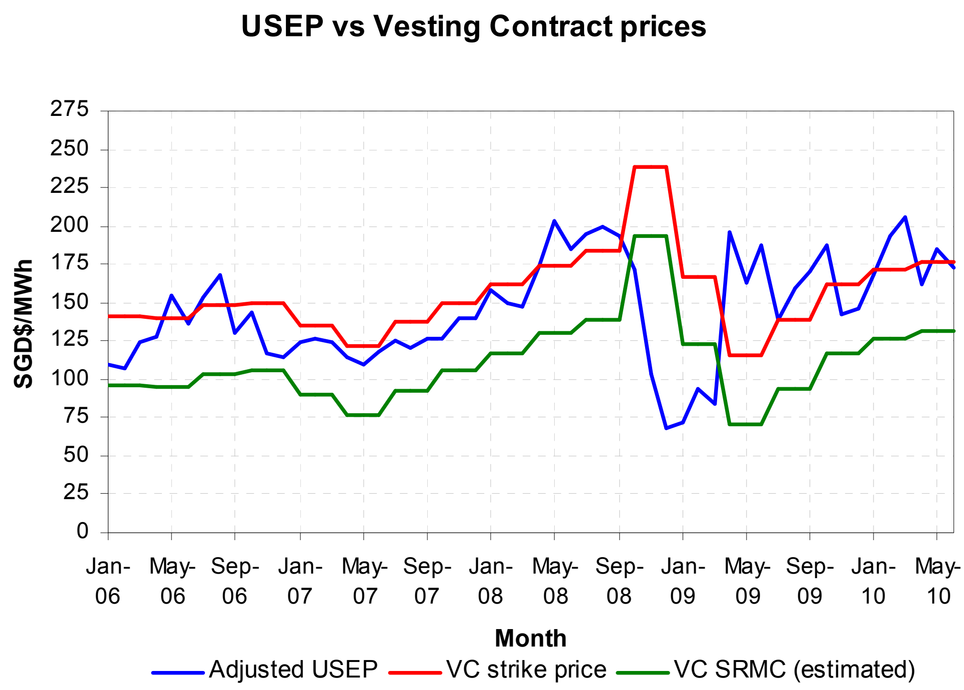
- **Fluctuations in Oil price**: The historical analysis has taken into account the effect of oil price as the Vesting Contract price is based on the forward HSFO price. However, any correlation between oil price and USEP may be obscured by the quarterly resolution and delays between oil price fluctuations and corresponding changes to Vesting Contract price (as shown in Figure 2 and Figure 3). Figure 4 eliminates these factors by comparing USEP to the SRMC and LRMC of a CCGT, based on the spot oil price. From the chart, it is evident that there is very little correlation between oil price movements and the price spikes observed in 2009 and 2010.

Figure 4: USEP vs. SRMC and LRMC



- **Gas Supply Curtailments:** If the cost of extra steam unit (ST) generation required to make up the shortfall in CCGT generation caused by the curtailments is subtracted from USEP, then the updated chart of USEP versus Vesting Contract price is as shown in Figure 5. It can be seen that the cost of extra ST generation does not account for the price spikes observed in 2009-2010. It should also be noted that gas curtailments increase the potential for the exercise of market power, as the market becomes more concentrated due to the reduction in the available generation capacity during those periods.

Figure 5: USEP Adjusted for Gas Curtailment



- **Outages**: Table 3 from the Annual Report by the Market Surveillance & Compliance Panel in 2009 shows the average amount of planned, unplanned and forced outages from 2003 to 2009. Total outages were greater in 2009 (1,266 MW) than in 2008 (1,020) MW, but lower than in 2007 (1,464 MW). The increase in 2009 was largely attributed to the increase in the amount of planned outages, which was attributed to the increase in planned outages of the steam units rather than the base-load units. It should also be noted that planned outages serve as a potential means for incumbent generators to exercise their market power as the market becomes more concentrated due to the reduction in the available generation capacity during those periods.
- **Demand Fluctuations**: Demand peaks in the presence of a reduced reserve margin are a potential cause of price peaks. They also increase the potential for the exercise of market power. Therefore, the presence of demand fluctuations coupled with a reduced reserve margin is in fact a reason to increase control over the potential exercise of market power.

Therefore, while gas supply curtailments, outages and demand fluctuations may have contributed to the high prices to some extent, these conditions also increases the potential for the exercise of market power by the incumbent generators.

3.4 Conclusion

There is no evidence for excessive exercise of market power up to the 2nd quarter of 2009. Indeed, given that USEP has been below the Vesting Contract price almost all the time over this period, the Vesting Contract regime may have been seen to over-constrain generator behaviour during this period.

However, a pattern of sustained prices spikes has emerged since the 2nd quarter of 2009, with the effect that average USEP has significantly exceeded the Vesting Contract price for 3 of the last 5 quarters up to the 2nd quarter 2010. This indicates that the Vesting Contract regime is no longer over-constraining generator behaviour, and that an increase in Vesting Contract levels may be necessary unless significant new generation enters the market.

4 Assessment of historical economic efficiency

As part of this review, PA has been requested to make an assessment on the level of economic efficiency in the NEMS achieved through the Vesting Contract Regime by assessing whether the Vesting Contract Regime had achieved its objective of promoting competition and allowing both incumbents and potential new entrants to compete on equal terms.

This section presents this assessment.

4.1 Approach

The design of the NEMS, being a mandatory gross pool market, ensures open competition amongst the participants of the market. By selecting the lowest cost generation to meet demand, it ensures the *allocative efficiency* of the market, and provides clear incentives for the generators to improve their *productive efficiency*. The level of competition achieved, however, is dependent on the number of participants in the market. The extent to which the market stays efficient over time - the *dynamic efficiency* - depends on the right quantity of efficient generation entering that market to meet rising demand and displace older, less efficient plant.

The Vesting Contract regime aims to ensure the dynamic efficiency of the market in two ways:

- By setting the target market price price at the Long-Run Marginal Cost (LRMC) of the most efficient generation technology available, this ensures appropriate price signals remain for investors to plant new and efficient generation capacity to meet demand growth, as it provides some assurance to investors that such new plantings will receive an appropriate return on investment.
- By controlling market power and hence encouraging competitive behaviour, the Vesting Contract regime discourages excessive capacity additions and inefficient generation that could arise from excessive market prices.

The extent to which the Vesting Contracts regime has achieved its objectives can consequently be assessed based on the extent to which new entrants have entered the market, and the type of new plant that has been constructed.

PA's approach to assessing historical economic efficiency consists of the following steps:

- Assess new entry: identify the type and extent to which new generation capacity has entered the market, and whether the new capacity was developed by incumbent or new suppliers. Identify, where possible, reasons why new entry has been more or less than would be expected in a competitive market.
- Impact of changes to the Vesting Contract regime: identify the impact of recent changes to the Vesting Contract regime – i.e. competitive tender for up to 12% of total demand, and the Vesting Relief scheme
- Draw conclusions about efficiency: based on the above analysis, in the context of market price outcomes as discussed in section 3, draw conclusions regarding the economic efficiency of the NEMS under the Vesting Contract regime.

4.2 New Entry in the Singapore Market

Table 6 shows the capacity additions to the Singapore market since the introduction of the Vesting Contract regime in 2004. This includes additions that are already in commercial operation and plant that are currently undergoing commissioning.

Table 7 shows currently planned new additions to the market, as supplied by the EMA.

Table 6: Capacity Additions Since 2004

Year	Participant	Type	Capacity	Notes
2004	Senoko Energy	CCGT	2 x 365 MW	
2005	Tuas Power Generation	CCGT	2 x 360 MW	
2006	Keppel Merlimau Cogen	CCGT	490 MW	Commercial operation in April 2007
2008	Schering-Plough	CCGT	2 x 4.8 MW	Generation Settlement Facility (GSF)
2008	Pfizer	CCGT	4.8 MW	Generation Settlement Facility (GSF)
2008	IUT	CCGT	2.1 MW	Generation Settlement Facility (GSF)
2009	Banyan Utilities	CCGT	5 MW	Generation Settlement Facility (GSF)
2009	ISK Singapore	CCGT	9.6 MW	Generation Settlement Facility (GSF)
2009	Senoko Waste to Energy	Incineration	55 MW	Not a new plant (ex NEA plant), but a new market participant
2009	Keppel Seghers	Incineration	22MW	
2010	PowerSeraya	CCGT	2 x 370 MW	Commercial operation in July 2010
2010	Shell Eastern Petroleum	Steam	60 MW	Undergoing commissioning

Source: EMA Statement of Opportunities (SOO), NEMS Market Reports and data supplied by the EMA

A 'Generation Settlement Facility' is a small generator (less than 10MW) that does not offer capacity into the NEMS, but receives the Market Energy Price for the power that it injects into the grid.

