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A Simulation Based Approach to Professional Development in Integrated Energy Markets

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A Simulation Based Approach to Professional Development in Integrated Energy Markets

Abstract

This article discusses a novel professional development workshop whose objective was to build an understanding of the relationships in the Australian energy sector and to appreciate the key issues for operating and investing in energy markets.

Firstly we provide a clear exposition of the relationships between energy market segments, and how these relationships impact the investment and operational activities of businesses.

Secondly we describe the formulation and reflect on experiences relating to a training workshop for energy professionals based on a simulation of the energy sector. The delivery mechanism was through game-based learning requiring active participation to simulate operational and investment decisions, where an understanding of the integrated energy market was essential for success.

The workshop succeeded in conveying the complex ways in which electricity, environmental and gas markets interact in Australia. An important observation from the training program was the way in which participants used the provided spreadsheet models to 'reverse-engineer' how the market operates, rather than simply using the software as a device for decision support.

Keywords

energy markets, decision support, portfolio management, investment, power station operations

1 Introduction

In this paper we describe the learning design, experiences and reflections of the author in delivering a novel professional development workshop in energy markets. As a supporting tool for the workshop, an extensive spreadsheet model was made available to participants to convey concepts, illustrate examples, and to offer decision support for a case study. The structure of the workshop engendered an active learning experience where participants experimented with spreadsheet tools to conduct simulations of investment and operational decisions for a portfolio with exposure to the integrated energy markets.

The author frequently presents highly focused training to energy market participants designed to drill into detail on a particular market segment. For example, the author delivers electricity trading and risk management workshops which train attendees in the particular skills to pass industry accreditation for trading in electricity market derivatives [14]. As part of the workshop, the presenter alludes to the relationships with other commodities and markets, but the focus is on the mechanics and structure of the National Electricity Market (NEM); the content is *deep* without a mandate to extend the *breadth*.

Interactions with industry participants identified the need for holistic education on the energy markets, beyond electricity alone, and covering environmental, gas, carbon and coal trading. In 2013, a one-day course was developed based on a team-based simulation game. Educationalists have long promoted the concept of active learning, and the use of hands-on experiments, case studies, simulations and games have found success in various fields [15], [23].

The key objectives of the workshop in both content and style were:

- To enable participants to recognize the interdependencies of various markets and financial securities and physical assets through experimental probing;
- To appreciate the complexities associated with operating a business and making investment decisions in the integrated energy market environment;
- To engage participants with an active learning style in a team environment to reinforce the learning experiences and to foster exchange of expertise between peers.

The course has been successfully delivered, and the author and participants have had an opportunity to reflect on the effectiveness of the workshop at achieving the learning objectives.

Other researchers have implemented an analogous program [24] which simulates the complexity within the Health and Finance sectors. Similar to our experience, the participants experienced several rounds and experimented with a decision tool to establish strategies consistent with risk and return objectives, operating within a very complex environment of interdependencies. They concluded that "*One of the most effective and successful pedagogical strategies for undergraduate education utilizes self-discovery simulations to illustrate and explain complex concepts*".

2 The Integrated Energy Market

2.1 Structure of the Integrated Market

The stationary energy market of the East Coast of Australia presents a complex web of market forces, government influence and regulation. The energy market is a transformative economic chain where natural resources are transformed into useful energy products and are delivered over extensive transmission networks. Various synthetic commodities (environmental certificates) are also created and demanded as part of the regulatory framework, which aims to support social, political and economic objectives.

The globalization of energy markets and the growth of export infrastructure also influences the domestic energy market for commodities, to the extent that channels exist for import and export.

A summary of the NEM can be found in [2] and domestic gas markets in [3] and [4]. The structure of Renewable Energy Target (RET) schemes is in [9], while the Queensland Gas Scheme (QGS) is explained in [13]. In the period since the workshop was conducted, further regulatory reform has occurred in the energy markets, particularly a process to integrate the disparate gas markets [20], and predicting this evolution constituted part of the scenario formulation for the workshops themselves. Developments in renewable energy regulation have seen the QGS closed and the targets reset in the RET.

Figure 1 illustrates the economic flows in the integrated energy market. Vertically integrated energy market participants have involvement across the full supply chain of commodities and markets. Other specialized players are involved only in generation, retailing, gas production or other subcomponents of the market.

Personnel working in the sector act in various roles of trading, risk management, strategy formulation, investment, engineering and operations. The workshop described in this article aimed to convey the way in which individuals' own area of specialization fit with the broader sector. The simulations and supporting spreadsheet tools were designed to enable users to probe the relationships between various commodities and sector activities. For example, operational roles generate and offer electricity to the physical market in five-minute increments, gas nominations are conducted on a day-ahead basis, medium term contracting and gas agreements extend from one to three years and long term investment is based on a 50-year asset life.

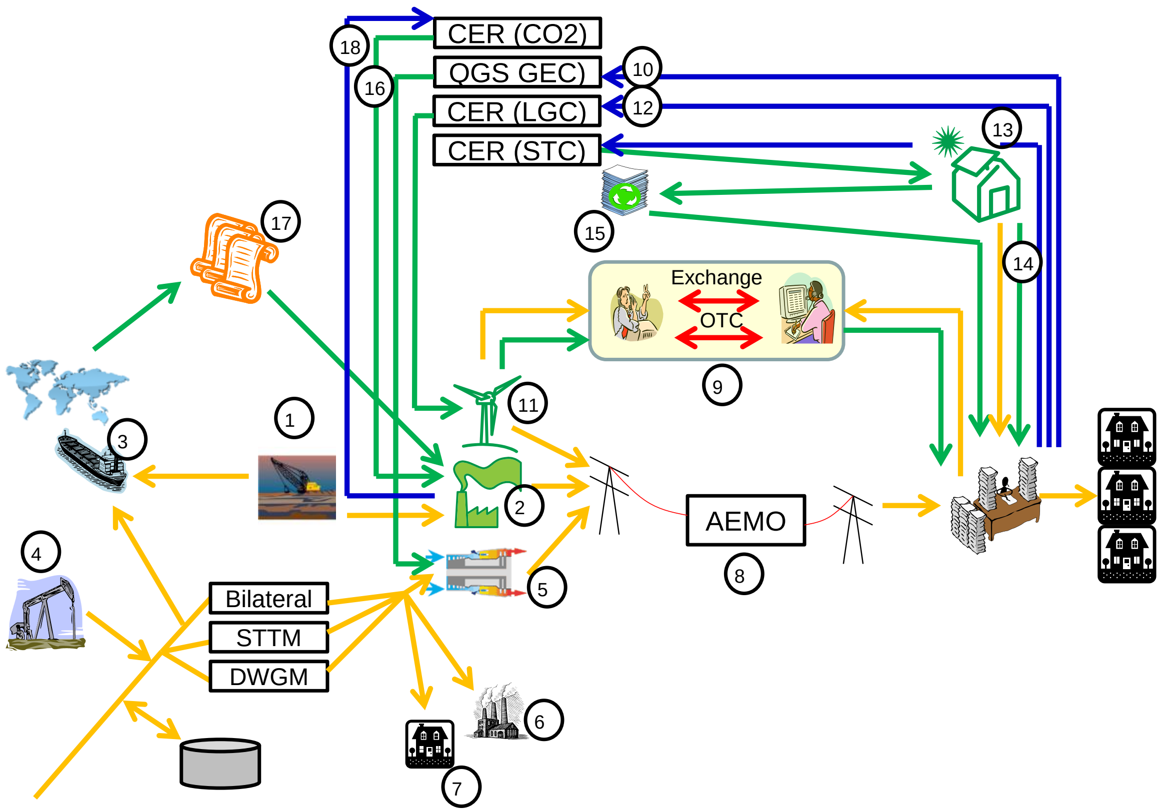

Figure 1: Integrated energy market commodity flows. Orange flows indicate energy commodities; green flows are environmental commodities and blue flows are the acquittals of the environmental commodities to extinguish liabilities.