Table 7: Indicative Future Capacity Additions, 2011 to 2012

Year	Participant	Type	Capacity
2010	Biofuel Industries	Biomass	9.9 MW Generation Settlement Facility (GSF)
2010	Soxal	Steam	14.9 MW
2010	Green Power	CCGT	8.34MW - Generation Settlement Facility (GSF)
2011	Wyeth Nutritionals	CCGT	5 MW - Generation Settlement Facility (GSF)
2011	ExxonMobil Asia Pacific	CCGT	2 x 110 MW – assumed to come online in 2012 in the modelling
2012	REC	CCGT	9 x 5 MW
2012	Tuas (Tembusu)	Steam	102 MW
2012	IUT	CCGT	6 X 1.063 MW - Generation Settlement Facility (GSF)
2012	Senoko Energy	CCGT	800 MW

Source: Supplied by the EMA

Notes:

- In addition to these, a further new entrant, Island Power Company, has planned to construct a new 800 MW CCGT plant since around 2002. The delay in implementing this project has been due to difficulties in securing access to gas supply, and is not attributable to any aspect of the design of the NEMS or Vesting Contract regime. This plant is now expected to enter the market in 2013, with the commissioning of the LNG terminal.
- With the new CCGT additions by PowerSeraya (2010) and Senoko Energy (2012), both of these companies are expected to be constrained by their gas supply until LNG comes online in 2013. As a result, they will reduce generation from their less efficient units to provide gas to their more efficient new plants. Therefore, the market will not see the full benefit of these capacity additions until LNG is available.
- With these capacity additions, all three ex-government owned generators (Tuas Power Generation, Senoko Energy and PowerSeraya) will have exceeded their regulated maximum capacity. As a result, these and any future new build will require them to reduce the registered capacity of their existing plants, and therefore any further new build will not result in a net capacity addition.

4.2.1 Summary of New Entry

In summary, the following new participants have entered the market under the Vesting Contract regime:

- Keppel Merlimau Cogen
- Senoko Waste-to-Energy
- Keppel Seghers
- Shell Eastern Petroleum (Note: for own use; not expected to offer capacity into NEMS)

- 5 Companies with small generators as GSFs (Note: for own use; not expected to offer capacity into NEMS)

In addition, the following companies have specific plans to build generation capacity in the near future:

- Island Power Company
- ExxonMobil (Note: for own use; not expected to offer capacity into NEMS)
- REC (Note: for own use; not expected to offer capacity into NEMS)
- 5 Companies with small generators, expected to be GSFs (Note: for own use; not expected to offer capacity into NEMS)

All 3 of the ex-government owned incumbent generators have increased, or have firm plans to increase their capacity with new plant that will increase their capacity beyond their regulated maximum. As a result, the new capacity will effectively displace older, less efficient plant in their portfolios.

Of all the large plant (100 MW or greater) that has been built, or is being planned, all but one are CCGT technology, which has been identified in the Vesting Contracts price parameters review as the most efficient technology available in Singapore. The only exception is the planned Tuas Power Generation's Tembusu cogen, which is a cogeneration plant supplying heat to neighbouring industries to achieve a projected overall efficiency of around 70%[19].

A summary of the capacity additions, separated by incumbent (as of 2004) participants and new market participants is presented in Table 8 (This table is adjusted for the steam plant retired by Senoko Energy and PowerSeraya in order to build their new plant). The capacity figures are gross installed capacity[20]. All embedded generators are also excluded from Table 8:

Table 8: Summary of New Build (MW)

	Incumbents	New Participants
Already Built or Commissioning	1,440	658
Planned New Build	652	307
Total	**2,092**	**965**

This data shows that while there has been significant new build by new market participants, there has been significantly more capacity added by the incumbent generators. This factor increases the market power of the incumbents, which offsets the competitive gains arising from the entry of new participants.

4.2.2 Total Capacity vs. Peak Load and Reserve Margin

The total capacity resulting from the capacity changes as detailed in this section, excluding embedded generation, is shown in Figure 6, compared with peak wholesale load, and peak load plus a 30% reserve margin, where the reserve margin is the gap between total generation capacity

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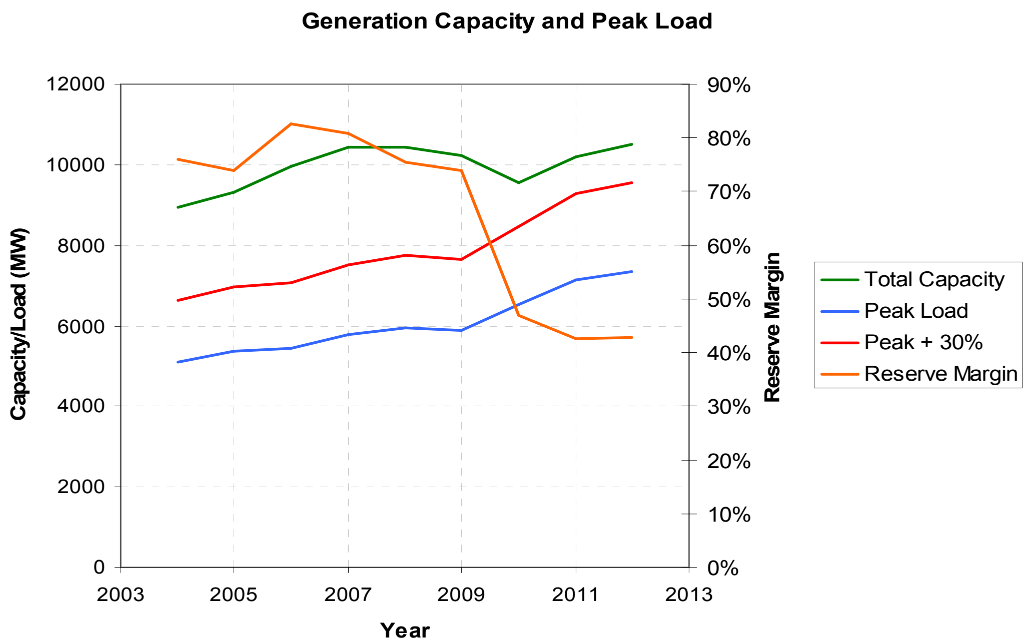
[19] http://www.tuaspower.com.sg/uploaded_files%5CPYF_2509200822159_34678_2509200830314.pdf

[20] Registered capacity with the EMC for existing plant, licensed capacity for planned new build.

and peak load (Capacity values are as of the start of each year). A 30% reserve margin has been determined to be the required reserve margin in Singapore, based on a loss of load probability of 3 days per year[21]. The actual reserve margin achieved with this generation capacity is also shown (plotted on the right hand axis).

Figure 6: Generation Capacity vs. Peak Load and Reserve Margin



It can be seen from Figure 6 that the reserve margin falls from over 70% to just over 40% over this time period. This is to be expected - the 70% reserve margin is significantly more than is required, and thus represents inefficiency in the market. The competitive market has responded by reducing the reserve margin to a more economic level, but at the same time building sufficient new capacity to ensure that the 30% minimum reserve margin is not breached.

This outcome supports the view that the NEMS with Vesting Contracts has succeeded in increasing the economic efficiency of the market over the long term. However, a reduced capacity margin also tends to increase the potential for exercise of market power.

4.3 Changes to the Vesting Contract Regime

There have been two recent changes to the Vesting Contract regime: The Vesting Relief Scheme, and Tendering for a Portion of the Non-Contestable Load. These are considered in turn in the following sections.

[21] EMA 2007 Statement of Opportunities, page 23

4.3.1 The Vesting Relief Scheme

The Vesting Relief Scheme has been implemented to allow Vested Non-Portfolio generators relief from their Vesting Contract obligations during periods of planned maintenance of their power plants. 'Vested Non-Portfolio generators' refers to generation companies that have opted in to Vesting Contracts, but do not have sufficient generation units to cover their Vesting Contract obligations when up to two of their generation units are unavailable (currently Keppel Merlimau Cogen and Sembcorp Cogen). The relieved Vesting Contract quantities will be transferred to the Vested Portfolio generators (currently PowerSeraya, Tuas Power, and Senoko Energy).

The intention of this scheme is to offset the increase in market concentration that occurs when a non-portfolio generator is unable to offer capacity into the market due to the planned maintenance of their power plants. This effectively removes one player from the market, and consequently increases the potential for exercise of market power by the remaining market participants. By reallocating the non-portfolio generator's Vesting Contract quantity to the portfolio generators, the portfolio generators' contract level is increased, and consequently their incentive to exercise market power is reduced.