Natural Gas: Natural gas is supplied from conventional or coal-seam sources (4) and transported in compressed form along dedicated pipelines. The destinations for the commodity are electricity generation (5), domestic consumption (6), industrial consumption (7), or LNG export (3). The gas pipeline is a storage facility itself and there also exist several bulk facilities capable of banking large volumes of compressed gas. Gas is sold to end-users through several alternative channels: a bilateral trade or spot markets operated by AEMO, being the Short Term Trading Market (STTM) in Queensland, New South Wales and South Australia or the Declared Wholesale Gas Market (DWGM) in Victoria.

Coal: Thermal coal is supplied from underground and open cut mines (1) and delivered to coal-fired power stations (2) via conveyor or rail. Where coal is of sufficient thermal quality and the mine has rail access to a port (3) and the port possesses sufficient capacity, coal mines have an additional channel to export markets.

Electricity: Generation plants produce electricity which is dispatched into the NEM grid, and generators are paid at the pool price from the central clearing house, AEMO (8). Retailers (on behalf of consumers) are liable for the power costs, also at the prevailing pool price. Generators and retailers engage in electricity derivative trading (9) to manage price risk and transfer volume risk.

Carbon Emissions Certificates: During the period 2012-2014 legislation introduced a liability to power stations on the basis of the Carbon Dioxide emitted through burning fuel. The Clean Energy Future (CEF) legislation [5] created a demand for emissions certificates, with requirement to surrender one permit for each tonne of CO_2 emitted. Under the legislation, certificates were sourced only from the Clean Energy Regulator (CER) (16) or international schemes (17) with recognized linkages to the Australian scheme. Each generator surrendered valid certificates (18) to the regulator to acquit liabilities at the end of each year. Legislation at the time envisaged certificate acquisition during a free-market regime of the scheme through (i) purchase at auction, (ii) purchase of international permits or (iii) bilateral trades, however the repeal of the legislation in 2014 [21] saw significant disruption to hedging strategies. The workshop in 2013 recognized that management of the regulatory risk formed an enormous challenge.

Large Generation Certificates: Large scale renewable power stations, such as hydro-electric generation and wind farms are eligible to create a Large-scale Generation Certificate (LGC) from the regulator for each megawatt hour of energy produced. Regulation [9] creates a demand for the certificates by legislating that retailers must surrender a number of LGCs to the regulator (12), calculated as a percentage of their load (around 10% in 2012 rising to 20% in 2020). LGCs are traded from renewable generators (11) to retailers through bilateral contracts in spot and forward trades (9), as well as being listed on the Australian Securities Exchange (ASX) futures market (9).

Small Technology Certificates: Small scale solar photovoltaic systems create certificates termed Small Technology Certificates (STC) upon installation of eligible units (13). A demand for the certificates is created by regulation [9] which enforces retailers to acquire and surrender a number of STCs specified as a proportion of their load. Holders of the STCs can sell the certificates directly to retailers in bilateral spot or forward trades (14). Alternatively, the regulator manages a clearing house which accepts all certificates for a fixed price, where sellers can sell STCs to the 'bottom' and retailers can purchase certificates from the 'top' of the stack (15).

Gas Electricity Certificates: In 2013, gas fired generators in Queensland were eligible to create a Gas Electricity Certificate (GEC) certificate (5) for the portion of the generation output which is used in Queensland. Demand for the certificates was created by State legislation [13] which required retailers to surrender a number of certificates (10) relating to a proportion of their load (around 15%). The QGS was designed to foster development of the Queensland gas industry, and with that objective achieved, the scheme was discontinued in 2014. Retailers acquired their certificates via bilateral trades (9) at negotiated prices. The workshop recognized that since the closure of the scheme was flagged in 2013, the risks could be effectively managed.

2.2 Market Supply, Demand and Price

Market forces in the guise of supply and demand guide prices for all of the commodities described. The particular commercial structure of each commodity and channel to market has individual rules surrounding how the supply and demand curves meet to set prices and clear production. As a result, each commodity is endowed with a particular market price characteristic. For example, highly storable commodities such as LGCs have a reasonably stable structure, while electricity which cannot be stored is highly volatile. Most commodities are also endowed with regulated price caps and floors.

In this section we provide a summary of the characteristics of three key commodities in the integrated market.

Electricity Power Market: End user consumption patterns drive the demand for electricity in a relatively price-inelastic manner. Electricity is offered into the market by various generator technologies with disparate cost structures. Generators offer a supply curve to the market operator AEMO, who then establishes the optimal dispatch patterns to meet consumer demand at the minimum cost. The spot price for electricity for all participants is set at the marginal price of generation.

As supply shortens, or demand grows, the spot price for electricity rises. A common way of illustrating the relationship is with a scatterplot of *Reserve* defined as (*Aggregate Supply – Aggregate Demand*) against the spot price. By compiling a projection of future supply and demand, it is possible to form a view on the future spot price.

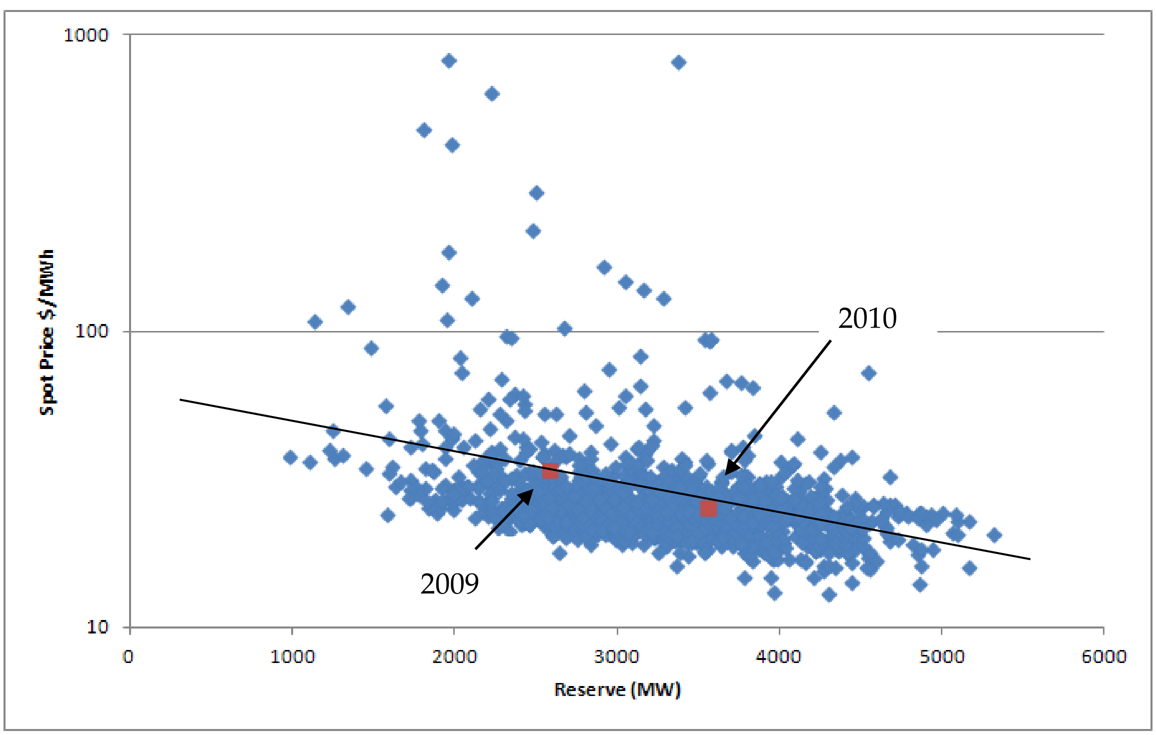

Figure 2: Price and Reserve diagram. Vertical axis is daily spot price on logarithmic scale; horizontal axis is daily Reserve in MW. A line of fit provides a guide to the effect of

withdrawing generation or adding demand. The average reserve and price over calendar years 2009 and 2010 in the state of Queensland is shown.

The electricity spot price is reset each half-hour and exhibits a highly volatile nature, with price spikes to the market price cap of around $13,000/MWh and occasionally to the price floor of -$1,000/MWh. The prices of financial derivatives (written on the electricity spot price) are more stable and demonstrate a trajectory similar to a geometric Brownian motion [16].

LGC Market: The demand for LGCs is enshrined in legislation. Each year, the regulator specifies a Renewable Power Percentage (RPP), and electricity retailers become liable to surrender a number of certificates calculated by multiplying their customers' energy consumption by the RPP. The percentage is specified in the Renewable Energy Target legislation.

Projecting into the future, the level of renewable generation investment in 2013 indicated that there was likely to be a significant shortfall of supply to meet the regulated demand. It may be argued that a continued delay in investment may lead to LGC prices rising to their regulated cap of around $93/certificate. The figure below shows the projected supply and demand, compiled by the electricity market operator, AEMO at the time.

In the period since the 2013 workshop, actual LGC prices have risen dramatically from around $30/certificate to around $80/certificate [22].

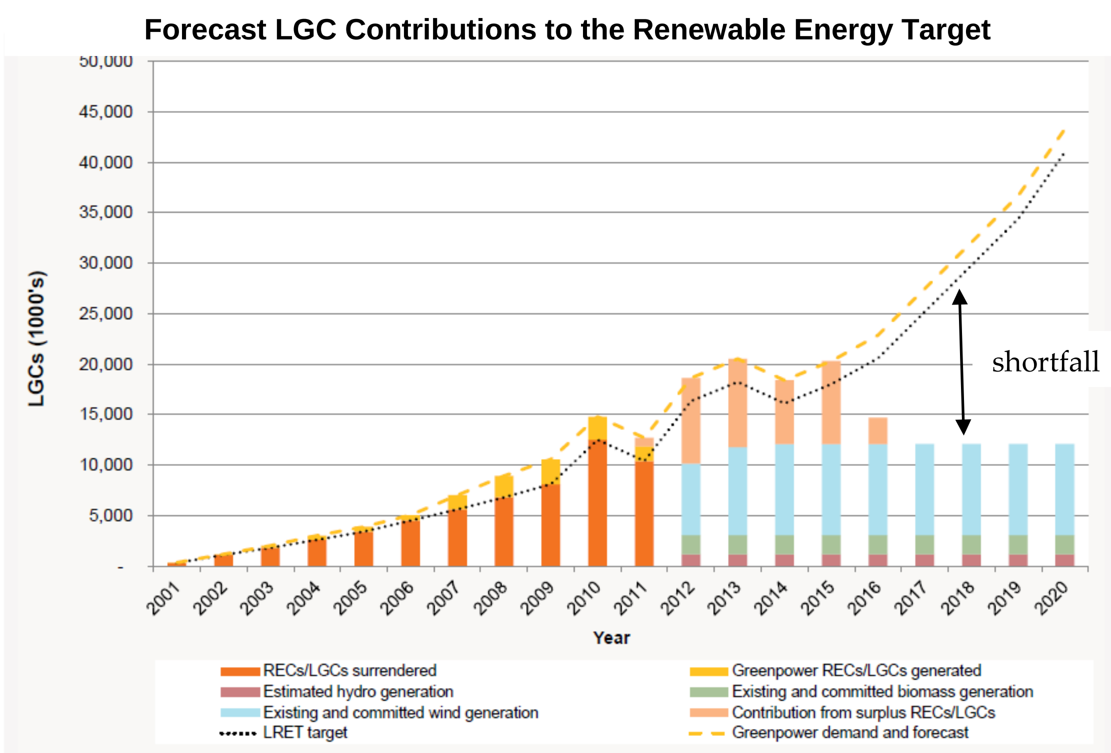

Figure 3: Projection of LGC creations (supply) and liabilities (demand). Taken from AEMO publication [6]

Gas Market: The gas industry in Queensland has undergone enormous structural changes in the past decade, beginning with a small conventional natural gas supply in the South-West to emerge with an expansive resource of coal-seam gas. In 2013, the resources were touted for export under contract via LNG conversion, with compression and export facilities under construction in Gladstone, Queensland. The economics of supply and demand in the gas market are intriguing. Over the period (2008-2014) fields were prepared by drilling numerous wells, which then released coal-seam gas. LNG export was anticipated to commence from 2015, and in the mean time, oversupply of gas provided a cheap fuel input to Gas Fired Generation, which represents the only flexible off-taker of the gas. However, as LNG exports commenced, strains emerged on domestic gas balances with producers' contractual obligations to deliver gas for LNG export. Consequently, the domestic price for gas suffered large rises even beyond the parity price for international energy. Figure 4 illustrates the projected volumes of gas used in industry and generation compared to the commitments for LNG export as they were understood in 2013.

Through bilateral channels, which dominate the gas market, no regulated price structure exists. In the STTM and DWGM there are regulated price floors and caps which correspond roughly to the price cap and floor of electricity, at the conversion rate of MWh of electricity generated per GJ of gas fuel consumed.

Since the period of the workshop, electricity prices in 2015 and 2016 in Queensland have exhibited much higher levels, with commentators attributing the price lift to the reduced access of gas fired generators to fuel, which is being reserved for LNG export.