The effect of this reallocation of contract quantities has been modelled using the Cournot Gaming model. The generation-weighted average (GWA) market price was simulated under three scenarios:

1. No outage (using scenario 1 as defined in section 5.3.7)
2. Planned outage of SembCorp Cogen’s CCGTs, but no Vesting Contract relief (the Vested Portfolio generator’s Vesting Contract levels remain unchanged)
3. Planned outage of SembCorp Cogen’s CCGTs, with Vesting Contract relief (Sembcorp Cogen’s Vesting Contract quantity is reallocated to the Vested Portfolio generators)

The results of these scenarios are as shown in Table 9:

Table 9: Vesting Contract Relief scenario results

Scenario	GWA
No Outage	192.94
Sembcorp Cogen Outage; No Vesting Contract Relief	205.96
Sembcorp Cogen Outage; Vesting Contract Relief	202.82

These results show that the Vesting Relief Scheme provides some, but not complete mitigation of market power due to the planned maintenance of Vested Non-Portfolio generators.

Effect of Vesting Relief Scheme on Recommended Vesting Contract Levels

As the vesting relief scheme has an effect on market prices, it may also have an effect on the Vesting Contract levels that are recommended by the model to achieve the Vesting Contract price. This effect has been modelled by adding the assumption that both Keppel Merlimau Cogen and Sembcorp Cogen use the scheme to the maximum extent allowed (up to four weeks per year). The effect on Vesting Contract levels is as shown in Table 10:

Table 10: Effect of Vesting Relief Scheme on Vesting Contract levels

Year	Scenario	
	No Vesting Relief Scheme	Vesting Relief Scheme
2011	61.9%	61.9%
2012	46.3%	45.3%

These results show that the effect on Vesting Contract levels is minimal.

4.3.2 Tendering for a Portion of the Non-Contestable Load

Under this scheme, a portion of the non-contestable load is tendered out for generation companies to bid on a competitive basis. The intention is to bring some benefits of competitive pricing the non-contestable consumers prior to the introduction of full retail contestability. Non-contestable consumers realise the benefits of this scheme by having the winning offer prices blended into their tariff formula. Initially, 3% of total load is to be tendered, in 3 tranches of 1% of total load each. The total amount tendered could potentially rise up to 12% of total load in later years.

When assessing the effect of this scheme on competition in the market, a key point to note is that the portion of load that is being tendered is load that is covered by Vesting Contracts. This load is considered by the EMA to be part of the Vesting Contract quantity, but is priced at the winning offer price(s), rather than at the prevailing Vesting Contract price. Therefore, this scheme does not change the total quantity of load that is covered by contracts, but does effectively increase the allocation of contract quantities to the market participants that win the tender from those that lose or do not participate in the tender.

It is this potential reallocation of contract quantities between market participants that may be significant in terms of its effect on competition. The effect has been considered by simulating the effect of this reallocation on market price using the Cournot Gaming model.

To clearly demonstrate the effect of this reallocation, we have compared the generation-weighted average (GWA) price for 2011 that arises from the Cournot gaming model without the tender (using scenario 1 as defined in section 5.3.7), against the price that results in the extreme case that 12% of total load is tendered, and the tender is entirely won by one participant. As a result, that participant's contract level is increased by 12% of the total load, and the other participant's contract level is reduced accordingly to maintain the same overall Vesting Contract level. This analysis was repeated for either PowerSeraya (the largest Vesting Contract participant), or Keppel Merlimau Cogen (the smallest Vesting Contract participant) winning the tender.

The results of this modelling are as shown in Table 11:

Table 11: Tendering scheme scenario results

Scenario	GWA Price
No Tender	192.94
PowerSeraya wins 12%	191.81
Keppel Merlimau Cogen wins 12%	194.24

These results show that the reallocation of contract quantities that may occur as a result of the tender have an impact on market prices. If the largest participant, with the most market power, increases its contract level as a result of the tender, it reduces its ability to exercise market power. This results in a reduction in market prices.

Conversely, if the smallest participant increases its contract level as a result of the tender, the contract levels of the larger participants will have to be reduced to maintain the overall Vesting Contract level. This will enable the larger participants to exercise more market power, resulting in increased market prices.

In conclusion, the scheme can result in either an increase or decrease in market prices, depending on which participants win the tender. This effect may influence the participants when preparing their tenders under this scheme.

4.4 Conclusion

In the following respects, the NEMS, under the Vesting Contracts regime, can be considered successful in promoting competition and economic efficiency:

- 4 new market participants (and 5 small generators as GSFs) have entered the market.
- A further 3 new market participants (and a further 5 GSFs) have specific plans to enter the market.
- All new plant built of significant capacity is highly efficient CCGT or cogeneration plant.
- The reserve margin has dropped from excessive levels over 70% to around 40%.

However, a less favourable aspect of the capacity additions is that capacity added by the incumbent generators has exceeded capacity added by new participants by a significant margin. This factor increases the market power of the incumbents, offsetting the competitive gains from the entry of new participants.

This trend can be expected to reverse in the future, as all 3 large incumbent generators will have reached their regulated maximum capacities with their planed new build in the next 2 years. Any new capacity additions will have to come from other market participants, resulting in real gains in terms of market competition.

Two changes to the Vesting Contract regime have been assessed in terms of their effect on market competition: The Vesting Relief scheme, and Tendering for a Portion of the Non-Contestable Load.

The Vesting Relief scheme is intended to offset the increase in market concentration that occurs when a non-portfolio generator is unable to offer capacity into the market due to the planned maintenance of their power plants. Modelling results indicate that the Vesting Relief scheme provides partial, but not complete, mitigation of market power due to the planned maintenance of the power plants of the non-portfolio generators. It will have a minimal impact on Vesting Contract levels.

Tendering for a Portion of the Non-Contestable Load is intended to bring some benefits of competitive pricing the non-contestable consumers prior to the introduction of full retail contestability. Modelling results indicate that the scheme can result in either an increase or decrease in market prices, depending on which participants win the tender.

5 Review of Vesting Contract level and period weighting factors

5.1 Introduction

This section describes the analysis and results for setting Vesting Contract volumes – both on average and in peak, shoulder, and off-peak demand periods.

The analysis represents a rerun of the same methodology employed previously for setting Vesting Contract levels and weighting factors. By using the same methodology, we provide continuity and stability in the process for setting the Vesting Contract level.

This section is structured as follows:

- Section 5.2 covers the basic input assumptions made to create the Cournot Gaming model of the Singapore electricity market.
- Section 5.3 defines the generation new build, re-powering, and decommissioning scenarios considered.
- Section 5.4 presents the results.
- Section 5.4.11 summarises the results.

5.2 Review of assumptions

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

- Plant build, re-powering, and decommissioning schedules have been reviewed and revised given current information.
- The long run marginal cost of the most efficient generator, resulting from the separate review of the parameters for the setting of the Vesting Contract price, is $192.91/MWh. This is for a new CCGT plant and includes a SRMC of $149.12/MWh and a gas price of $19.26/GJ[22]. This SRMC is based on the 2011/12 Vesting Contract parameters review.
- The model assumes that the contestable retail customers provide cover for their associated generation company.

Appendix A: contains the detailed model assumptions.

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[22] PA monitors monthly Singapore HSFO and diesel prices from the OPEC Monthly Oil Market Report. Simultaneously, PA monitors Singapore pipeline gas prices, as published by the MSSL in its Vesting Contract price determinations. By performing a linear regression, we determine an estimated relationship between HSFO prices and gas prices. By projecting the long-term trend in real HSFO and diesel prices, we arrive at 2011 prices of 18.31 SGD/GJ and 23.53 SGD/GJ for HSFO and diesel, respectively. By applying the regression results, we calculate a gas price of 19.26 SGD/GJ.

It is important to note that the analysis is largely invariant to fuel prices. This is because the same correction must be made to the target price and the SRMCs of the generation plant, since all are tagged (to a large extent) to the price of oil.

5.3 Determination of scenarios

5.3.1 Overview of scenarios

The following factors are considered for analysis as scenarios:

- The relationship between the period weighting factors and the target price – specifically, whether the period weighting factors should be different or equal, or fixed at 100 +/- 10%.
- The commissioning of Senoko Energy's repowered CCGT unit, with a current COD of Q3 2012; and
- The commissioning of Tuas Power Generation's Tembusu cogen, with a current COD of 2012.