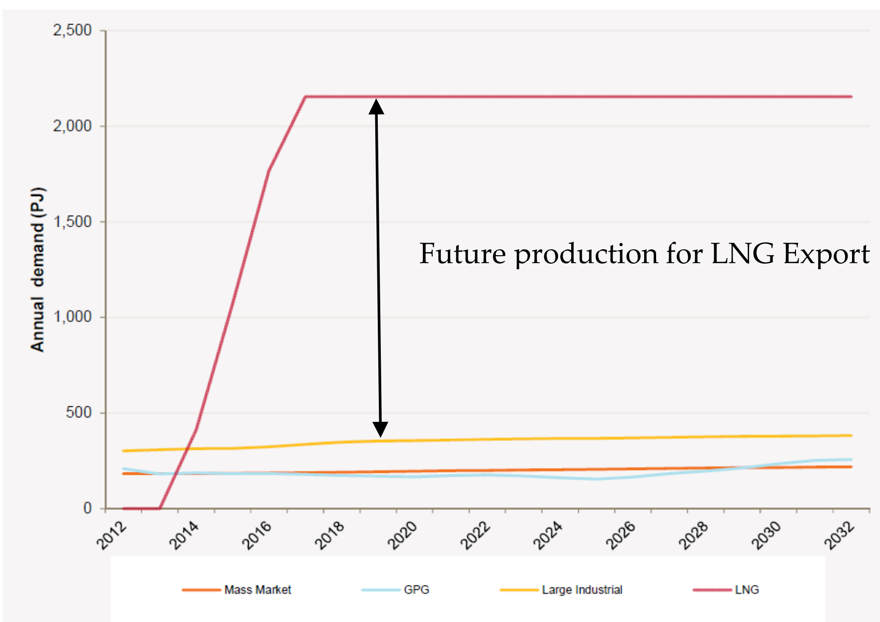

Figure 4: Projection of Natural gas consumption. Taken from AEMO publication [7] comparing *Mass Market* (domestic consumption) *GPG* (gas powered generation for electricity), *Large Industrial* consumption and *LNG* (liquefied natural gas for export).

2.3 Hedging Business Operations

The simulation in the workshop allocated portfolios to teams and conducted case studies on the management of those portfolios. At their core, the portfolios were electricity generation and retailing businesses, but consistent with Figure 1, there are significant exposures to other commodities to manage.

To successfully operate in the integrated energy market, businesses need to manage their 360 degree exposures, that is, input resource costs and revenue volatility.

Both retailers and generators are subject to the high price volatility exhibited by the NEM spot price for electricity, as well as the exposures to price fluctuations of the other inputs and outputs.

Figure 5 illustrates the price exposures and business operations required of a generation and retailing portfolio.

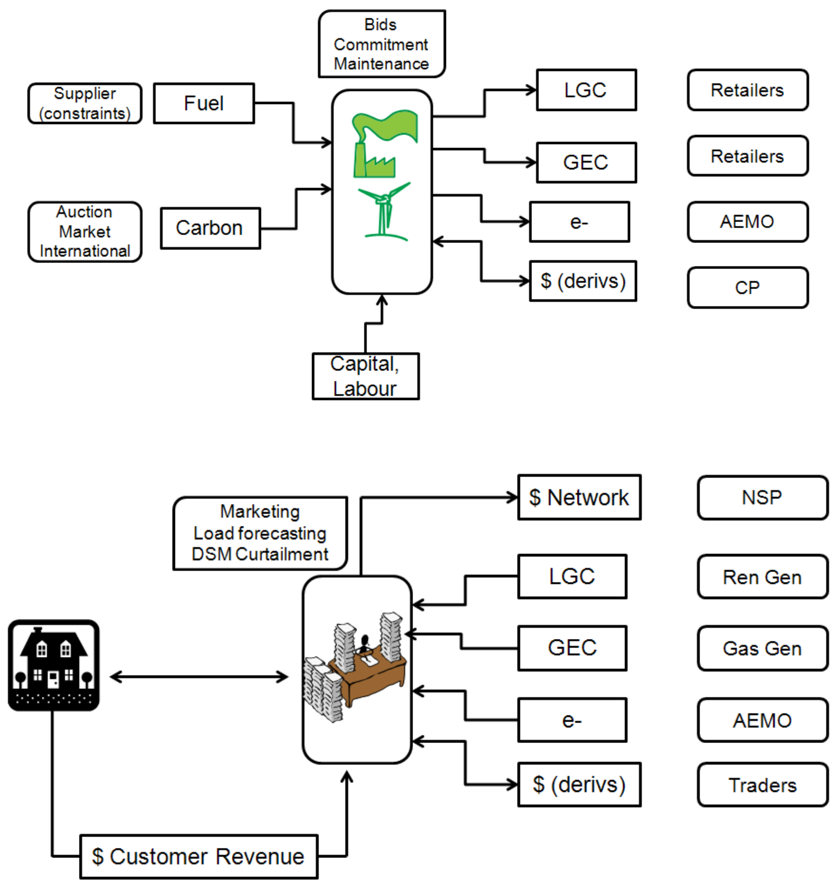

Figure 5: TOP: Economics of a generator portfolio; BOTTOM a retailing portfolio.

Generator with exposure to LGC (seller), GEC (seller), electricity (seller) and cash settled derivative instruments, as well as fuel price and carbon price volatility (buyer).

Retailer with exposure to network costs through the NSP Network Service Provider (buyer), LGC (buyer), GEC (buyer), electricity (buyer) and cash settled derivative instruments. Customer prices are established at regulated levels or at prices designed to cover the volatile costs.

Apart from simply investing in a business, there is significant effort on trading and operational management in the power sector. The activities include:

- Establishing optimal preventative maintenance expenditure at power stations [10] (generator)
- Negotiating fuel and resource contracts (generator)
- Operating (committing and bidding) the power station to fit with the fuel constraints [11] (generator)
- Forecasting customer consumption [8] (retailer)
- Establishing optimal expenditure to market for new customers [12] (retailer)
- Executing forward contracts to hedge the price exposure of LGCs, GECs and electricity produced by the plant or incurred as liabilities [19] (generator and retailer).

A retailing business is subject to exposures at the electricity spot price, as well as fluctuations of its load. Retailing businesses buy electricity derivative contracts in the form of swap or cap contracts [2] to protect against price excursions. But wholesale derivative contracts are available only in standard forms: base (all periods) and peak (working days from 7am to 10pm). The objective of a retailing business is to establish an appropriate level of contracts to perform a good job at financial hedging. That is:

- Determine the right mix of peak and baseload contracts;
- Determine the right mix of swap and cap instruments.

By hedging at levels too low (respectively too high), the portfolio will still suffer a short (resp. long) exposure to spot prices. The art is to establish a position where the 'unders-and-overs' of load and contract levels cancel each other [17]. Figure 6 shows a typical week of consumption patterns (blue) overlaid with a contract portfolio of flat swaps, peak swaps and peak caps to achieve a hedge cover.

Figure 6 also shows the electricity spot price (green) demonstrating how periods of high demand (presumably a hot day) coincides with high spot prices. Without appropriate hedging, the retailer is at risk of the 'double whammy' of high spot prices as well as an elevated customer load. While this figure shows some small fluctuations in the customer load, a typical mass market load may rise by 150% on an extreme weather day.