5.3.2 Relative size of period weighting factors

We consider scenarios in which the period weighting factors are:

- Differential Period Weighting Factors: Each of the peak, shoulder, and off-peak demand blocks has a different period weighting factor, to control peak market prices.
- Unity Period Weighting Factors: Each of the peak, shoulder, and off-peak demand blocks has an equal period weighting factor. Specifically, each period weighting factor is set equal to 1.
- Fixed Period Weighting Factors: As an intermediate position, period weighting factors are fixed so that the peak weighting factor is 1.1, and the off-peak factor is the factor required to balance this on a load-weighted basis.

Differential period weighting factors

In the market power analysis, we divide demand into three demand periods (otherwise known as "blocks"): off-peak, shoulder, and peak.

The standard Vesting Contract analysis approach aims at equilibrating the target market price across the three blocks (peak, shoulder, and off-peak). Consequently there are differential Vesting Contract proportions in each period. This means having a high period weighting factor for the peak block, a moderate period weighting factor for the shoulder block, and a relatively low period weighting factor for the off-peak block.

In setting the Vesting Contract level, the analysis targets a price in each of the demand blocks equal to the long run marginal cost of the most efficient generator. Due to the requirement that the weighted average of the period weighting factors must equal 1, it is not generally possible to achieve a price in each demand block that is equal to the target price. Consequently, we allow the off-peak price to deviate from the target price – usually to a lower price.

Unity and Fixed period weighting factors

An alternative approach is to set the period weighting factors to be equal to 1 in all blocks, hence allowing the expected market prices to differ across the blocks. The rationale for this approach is based both on both practical experience and the theory of markets:

- A higher weighting factor for peak periods results in the generators having relatively high Vesting Contract volumes, in addition to their retail and other contracts, during peak demand periods. The result may be that they are over contracted during peak times. Conversely, a lower weighting factor during off-peak periods may result in the generators being under-contracted during off-peak times.
- Normally a market will see lower prices when generation capacity is much greater than demand (i.e. during off-peak times) and higher prices when the supply/demand balance tightens (i.e. during peak times). If the Vesting Contract analysis seeks equal prices in each demand block, then there is potential for the market outcomes to deviate from normal market behaviour.

An argument for equal weighting for all periods has been mounted on these two bases. We have considered these arguments and concluded that these they have sufficient merit to be viewed as a serious alternative to the standard approach.

In setting the Vesting Contract level, the analysis targets a generation-weighted-average (GWA) price across the demand blocks equal to the LRMC of the most efficient generator.

From a regulatory viewpoint there is value in the status quo in that the alternative, equal weighting factors, lessen the mitigation of market power in the high demand / high price periods. So the design of the original regime, that cautiously assumed a strict mitigation measure that aimed for the same level of mitigation but unequal weights, was justified. EMA may still wish to adopt a conservative approach and opt for unequal weights.

As an intermediate position, we have also evaluated the effect of fixing period weighting factors so that the peak weighting factor is 1.1, and the off-peak factor is the factor required to balance this on a load-weighted basis.

It should be noted, however, that in this alternative approach the end result is aimed at giving the same overall market power mitigation and the same weighted average price as for the standard approach – it is just the allocation over the demand periods that differs.

5.3.3 Treatment of embedded generators

We use total system demand to forecast load. This includes losses, station load as well as demand met by embedded generators. As such all embedded generators are included in the model as must-run units.

5.3.4 Senoko Energy Repowering

Senoko Energy is currently constructing an 800MW CCGT (repowering of their existing Steam units.) According to data received from the EMA, this has an expected COD of 3rd quarter 2012.

We consider scenarios in which this plant is:

- available in 2012; or
- not available until after 2012.

5.3.5 Tuas Tembusu Complex

Tuas Power Generation is currently constructing a multi-utilities complex in Tembusu, including a 102 MW coal/biomass generator which is expect to offer capacity into the market. According to data received from the EMA, the generator has an expected COD of 2012.

We consider scenarios in which this plant is:

- available in 2012; or
- not available until after 2012.

5.3.6 Capacity additions not considered for scenarios

The following significant capacity additions are planned for the 2011-2012 period of this review, but are not considered as scenarios for the following reasons:

- The ExxonMobil CCGT is understood to generate power for ExxonMobil's own use, and not to offer capacity into the NEMS. As such it is not able to exercise market power in the way that this model simulates.

5.3.7 Scenario definitions

Combining the factors above, we have the scenarios defined in Table 12.

Table 12: Scenario definitions

Factor	Value	Scenario									
		1	2	3	4	5	6	7	8	9	10
Period weighting factors	Differential	✓		✓		✓		✓			
	Unity		✓		✓		✓		✓		
	Fixed									✓	✓
Senoko Energy repowering	In 2012	✓	✓			✓	✓			✓	
	After 2012			✓	✓			✓	✓		✓
Tuas Tembusu complex	In 2012	✓	✓	✓	✓					✓	
	After 2012					✓	✓	✓	✓		✓

These scenarios represent all possible combinations of these factors for differential and unity weighting factors, and key new build scenarios with fixed weighting factors.

5.4 Scenario results

5.4.1 Introduction

There are several over-riding qualitative results that under-pin these numbers. Other things being equal, an increase in competitiveness reduces the need to mitigate market power and hence reduces the level of Vesting Contracts. The greater the supply-demand gap the more competitive the industry is (unless there is also a high concentration of ownership).

We observe the following relationships between the assumptions and the subsequent results:

- An increase in demand causes a reduction in the supply-demand gap. There is therefore a less competitive market and more ability to exercise market power. Consequently, the level of Vesting Contracts required to mitigate market power goes up.
- Conversely, an increase in generation capacity widens the supply-demand gap and so increases competition and reduces the level of Vesting Contracts required to mitigate the exercise of market power.
- An increase in the target price reduces the need to exercise market power, unless fully covered by fuel price increases also reflected in the SRMC of existing plant in the industry. Consequently, the level of Vesting Contracts required decreases.

5.4.2 Scenario 1

Assuming that both the Senoko Energy's repowered CCGT unit and the Tuas Power Generation's Tembusu cogen are operating in 2012, and differential period weighting factors, we obtain the results shown in Table 13.

Table 13: Scenario 1 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	67.8%	1.13	1.00	0.83	192.91	192.87	173.28
2012	40.4%	1.71	1.00	0.05	192.92	192.9	181.85

5.4.3 Scenario 2

Assuming that both the Senoko Energy's repowered CCGT unit and the Tuas Power Generation's Tembusu cogen are operating in 2012, and unity period weighting factors, we obtain the results shown in Table 14.

Table 14: Scenario 2 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	64.5%	1.00	1.00	1.00	207.96	195.61	170.46
2012	48.5%	1.00	1.00	1.00	221.82	185.93	164.04

5.4.4 Scenario 3

Assuming that the Tuas Power Generation’s Tembusu cogen is operating in 2012, but the Senoko Energy’s repowered CCGT unit is not, and differential period weighting factors, we obtain the results shown in Table 15.

Table 15: Scenario 3 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	67.8%	1.13	1.00	0.83	192.85	192.87	173.3
2012	50.9%	1.38	1.00	0.49	192.92	192.94	179.53

5.4.5 Scenario 4

Assuming that the Tuas Power Generation’s Tembusu cogen is operating in 2012, but the Senoko Energy’s repowered CCGT unit is not, and unity period weighting factors, we obtain the results shown in Table 16.

Table 16: Scenario 4 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	64.5%	1.00	1.00	1.00	207.96	195.61	170.46
2012	54.0%	1.00	1.00	1.00	213.72	190.26	169.32

5.4.6 Scenario 5

Assuming that the Senoko Energy’s repowered CCGT unit is operating in 2012, but the Tuas Power Generation’s Tembusu cogen is not, and differential period weighting factors, we obtain the results shown in Table 17.

Table 17: Scenario 5 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	67.8%	1.13	1.00	0.83	192.85	192.87	173.3
2012	45.6%	1.52	1.00	0.30	192.92	192.9	176.86

5.4.7 Scenario 6

Assuming that the Senoko Energy’s repowered CCGT unit is operating in 2012, but the Tuas Power Generation’s Tembusu cogen is not, and unity period weighting factors, we obtain the results shown in Table 18.

Table 18: Scenario 6 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	64.5%	1.00	1.00	1.00	207.96	195.61	170.46
2012	50.6%	1.00	1.00	1.00	218.9	188.62	164.72

5.4.8 Scenario 7

Assuming that neither the Senoko Energy's repowered CCGT unit nor the Tuas Power Generation's Tembusu cogen are operating in 2012, and differential period weighting factors, we obtain the results shown in Table 19.

Table 19: Scenario 7 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	67.8%	1.13	1.00	0.83	192.85	192.87	173.28
2012	59.8%	1.18	1.00	0.76	192.86	192.94	174.18

5.4.9 Scenario 8

Assuming that neither the Senoko Energy's repowered CCGT unit nor the Tuas Power Generation's Tembusu cogen are operating in 2012, and unity period weighting factors, we obtain the results shown in Table 20.

Table 20: Scenario 8 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	64.5%	1.00	1.00	1.00	207.96	195.61	170.46
2012	57.5%	1.00	1.00	1.00	209.36	194.51	169.96

5.4.10 Scenario 9

Assuming that both the Senoko Energy's repowered CCGT unit and the Tuas Power Generation's Tembusu cogen are operating in 2012, and fixed period weighting factors, we obtain the results shown in Table 21.

Table 21: Scenario 9 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	61.9%	1.10	1.00	0.87	203.32	197.39	174.24
2012	46.3%	1.10	1.00	0.87	217.68	187.82	167.07

5.4.11 Scenario 10

Assuming that neither the Senoko Energy's repowered CCGT unit nor the Tuas Power Generation's Tembusu cogen are operating in 2012, and fixed period weighting factors, we obtain the results shown in Table 22.

Table 22: Scenario 8 results

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	61.9%	1.10	1.00	0.87	203.38	197.39	174.24
2012	55.2%	1.10	1.00	0.87	205.28	196.15	173.27

5.5 Summary of scenario results

Table 23 summarises the results of the scenarios from the previous sections.

Table 23: Summary of scenario results

Year			Scenario									
			1	2	3	4	5	6	7	8	9	10
2011	Vesting Contract Level		67.8%	64.5%	67.8%	64.5%	67.8%	64.5%	67.8%	64.5%	61.9%	61.9%
	Weight-ing factor	Peak	1.13	1.00	1.13	1.00	1.13	1.00	1.13	1.00	1.10	1.10
		Shoulder	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Off-Peak	0.83	1.00	0.83	1.00	0.83	1.00	0.83	1.00	0.87	0.87
	Target price ($/MWh)	Peak	192.91	207.96	192.85	207.96	192.85	207.96	192.85	207.96	203.32	203.38
		Shoulder	192.87	195.61	192.87	195.61	192.87	195.61	192.87	195.61	197.39	197.39
		Off-Peak	173.28	170.46	173.3	170.46	173.3	170.46	173.28	170.46	174.24	174.24
2012	Vesting Contract Level		40.4%	48.5%	50.9%	54.0%	45.6%	50.6%	59.8%	57.5%	46.3%	55.2%
	Weight-ing factor	Peak	1.71	1.00	1.38	1.00	1.52	1.00	1.18	1.00	1.10	1.10
		Shoulder	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Off-Peak	0.05	1.00	0.49	1.00	0.30	1.00	0.76	1.00	0.87	0.87
	Target price ($/MWh)	Peak	192.92	221.82	192.92	213.72	192.92	218.9	192.86	209.36	217.68	205.28
		Shoulder	192.9	185.93	192.94	190.26	192.9	188.62	192.94	194.51	187.82	196.15
		Off-Peak	181.85	164.04	179.53	169.32	176.86	164.72	174.18	169.96	167.07	173.27

The following conclusions can be drawn from these results:

- Until new significant new capacity comes online in 2012, an increase in Vesting Contract level from the present 55% to around 65% is suggested by the model. This is due to the following factors:
  - A decrease in the reserve margin, greater potential for market power to be exercised in a supply constrained environment if unchecked;
  - An increase is also supported by the pattern of high market prices in excess of the LRMC seen in 2009 and early 2010
  - These factors are partially offset by the commissioning of efficient new CCGT capacity introduced since the previous reset. This will have moderated the effect of the other factors listed above, i.e. the recommended Vesting Contract level would have been even higher without them.
- Once both the Senoko Energy's repowered CCGT unit and Tuas Power Generation's Tembusu cogen are complete, Vesting Contract levels can reduce to around 48% or below (see results for year 2012 in scenario 9). This is due to the increased reserve margin and market competition that will result from these generators.

6 Sensitivities

6.1 Overview of sensitivity analysis

The Cournot modelling requires many input assumptions, as listed in Appendix A:. To understand the robustness of the recommendations, it is important to assess how sensitive the results are to the specific values chosen for key assumptions.

Sensitivity analysis has been conducted for the following assumptions:

- Load growth: Change in forecasted total load growth.
- Fixed component of LRMC: Changing the fixed component of LRMC which represents the difference between LRMC and SRMC.
- SRMC: Changing the SRMC while keeping the fixed component of LRMC held constant.

6.1.1 Sensitivity to Load Growth

The change in Vesting Contract levels that result from 1% - 2% increase or decrease in load growth is as shown in Table 24:

Table 24: Load growth sensitivity results

Year	Load Variation				
	-2%	-1%	0%	1%	2%
2011	58.5%	59.9%	61.9%	63.5%	64.5%
2012	38.4%	43.5%	46.3%	48.1%	53.3%

The model results are not particularly sensitive to the total load growth forecast, but are more sensitive at higher Vesting Contract levels. Over the relatively short 2-year horizon of the modelling, a +/- 1% change in the load growth rate is not material. However, a +/- 2% change in load growth, compounded over 2 years, does result in significantly different Vesting Contract levels for 2012.

As a guide, if the forecast demand is increased by 1%, then (all else being equal) the Vesting Contract levels increase by 1 - 2%.

6.1.2 Sensitivity to Fixed Component of LRMC

The change in Vesting Contract levels that result from $5 increase or decrease in the fixed component of the LRMC are as shown in Table 25:

Table 25: Fixed LRMC component sensitivity results

Year	LRMC		
	$187.91	$192.91	$197.91
2011	67.8%	61.9%	56.0%
2012	51.1%	46.3%	41.6%

The recommended contract cover increases as the fixed component of LRMC (i.e. LRMC less SRMC) decreases in order to control incentives to bid up the market 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. A $5/MWh decrease in the size of the fixed component resulted in approximately a 5 - 6% increase in the Vesting Contract level, and vice versa.

6.1.3 Sensitivity to SRMC

The change in Vesting Contract levels that result from $5 increase or decrease in the SRMCs of the generators, while holding the fixed component of the LRMC constant are as shown in Table 26:

Table 26: SRMC sensitivity results

Year	Change in SRMC		
	-$5	0	+$5
2011	61.9%	61.9%	61.9%
2012	46.3%	46.3%	46.3%

Changes in the SRMC do not produce a material change in the Vesting Contract levels, provided the fixed component of the LRMC is held constant.

6.2 Additional sensitivity analysis

In addition to these sensitivity analyses, we have examined the sensitivity of the results to the following assumptions:

- Effective retail contracts. That is, the contribution made by retail contracts to the overall effective contract level. The base analysis assumes that retail customers contribute 50% of their volume in the form of effective retail contracts. Sensitivity to this assumption is analysed in Section 6.2.1.
- Role of inflation. Specifically, does inflation over time change the recommended Vesting Contract levels.

6.2.1 Sensitivity to effective retail contracts

The 50% assumption for retail contribution to effective contracts, otherwise known as customer “stickiness”, is based on PA’s experience in other markets. There is no known theoretical or empirical literature available to support this assumption.

The concept of customer stickiness is closely related to elasticity. Consequently, instead of varying the retail contribution in isolation, the Cournot Gaming model should be calibrated by considering retail contribution and elasticity simultaneously. When we did so, changes in the two assumptions effectively cancel out, and so the Vesting Contract levels are actually quite insensitive to the retail contribution.

That is, we made a relatively large 10% change in the retail contribution and then recalibrated the model's elasticity assumptions. The resulting Vesting Contract levels vary by a maximum of ±2% depending on the scenario and year, with an average of approximately 0% across the selection of cases analysed.

The conclusion from this sensitivity analysis is that when considering the retail contribution rate and the elasticities simultaneously, the Vesting Contract levels are not materially sensitive to this assumption.

6.2.2 Sensitivity to inflation

It has been questioned whether inflation plays a role in changing recommended Vesting Contract levels over time.

Having examined this issue, we can confirm that simply inflating assumptions over time does not change the Vesting Contract levels. Specifically, if the SRMC and LRMC assumptions are scaled uniformly by an inflation rate from year to year, then there is no change in the resulting Vesting Contract levels.

It should be noted that if different components of the SRMC and LRMC assumptions are affected differently by inflation, then the Vesting Contract levels may change. For example, the LRMC fixed component has changed from the 2007/2008 reset to the current reset at a rate that differs from the rate of change of the SRMC assumptions, leading to changes in the Vesting Contract levels.

7 Recommendation

7.1 Framework of recommendation

Setting the Vesting Contract level for 2011 and 2012 needs to take account of a number of factors, including:

- The assessment of actual historical market power; and
- The relative size of the period weighting factors.