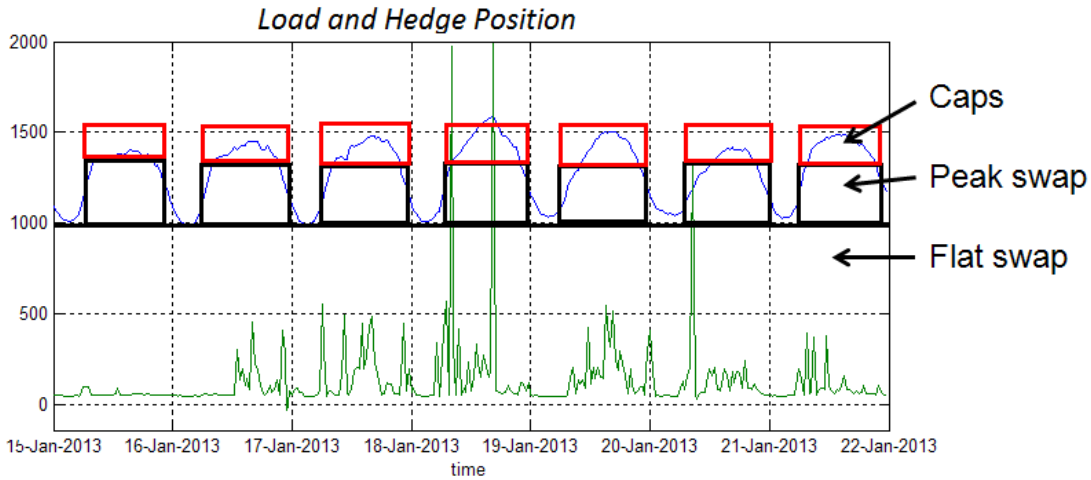

Figure 6: The hedging problem faced by retailers. For a forecast load, what is the right combination of base and peak, swaps and caps to cover the position? Load in blue, swap positions in black, cap positions in red, spot price for power in green.

The decision on expenditure for preventative maintenance at a generator avails its operator a control to target a higher or lower level of reliability. The nature of electricity spot prices mean that extended periods are spent at moderate price levels and significant value is contained in relatively few very high price events.

Figure 7 illustrates a price duration curve for the Queensland electricity price over the historical year 2011 (a representation of the cumulative probability density of halfhourly electricity spot prices). Also shown is a constant price of $22/MWh, which is typical of the short-run marginal cost (SRMC) of a baseload power station, and $38/MWh which is typical of the long-run marginal cost (LRMC, which includes the capital cost of the power station) [1] in 2013.

The figure shows that 17% of the year is spent below the station's SRMC, and 91% spent below the LRMC. The annual price average is $35/MWh, yielding a gross margin of around $13/MWh. In the top 1% of the year, the value is around $7.50. In other words, if a power station is unreliable and due to mechanical failure misses the 1% of the year when top prices arise, the gross margin will dramatically fall from $13/MWh to $6.50/MWh.

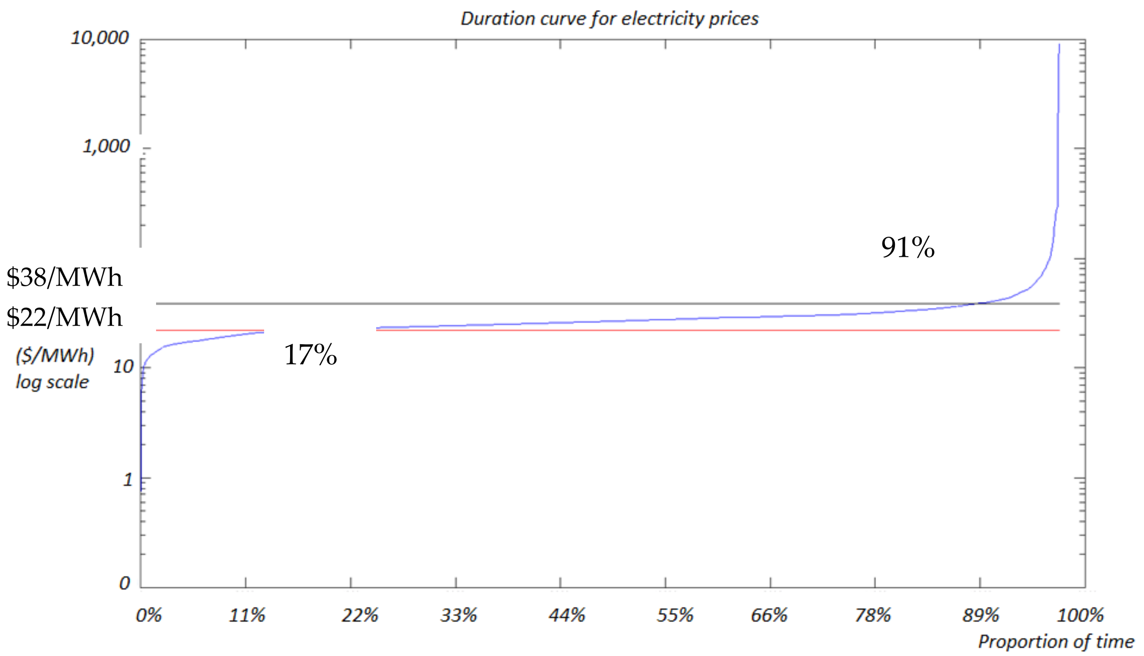

Figure 7: Duration curve for electricity over year 2011, with power station cost points.

An increased expenditure on maintenance may be successful at preventing unplanned outages, and assist the power station to capture the revenue during high prices. On the other hand, excessive maintenance expenditure cuts directly into profitability. The operational action to balance these opposing effects is part of the portfolio management problem.

2.4 Market Interrelationships

Fuel and carbon provide the two primary variable input costs to power generation. Generators consider these inputs in the formulation of their supply curve. Consequently, the electricity spot and forward prices are strongly influenced by market prices for fuel and carbon.

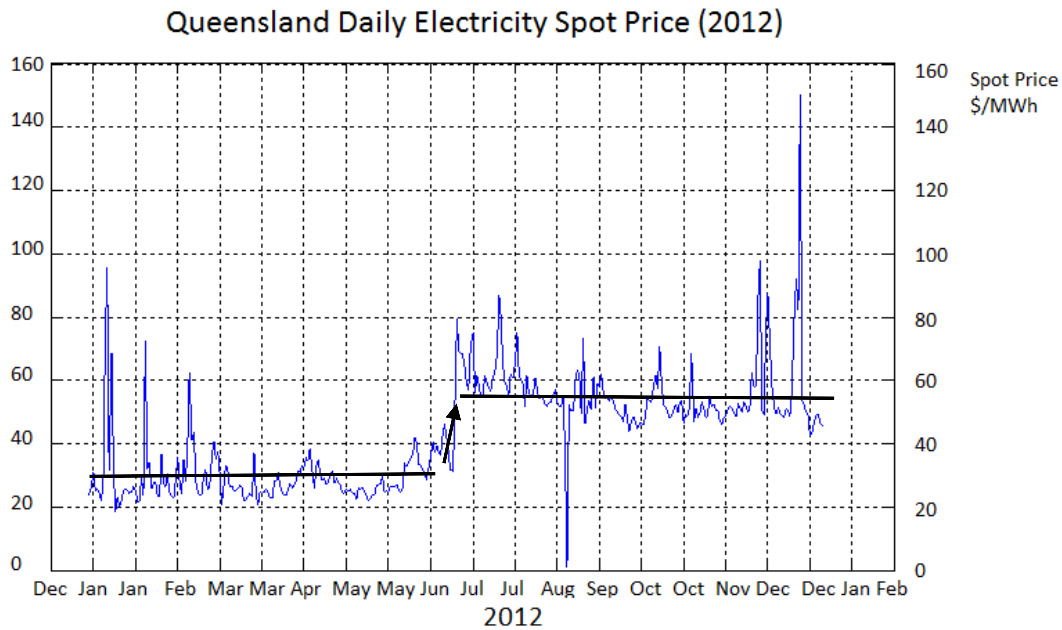

Figure 8: Daily electricity spot prices over Calendar 2012. The price step at mid-year relates to the introduction of the Carbon Tax, which incurred around $20/MWh additional cost of generation on the generator fleet.