7.1.1 Assessment of historical market power

There is no evidence for excessive exercise of market power from the start of the Vesting Contract regime up to the 2nd quarter of 2009. Indeed, given that USEP has been below the Vesting Contract price almost all the time over this period, the Vesting Contract regime may have been seen to over-constrain generator behaviour during this period.

However, a pattern of sustained prices spikes has emerged since the 2nd quarter of 2009, with the effect that average USEP has significantly exceeded the Vesting Contract strike price for 3 of the last 5 quarters up to the 2nd quarter 2010. This indicates that the Vesting Contract regime is no longer over-constraining generator behaviour, and that an increase in Vesting Contract level may be necessary until significant new generation enters the market.

7.1.2 Relative size of the period weighting factors

There is a strong rationale for the Vesting Contract regime to support price differentiation between peak, shoulder, and off-peak demand blocks. More efficient price signalling would likely be achieved under a flatter weighting of the Vesting Contract levels across the demand blocks, since that would likely lead to relatively high spot prices in the peak period and relatively low spot prices in the off-peak period.

The rational for targeting the same price outcome in each demand block is also strong, in that it does not expose the high load period to a greater threat of market power than in other periods. This approach also recognises that low load periods are more likely to see a competitive market. This is consistent with EMA's long-held policy of using Vesting Contracts for the sole purpose of mitigating the threat of market power.

In their final determination for the 2009/2010 Vesting Contracts, the EMA decided on a balanced approach between the two options. PA recommends that this approach be maintained.

7.2 Recommendation for Vesting Contract level

On the basis of our modelling, we recommend that the Vesting Contract level for 2011 to 2012 be defined as per the results of Scenario 9, as shown in Table 27. Scenarios 1, 2 and 9 represent the most likely generation scenario, and Senario 9 is consistent with the EMA's current policy of applying a balanced approach to period weighting factors. Note that the 2012 results include both the Senoko Energy's repowered CCGT unit and the Tuas Power Generation's Tembusu cogen in operation, so the values indicated for 2012 should not be invoked until both these plant are in operation. Therefore adopting the scenario 9 results involves a single change to the Vesting Contract level when both projects are in operation.

Table 27: Recommended Vesting Contract level

Year	Vesting Contract level	Period weighting factors			Target prices ($/MWh)		
		Peak	Shoulder	Off-peak	Peak	Shoulder	Off-peak
2011	61.9%	1.10	1.00	0.87	203.32	197.39	174.24
2012	46.3%	1.10	1.00	0.87	217.68	187.82	167.07

7.3 Comparison with previous Vesting Contract reset

PA's recommendation for the previous Vesting Contract reset made recommendations for the Vesting Contract level as shown in Table 28.

Table 28: Previous reset

Year	Previous Reset
2009	59%
2010	57%

In its final determination, the EMA determined a Vesting Contract level of 55% for both years.

PA's recommendation that the Vesting Contract level be increased for 2011 to around 62% reflects the following changed market conditions:

- A decrease in the reserve margin, greater potential for market power to be exercised in a supply constrained environment if left unchecked;
- An increase in the Vesting Contract level for 2011 is also supported by the pattern of high market prices in excess of the LRMC seen in 2009 and early 2010
- These factors are partially offset by the commissioning of efficient new CCGT capacity introduced since the previous reset. This will have moderated the effect of the other factors listed above, i.e. the recommended Vesting Contract level would have been even higher without them.

With the addition of new capacity in 2012, Vesting Contract levels could reduce to 46%.

Appendix A: Detailed model assumptions

A.1 Herfindahl-Hirschman Index Calculation

In calculating the HHI, there are different possible ways of estimating market share. The key question is how robust the HHI is under different market share assumptions. Consequently, we have made HHI calculations based on three different metrics:

- registered capacity with EMC;
- registered capacity with EMC excluding GTs (which do not significantly contribute to generation volume);
- de-rated capacity covering outages and reserves;
- exclude units not in commercial operation; and
- exclude embedded generators that are GSFs and legacy units as these units do not participate in the wholesale electricity market.

As shown in Table 29, the 2010 HHI calculation is approximately 2,400-2,500 in each case.

Table 29: Data for Herfindahl-Hirschman Index (HHI) calculation, 2010

Company	Registered capacity with EMC (MW)		De-rated capacity (MW)
	Total	Excluding GTs	
Senoko Energy	2,635	2,445	1,965
PowerSeraya	3,100	2,920	2,558
Tuas Power Generation	2,640	2,640	2,395
SembCorp Cogen	785	785	581
Keppel Merlimau Cogen	490	490	428
Other	257	257	251
Total	**9,907**	**9,537**	**8,178**
HHI	**2,491**	**2,462**	**2,500**

A.2 Number of Generation Units and Gross Unit Capacity

Table 30: Generation station capacity (per unit) – based on registered capacity with EMC

Station name	Number of generation units		Gross unit capacity (MW)	
	2011	2012	2011	2012
SenokoCCP12	2	2	425	21.75
SenokoCCP345	3	3	365	365
Senoko7	1	1	250	250
Senoko8	1	1	250	115
SenokoCCP8	0	1	0	800
PPBGT1	1	1	105	105
PPBGT2	1	1	85	85
SerayaG123	3	3	250	250
SerayaG45	2	2	233	233
SerayaG6	1	1	232	232
JURGT12	2	2	90	90
SerayaCCP1	1	1	172.9	172.9
SerayaCCP2	1	1	168.9	168.9
SerayaCCP34	2	2	370	370
TuasUnit1	1	1	600	600
TuasUnit2	1	1	600	528
TuasCCP12	2	2	360	360
TuasCCP34	2	2	360	360
SembCorpCCP12	2	2	392.5	392.5
Keppel12	2	2	245	245
TuasIncineration	1	1	47.8	47.8
SenokoIncineration	1	1	55	55
TuasSthIncineration	1	1	132	132
IUT	1	1	2.13	2.13
Pfizer	1	1	4.8	4.8
Banyan	1	1	5	5
ScheringPlough	2	2	4.8	4.8
ISK	1	1	9.6	9.6
KeppelRefuse	1	1	22	22
BiofuelInd	1	1	9.9	9.9
GreenPower1	1	1	6.34	6.34
GreenPower2	1	1	2	2
SoxalSteam1	1	1	9.9	9.9
SoxalSteam2	1	1	5	5
ShellEastSteam	1	1	60	60
ExxonCCGT12	0	2	0	110
WyethNut	1	1	5	5
RECCCGT	0	9	0	5
TuasTembusuST	0	1	0	102
IUTCCGT	0	6	1.063	1.063
ExxonLegacy	2	2	88	88

With the new CCGT additions by PowerSeraya (2010) and Senoko Energy (2012), both of these companies are expected to be constrained by their gas contracts until LNG comes online in 2013. As a result, they will have to reduce generation from their less efficient units to provide gas to their more efficient new plants. Therefore, the market will not see the full benefit of these capacity additions until LNG is available. The output from their CCGT units (existing and new) is capped based on the amount of PNG gas contracts that they currently have. This is reflected in the modified gross unit capacities for SenokoCCP12, SerayaCCP1 and SerayaCCP2, which have been set to result in the required net CCGT capacity for Senoko and Seraya when combined with the de-ratings specified in sections A.3 and A.4.

A.3 Reserve, Auxiliary AND Cogeneration Usage

Table 31: Generation station reserve, auxiliary usage, and cogen usage

Station name	Reserve usage, 2011 (MW)	Reserve usage, 2012 (MW)	Auxiliary Usage (%)	Cogen usage (MW)
SenokoCCP12	57.39	3.37	0%	0
SenokoCCP345	24.05	24.05	0%	0
Senoko7	10.98	10.98	0%	0
Senoko8	10.18	10.18	0%	0
SenokoCCP8	0	108.04	0%	0
PPBGT1	0	0	0%	0
PPBGT2	0	0	0%	0
SerayaG123	19.59	19.59	0%	0
SerayaG45	17.99	17.99	0%	0
SerayaG6	17.99	17.99	0%	0
JURGT12	0.08	0.08	0%	0
SerayaCCP1	9.11	9.11	0%	0
SerayaCCP2	9.11	9.11	0%	0
SerayaCCP34	10.52	10.52	0%	0
TuasUnit1	0.24	0.24	0%	0
TuasUnit2	0.24	0.24	0%	0
TuasCCP12	13.32	13.32	0%	0
TuasCCP34	11.23	11.23	0%	0
SembCorpCCP12	71.69	71.69	0%	0
Keppel12	22.16	22.16	0%	0
TuasIncineration	0	0	0%	0
SenokoIncineration	0	0	0%	0
TuasSthIncineration	0	0	0%	0
IUT	0	0	0%	0
Pfizer	0	0	0%	0
Banyan	0	0	0%	0
ScheringPlough	0	0	0%	0
ISK	0	0	0%	0
KeppelRefuse	0	0	0%	0
BiofuelInd	0	0	0%	0
GreenPower1	0	0	0%	0
GreenPower2	0	0	0%	0
SoxalSteam1	0	0	0%	0
SoxalSteam2	0	0	0%	0
ShellEastSteam	0	0	0%	0
ExxonCCGT12	0	0	0%	0
WyethNut	0	0	0%	0
RECCCGT	0	0	0%	0
TuasTembusuST	0	0	0%	0
IUTCCGT	0	0	0%	0
ExxonLegacy	0	0	0%	0

Note: The reserve data is based on historical reserves provided between January and December 2009. Auxiliary usage is set to zero, because the demand forecast supplied by the EMA includes auxiliary use.

A.4 Scheduled Outage, Forced Outage and Other De-rating

Table 32: Generation outage rates

Station name	Scheduled Outage (%)	Forced Outage (%)	Other derating (%)
SenokoCCP12	6.13%	0.02%	11.50%
SenokoCCP345	7.45%	0.03%	11.50%
Senoko7	18.57%	0.01%	0.00%
Senoko8	15.44%	0.01%	0.00%
SenokoCCP8	5.48%	0.00%	11.50%
PPBGT1	15.66%	0.00%	0.00%
PPBGT2	1.23%	2.08%	0.00%
SerayaG123	17.84%	0.03%	0.00%
SerayaG45	13.20%	0.02%	0.00%
SerayaG6	13.20%	0.02%	0.00%
JURGT12	1.64%	0.06%	0.00%
SerayaCCP1	4.57%	0.02%	6.27%
SerayaCCP2	4.57%	0.02%	6.27%
SerayaCCP34	4.57%	0.02%	6.27%
TuasUnit1	6.38%	0.01%	0.00%
TuasUnit2	6.38%	0.01%	0.00%
TuasCCP12	5.89%	0.01%	2.75%
TuasCCP34	5.15%	0.00%	2.75%
SembCorpCCP12	5.57%	0.06%	2.06%
Keppel12	3.60%	0.02%	0.00%
TuasIncineration	4.71%	0.02%	0.00%
SenokoIncineration	11.64%	0.01%	0.00%
TuasSthIncineration	12.60%	0.01%	0.00%
IUT	0.00%	0.01%	73.60%
Pfizer	0.00%	0.01%	10.79%
Banyan	0.00%	0.01%	98.80%
ScheringPlough	0.00%	0.01%	6.38%
ISK	0.00%	0.01%	19.79%
KeppelRefuse	7.67%	0.06%	0.00%
BiofuelInd	0.00%	0.01%	0.00%
GreenPower1	0.00%	0.01%	0.00%
GreenPower2	0.00%	0.01%	0.00%
SoxalSteam1	0.00%	0.01%	0.00%
SoxalSteam2	0.00%	0.01%	0.00%
ShellEastSteam	0.00%	0.01%	25.77%
ExxonCCGT12	8.61%	0.01%	25.77%
WyethNut	0.00%	0.01%	0.00%
RECCCGT	0.00%	0.01%	0.00%
TuasTembusuST	0.00%	0.01%	0.00%
IUTCCGT	0.00%	0.01%	0.00%
ExxonLegacy	8.61%	0.01%	25.77%

This Scheduled Outage and Forced Outage data has been based on an average of the outage data for 2006-2010. Other de-rating ensure realistic generation for existing embedded generators, based on historic 2009 to 2010 data provided by the EMA. Other de-rating also account for the effect on gas curtailments on CCGT capacity, based on 2009 data provided by the EMA.

A.5 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 cogeneration usage, in MW, from each unit.

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

R = 'Reserve': The average 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. The resulting net generation capacity data is shown in Table 33.

Table 33: Net generation capacity (total station MW)

Station name	Net generation capacity	
	2011	2012
SenokoCCP12	585.17	29.08
SenokoCCP345	815.03	815.03
Senoko7	192.59	192.59
Senoko8	201.2	87.06
SenokoCCP8	-	556.11
PPBGT1	88.55	88.55
PPBGT2	82.18	82.18
SerayaG123	557.2	557.2
SerayaG45	368.44	368.44
SerayaG6	183.34	183.34
JURGT12	176.79	176.79
SerayaCCP1	145	145
SerayaCCP2	141.55	141.55
SerayaCCP34	638.56	638.56
TuasUnit1	561.40	561.40
TuasUnit2	561.42	494.02
TuasCCP12	631.14	631.14
TuasCCP34	640.66	640.66
SembCorpCCP12	581.3	581.3
Keppel12	427.89	427.89
TuasIncineration	45.54	45.54
SenokoIncineration	48.59	48.59
TuasSthIncineration	115.36	115.36
IUT	0.56	0.56
Pfizer	4.28	4.28
Banyan	0.06	0.06
ScheringPlough	8.99	8.99
ISK	7.7	7.7
KeppelRefuse	20.3	20.3
BiofuelInd	9.9	9.9
GreenPower1	6.34	6.34
GreenPower2	2	2
SoxalSteam1	9.9	9.9
SoxalSteam2	5	5
ShellEastSteam	44.53	44.53
ExxonCCGT12	-	144.34
WyethNut	5	5
RECCCGT	-	45
TuasTembusuST	-	101.99
IUTCCGT	-	6.38
ExxonLegacy	115.47	115.47

A.6 Long Run Marginal cost of the most efficient generator

The most efficient generator in the Singapore electricity market would take the form of a CCGT plant. Based on the 2011/12 Vesting Contract parameters, review the LRMC of such a plant would be $192.91/MWh.

A.7 Plant Heat Rates

Table 34 shows the plant heat rates for each plant, used by the model to determine the marginal cost for each plant. This is based on historical data supplied by the EMA for January – April 2010.

Table 34: Efficiency of each generator

Station Name	Heat Rate (GJ/MWh)
SenokoCCP12	8.96
SenokoCCP345	7.28
Senoko7	10.24
Senoko8	10.89
SenokoCCP8	7.36
PPBGT1	25.51
PPBGT2	25.51
SerayaG123	7.69
SerayaG45	9.7
SerayaG6	9.7
JURGT12	20.9
SerayaCCP1	7.69
SerayaCCP2	7.69
SerayaCCP34	7.87
TuasUnit1	11.79
TuasUnit2	11.79
TuasCCP12	7.45
TuasCCP34	7.47
SembCorpCCP12	8.73
Keppel12	7.82
TuasIncineration	0
SenokoIncineration	0
TuasSthIncineration	0
IUT	0
Pfizer	0
Banyan	0
ScheringPlough	0
ISK	0
KeppelRefuse	0
BiofuelInd	0
GreenPower1	0
GreenPower2	0
SoxalSteam1	0
SoxalSteam2	0
ShellEastSteam	0
ExxonCCGT12	0
WyethNut	0
RECCCGT	0
TuasTembusuST	10.47
IUTCCGT	0
ExxonLegacy	0

The heat rates are based on historical efficiency data between January and to April 2010. Where no historical data for a plant was available, an average of the efficiencies of the other plants in the same class was used. Efficiencies for waste-to-energy plants is set to 100% as the fuel cost is assumed to be zero

A.8 Peak Load Forecast

The peak load forecast (based on system demand which include losses and auxiliary use, and demand met by embedded generators), supplied by the EMA, is shown in Table 35.

Table 35: Peak load forecast

Year	2011	2012
Peak Load (MW)	6,740	6,935

A.9 Total Load Forecast

The total load forecast (based on system demand), supplied by the EMA, is shown in Table 36. This is the total forecast gross generation, including losses, auxiliary use and demand met by embedded generators.

Table 36: Total load forecast

Year	2011	2012
Total Load (GWh)	46,476	47,958

A.10 Retail Load

It is assumed that all of non-contestable customers are covered by Vesting Contracts. It is also assumed that 50% of contestable customers contribute to the "effective contracting" level of the genco/retailers (see Section B.5).

A.11 Demand elasticity

The demand elasticities used in the modelling are shown in Table 37. These elasticities are the same as those used for the previous two Vesting Contract resets, on the basis that:

- Demand elasticity does not normally change much from year to year; and
- Fuel prices, especially for oil, have been highly volatile over the last few years. This degree of change makes it difficult to calibrate the Cournot Gaming model's elasticity assumptions against actual market outcomes. Hence, we have used a more stable year's data for calibrating the elasticities.

Table 37: Calibrated demand elasticities

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

A.12 Fuel Prices

The following fuel prices are used in the analysis:

Fuel	Price (SGD/GJ)
Gas	19.26
HSFO	18.31
Diesel	23.53
Coal	6.30

Appendix B: Operation of the model

B.1 Basic Cournot assumptions

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. 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.