Upon the introduction of the Carbon Tax [5], coal fired generators incurred an impost at their carbon intensity (around 1.0 tCO2 per MWh produced), but gas fired generation, with a much lower intensity of 0.3 to 0.6 tCO2 per MWh became more competitive. This shift introduced elevated demand for gas, which contributed to a rise in gas prices. The figure below shows the daily gas price over 2012 on the Queensland gas STTM exhibiting a step change in July 2012.

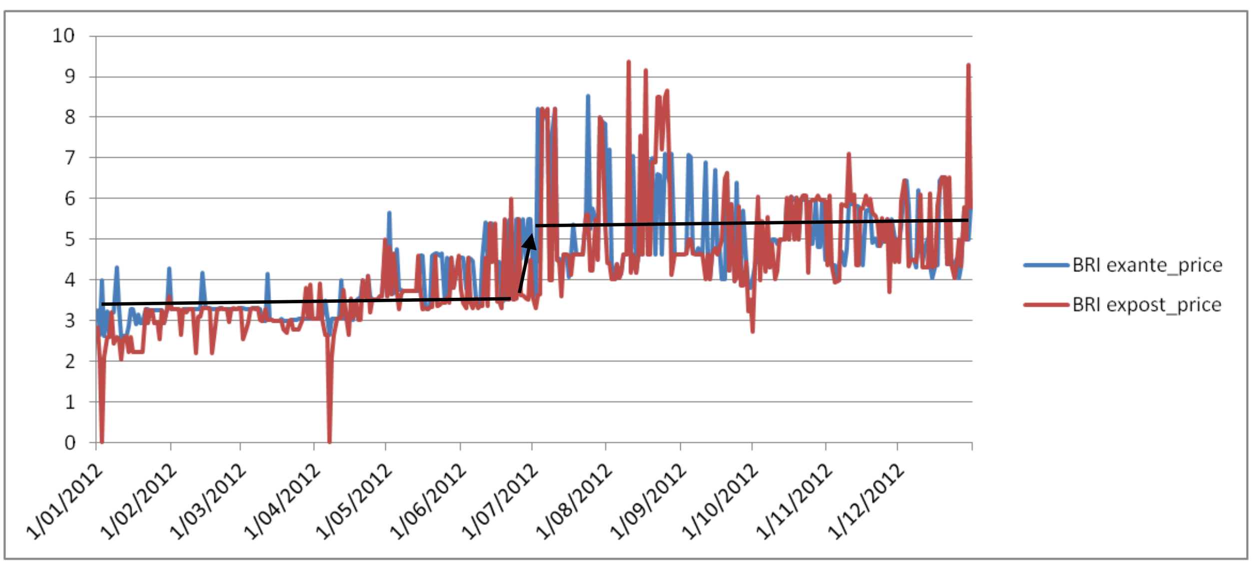

Figure 9: Daily Brisbane STTM gas spot prices ($/GJ) over Calendar 2012. The price step at mid-year relates to the introduction of the Carbon Tax.

Renewable generators receive revenue from two distinct sources: (i) electricity and (ii) LGC sales. The economics of a wind farm investment combine these two sources. Using familiar economic arguments on supply and demand curves, a dearth of renewable generation is likely to lead to an increase in the LGC price. Consequently, we may find that renewable investment can proceed with less reliance on the electricity price. According to these investment arguments, the LGC price has the potential to suppress electricity prices as LGC price reaches elevated levels. In the period leading up to 2013, the LGC price remained well away from its price cap.

3 Structure of the Simulation Workshop

3.1 How it worked

The workshop was structured as a simulation activity where participants operated in teams to make virtual operational and investment decisions for assigned portfolios.

The flow through the game is described by the sessions below:

Session 1: Discussion of the theory: market structures, regulatory frameworks, supply-demand relationships and the interdependencies of the commodities.

Session 2: Introduction to the structural model: walkthroughs of how various input parameters affected the financial outcomes of a portfolio.

Session 3: Introduction of the portfolios for each team. Discussions on the consequences of holding particular assets and contracts, and typical operating profiles.

Session 4: Introduction of a market scenario for a future three-year period: illustration of the current supply, trends in prices and an overview of the economic, market, regulatory and political environment.

Session 5: An extended opportunity for teams to conduct experiments with the model, develop a view on market outcomes, formulate strategy and decide upon a contracting and operating position.

Session 6: Presentation and justification of each teams' strategy decisions by each team's nominated spokesperson.

Session 7: Revelation of the actual market outcomes and assessment of the financial performance of each portfolio. Group discussion reflecting on consistency of the outcomes from messages in the market scenario. Discussions on performance of the strategies at achieving investment objectives.

3.2 Team Portfolios

Teams were allocated portfolios with different attributes and objectives.

Team 1: A dedicated baseload generation portfolio.

Assets and Loads: The team inherited a dedicated generation portfolio. This portfolio was constructed from a baseload power station and identified against an actual generating power station in the NEM. The portfolio contained no consumer loads.

Agreements: The power station was endowed with a complex coal supply agreement, which is consistent with real-world commercial arrangements. Fuel was supplied in tranches at increasing prices as the fuel consumption increased, which in essence represents a cost for contract flexibility

Board directives: The board specified a conservative approach to portfolio management. The imperative was reinforced by the financing nature of the portfolio: if the overall position was negative in any year, then the corporation would suffer foreclosure by its financiers (end of the game for its players).

Team 2: A retail-focused vertically integrated portfolio.

Assets and Loads: The portfolio was endowed with a peaking power station of 280 MW capacity whose attributes were identified against the attributes of an existing power station in the NEM. The portfolio contained a large consumer load peaking at around 1,000MW, and was structured on one of the regional load profiles published by AEMO.

Agreements: The power station was assigned a fuel contract allowing completely flexible consumption at a high price of $10/GJ.

Board Directives: The board dictated a strong drive for profitability with an incentive of profit sharing with the management team, that is, risk taking was encouraged.

Team 3: A generation focused vertically integrated portfolio.

Assets and Loads: The portfolio contained a baseload power station of around 750 MW and a wind farm of around 100 MW. The business also operated a retail portfolio with peak consumption of around 200 MW and consumption patterns based on an actual market regional load profile published by AEMO.

Agreements: Power stations were assigned stable, low cost fuel contracts.

Board Directives: An objective for business growth was declared by the board.

3.3 Decision Support Model

Each team was supplied with a decision support spreadsheet which enabled them to conduct experiments, review the relationships with market commodities and to refine their strategies.

The overall objective of the spreadsheet was to determine the financial outcome from holding a portfolio of power stations, loads and contracts under various market outcomes. The type of model is classified as a *structural* model, as it aims to replicate the characteristics of the portfolio and market at a detailed level. Consequently, the extent of the spreadsheet was large and contained considerable pre-programmed data.

Participants were able to modify the parameters of generic power stations to suit their particular portfolio. They were also able to select alternative price simulations to establish the financial performance of the portfolio under different market outcomes.

The tables below list the attributes of each of the portfolio elements, and summarise the detailed modeling conducted 'under the hood'.

Power station attributes and input resource agreements:

Attributes	**Effect**
Marginal Loss Factor (MLF)	A measure of losses incurred in the power station dispatch, which reduces payments from AEMO for the energy produced.
Fuel cost	The cost per GJ of fuel, either gas or coal in an agreement with a supplier. Stations were endowed with contracts of different complexity: some were a flat rate, while others contained fuel priced in tranches.
LGC eligibility	A regulatory factor based on the station technology. The number of LGC (certificates) produced for each MWh generated: typically 0% for fossil fuel stations and 100% for renewable.
GEC eligibility	A regulatory factor based on the station technology and state of installation. The number of GEC (certificates) produced for each MWh generated. Typically near 100% only for gas fired generators
Auxiliary consumption (AUX)	The proportion of energy produced by the station which is imported to run electrical facilities
Restart cost	The cost for each restart of the power station: typically small for gas peakers and very large for baseload generators.
Heat Rate	The thermal efficiency for the power station, converting GJ of fuel to MWh of electricity.
Carbon Intensity	The carbon emissions in tCO2 per GJ of fuel consumed
Water consumption rate	The rate in megalitres of water consumed per MWh of electricity produced.
Variable operating cost	The cost in $/MWh for operating a station, apart from the identified input resources
Capital cost	The capital expense of the power station; typically initial cost of installation and interest repayments.

Power station operating controls:

Controls	**Effect**
Maintenance Spend Level ($/MWh)	The maintenance spend determines the forced outage rate, which yields a level of randomized outages in the simulation. Spending more improves the modeled power station reliability. A diminishing returns model was applied so that continued expenditure led to diminishing reliability improvements.
Bids	Power stations are offered into the market by specifying a bid structure of volume offered at a price: in essence an economic supply curve.
Commitment	An operator can decide to withdraw a generating unit from service altogether (mothballing) because (a) it is not a profitable generator or (b) a strategy to support the market price can be entertained.

Portfolio derivatives:

Derivative	**Description**
A whole of meter contract for electricity	The buyer of the contract pays a fixed rate in $/MWh for all electricity produced by the nominated power station.
A firm swap contract for electricity (flat or peak)	A settlement arises for a bought contract of V MW according to the formula: $H \times V \times (P - K)$ Where H is the (peak or flat) hours in the year; V is the volume in MW, P is the average (peak or flat) pool price and K is the contract strike price.
A firm cap contract for electricity (flat or peak)	A settlement arises for a bought contract of V MW according to the formula: $H \times V \times max(0,P - 300)$ Where H is the (peak or flat) hours in the year; V is the volume in MW, P is the average (peak or flat) pool price and K is the contract strike price.
A whole of meter contract for LGC	The buyer of the contract pays a fixed rate in $/cert for all LGC produced by the nominated power station.
A firm forward contract for LGC	The buyer of the contract pays a fixed rate for a nominated number of LGC and the station is left with residual LGC or must purchase from the spot market to make up the difference.

Customer Load Attributes:

Attributes	**Effect**
Consumption volume	The MWh at the node of customer energy consumption
LGC liability rate (RPP)	The LGC liability is calculated by a percentage (tabulated in CER regulations) of the energy consumed
STC liability rate (STP)	The STC liability is calculated by a percentage (tabulated in CER regulations)of the energy consumed
GEC liability rate	The GEC liability is calculated by a percentage (tabulated in QGS regulations) of the energy consumed

Customer Load Controls:

Controls	**Effect**
Marketing Spend Level ($/year)	By making additional marketing expenditure, the business managers were able to capture a higher percentage of load. The structure was formulated with diminishing returns so that progressively more spend was required to continue the customer growth.

Formulating an efficient bidding profile for the power station is a nontrivial exercise.

- All power stations incur a cost on restart of the plant, with some technologies extremely expensive. If the bid is structured in a way that interacts with the spot price to incur frequent switching, then a large cost may be incurred in the restart cost category.
- The price bands for the bid must be carefully considered around the marginal cost of the generator, including fuel, carbon, water and maintenance costs. If the power station is offered to the market at a bid price below cost, then every MWh dispatched yields a loss to the corporation rather than profit.
- A fuel cost structure which is nonlinear (tranches of fuel) does not have a clear short run marginal cost, and analysis or experiment is required to structure a bid so that additional fuel penalties are avoided later in the year when the 'cheap' fuel has been exhausted.

All of the station attributes can be passed through simple calculations to establish the short run marginal cost of a power station:

$$\begin{aligned}\textit{Gross Margin} &= \textit{MLF} \times (1\text{-}\textit{AUX}) \times \textit{Pool Price} \\ &\quad - \textit{Heat Rate} \times \textit{Fuel Price} - \textit{Carbon Intensity} \times \textit{Carbon Price}\end{aligned}$$

– Variable Operating Cost – Restart Cost

Power stations bid at the market floor to ensure that their minimum load is dispatched, and then the SRMC becomes a price point at which is becomes profitable to offer additional volume to the market.

Financial Outcome

The financial outcome for a portfolio with Generation, Load and Derivatives is then compiled from

Profit/Loss

= Generation Pool Revenue + Generation LGC Revenue + Generation GEC Revenue

– Generation Carbon Costs – Generation Fuel Costs – Generation Maintenance Costs

– Generation Variable Operating Costs – Generation Start Costs – Generation Capital Costs

+ Derivative Settlements

+ Load Revenue – Load LGC Costs – Load STC Costs – Load GEC Costs – Load Marketing Costs – Load Pool Costs

Model Illustration

Figure 10 illustrates how the decision supporting spreadsheet was compiled to enable users to experiment. The spreadsheet contained a 10-year history of spot price and load and wind outcomes. A user selected a particular historical year, and then the analysis of a future year was based on the market outcomes from the historical period. A randomized forced outage model was employed for power station unreliability using a Markov chain model [18].