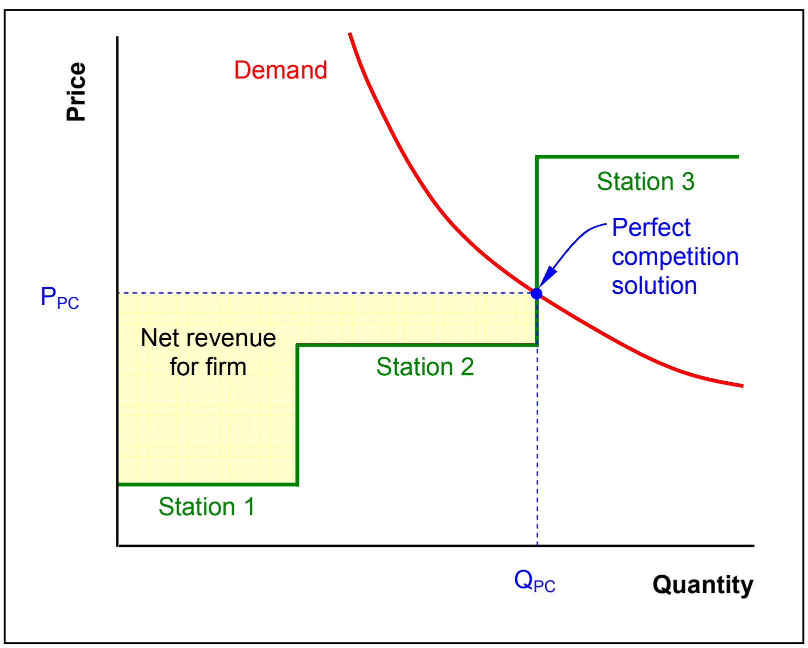
Beginning with the generation quantities produced by the cost minimisation modelling approach, we assume that an elastic demand curve passes through the perfect competition demand level. However, these generation levels may not produce the maximum trading net revenues for the individual firms. If a firm 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 7 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 (QPC x PPC) and its SRMC costs (the area under the supply curve).

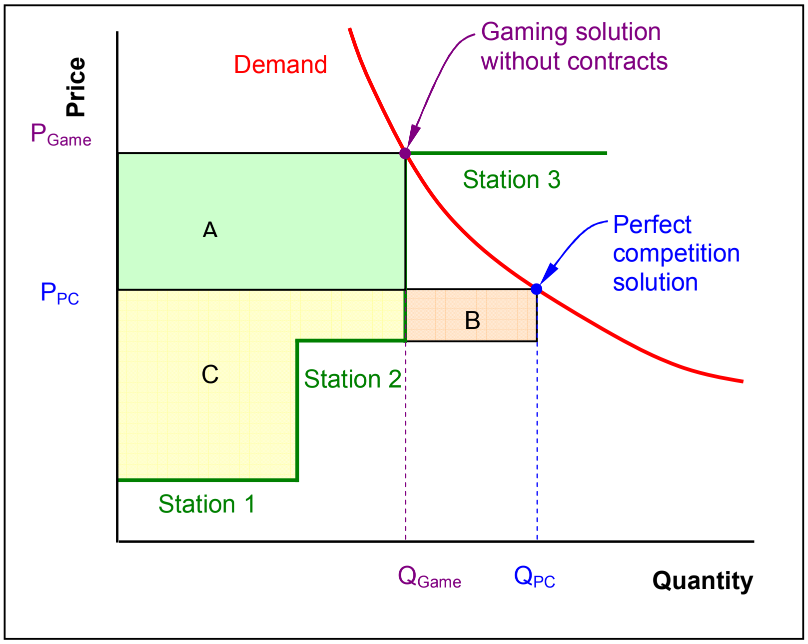
Figure 7: First step of Cournot game – perfect competition solution



But suppose that the firm has some market power. Given the situation shown in Figure 7, 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 8. The quantity offered by Station 2 has reduced, and now Station 3 is setting the market price PGame. 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 8: 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

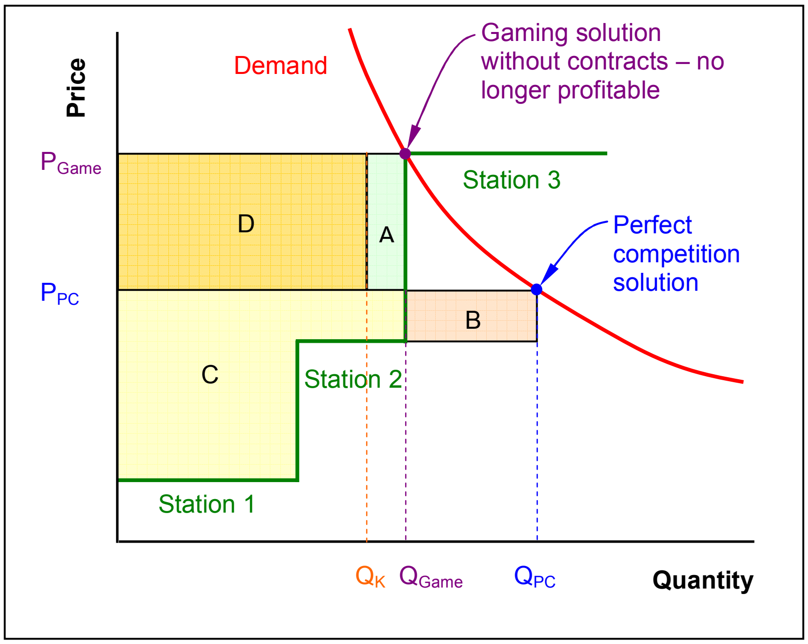
The strength of a company's incentive to extract price benefits in such a market depends on its exposure to the spot market price. This incentive can be weakened in two ways:

4. Either the company's market share must be reduced, and/or
5. 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 9, with quantity QK of hedge contracts, the size of area A is reduced by area D – because QK 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 9: 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 QK increases, incentives are weakened further until the perfect competition level QPC is reached where there is no more incentive to "game" the market. Increasing QK beyond QPC 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 target price, then the generator is paid (by the other party to the contract) the difference between the spot and the target price, for the quantity specified in the contract. If the spot price is greater than the contract target price, then the generator pays the difference between the spot and the target 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 2007 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.

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.

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.

Appendix C: Glossary

Acronyms which may be used in this report are defined in Table 38.

Table 38: Acronym definitions

Acronym	Definition
CBP	Competitive benchmark price
CCGT	Combined-cycle gas turbine
CfD	Contract for differences
DOJ	(US) Department of Justice
EMA	Energy Market Authority
GT	Gas turbine
GWA	Generation-weighted-average
HHI	Herfindahl-Herschman Index
HSFO	High sulphur fuel oil
LRMC	Long run marginal cost
LWA	Load-weighted-average
MSSL	Market Support Services Licensee
NEMS	National Electricity Market of Singapore
PA	PA Consulting Group
PCMI	Price-cost margin index
SFE	Supply function equilibrium
SRMC	Short run marginal cost
ToP	Take-or-pay
USEP	Uniform Singapore energy price
VC	Vesting Contract
VOM	Variable operating and maintenance (cost)

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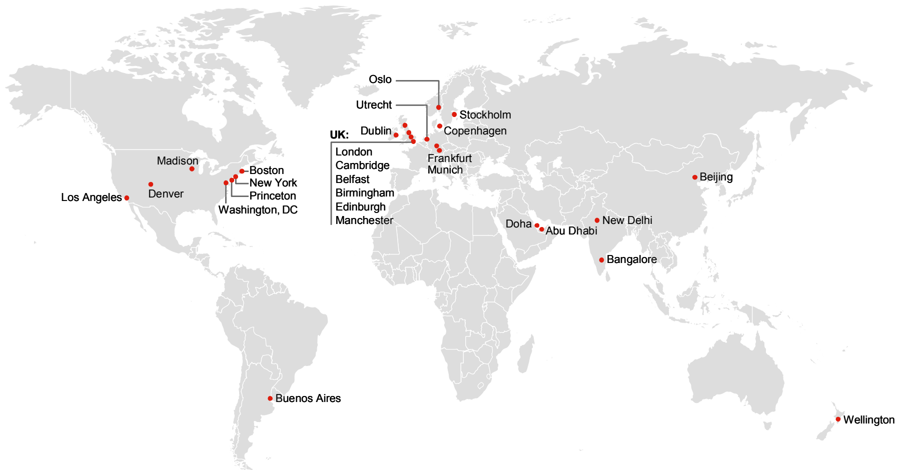

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