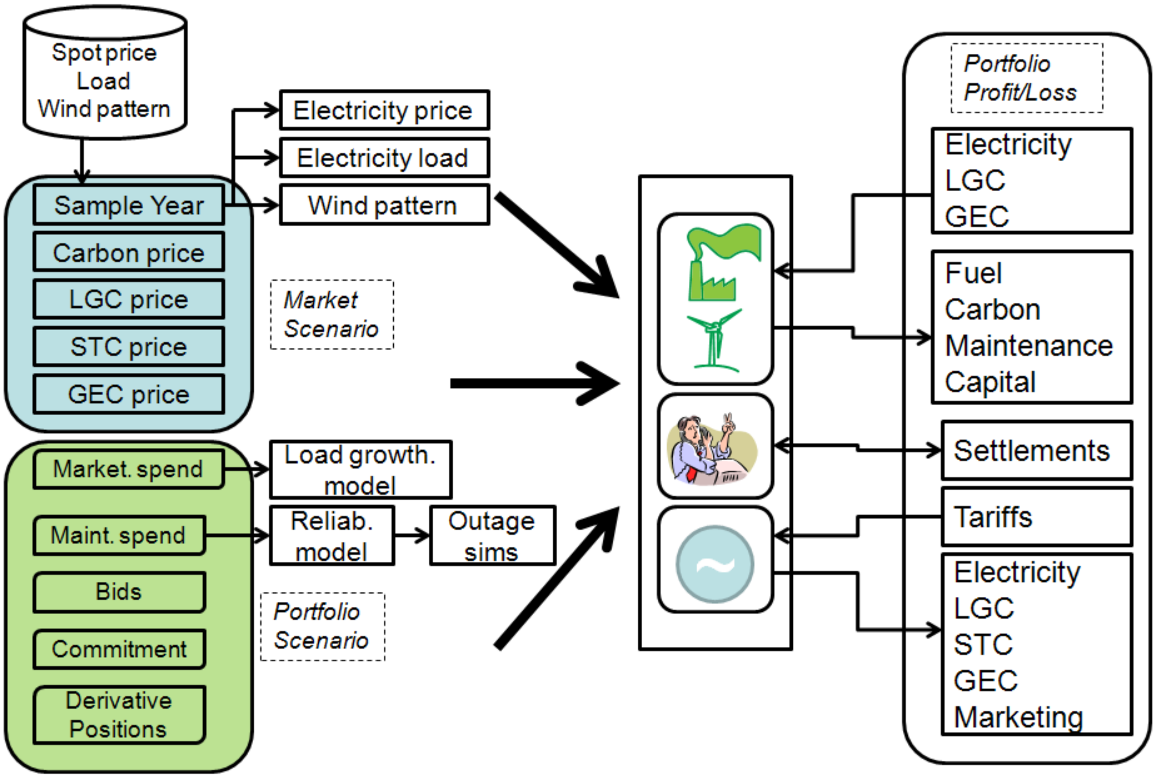

Figure 10: Decision support model flows

Users enter their projected carbon certificate price, LGC price, STC price and GEC price. Users also enter an historical year, and the spreadsheet extracts historical data, makes a transformation to account for carbon and inserts that price as the forecast for a future period. A control also provides a *stress test* for the model, where the price can be scaled proportion up or down. From the same year, the load time series and wind patterns are extracted. Altogether, this yields the market scenario.

Users also make decisions (see section 2.3) on operating and investing in their portfolio, which include:

- Bid profiles for power stations
- Levels of maintenance spend for power stations
- Levels of marketing spend for customer loads
- The decision about which generators to commit to market
- The derivative portfolio, including electricity swap and cap contracts and contracts to fix the price of LGC and Carbon.

All of these parameters are submitted to the structural model, which simulates the dispatch of the power station, and then calculates the component cashflows illustrated in the right panel of Figure 10.

The aggregate of all cashflows yields a single number representing the Profit/Loss of the business.

It then becomes an easy activity for a workshop participant to experiment:

- *What happens if I apply alternative of historical years?* This was a task of the team's 'Risk Manager' to ensure that all range of low and high market prices were covered.
- *What happens if the derivative position is set at progressively higher levels?* The team's 'Strategy Manager' gains insight into how the profitability and risk level changes.
- *What happens as the bid profiles are adjusted?* The team's 'Power Station Trader' can see the cashflow line item representing the cost for restarts, and as the bids change this number can vary dramatically.
- *What happens as the maintenance spend is adjusted?* By increasing the spend dramatically, the team's 'Power Station Manager' observes the profitability decline. However, with a low spend, by resimulating the forced outages the variability of profit becomes apparent.

3.4 Participant Decisions Processes

The decision-making process for the participants typically followed the decision stages described here.

1. Identification of the nature of supply and demand attributes in each market from the market scenario:

   The host provided information on the market environment, including the current levels of power station investment, coal prices, renewable energy target, regulatory environment, status of gas field development and customer load growth trends. From the qualitative and quantitative descriptions, users identified the levels of supply/demand imbalance to establish if there were upward or downward price pressures of each of the market commodities.

2. Electricity year identification:

   With these attributes, the year is expected to 'look like' a particular historical year. If the price level is predicted to be higher, then there was a scaling factor to shift up or down the prices.

3. Power station operations:

   The bid structures could be refined and estimated margins from the power stations ascertained. Pushing too much electricity into the market led to generating during unprofitable times, while offering supply only at excessively high prices meant missing out on profitable opportunities. Bids which led to excessive restarts also cut into the bottom line. The level of maintenance spend was experimented to deliver a 'sweet spot' between reliability and cost, and was refined consistent with the investment objectives of the board directives. A process of intelligent trial-and-error was applied using the calculated cost structures to set bids.

While bids were refined on a base-year, the teams stress-tested the power stations by using the same bidding profiles on price outcomes from different historical years.

4. Contracting

Derivative contracts were overlaid on the portfolio and different historical years of market outcomes were run to determine how much variability resided in the portfolio profitability. Contracting at a sweet spot (a minimum risk level) was found to insulate much of the bottom line from spot price exposures. However, several of the teams' boards required that portfolios retained an exposure with the objective to enhanced returns by taking a position of risk. Each team was able to bias the portfolio to positive returns by making intelligent deductions from the market scenario. For example, a deficiency in LGC production was likely to lead to elevated prices, and therefore for a wind generator it was more profitable (although more risky) to not hedge the certificates through forward contracts.

3.5 Example of Decisions Support

We provide an example of some of the assertions, experiments and deductions that were conducted by one of the groups using the decision support spreadsheet. The observations relate to Team 1 (see section 3.2).

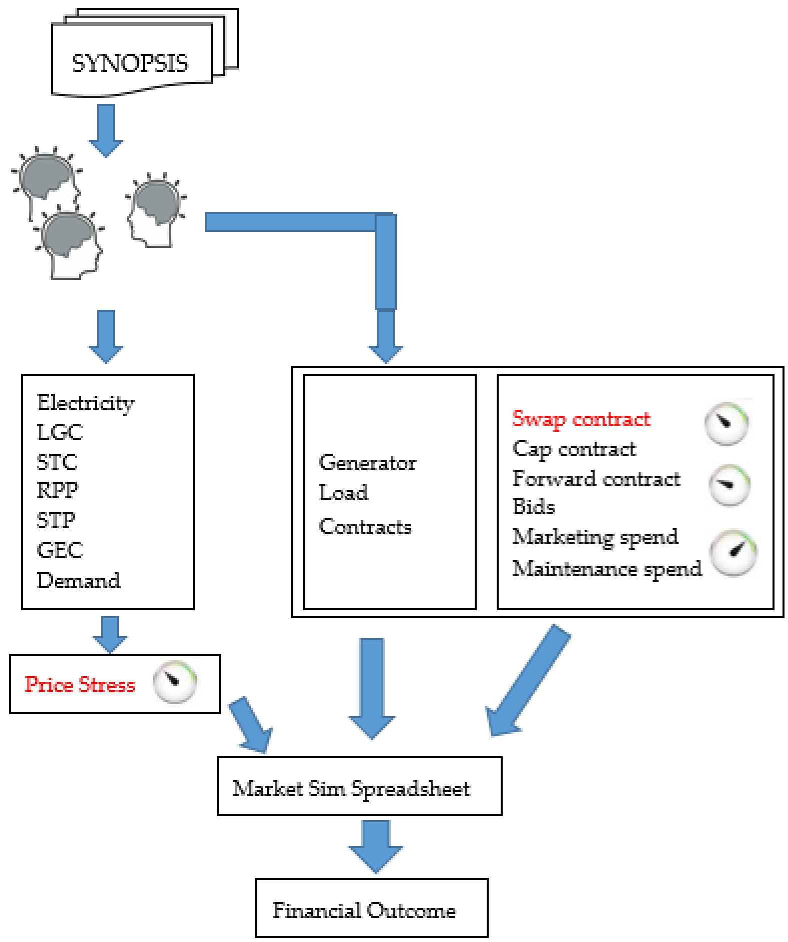

Figure 11: Processing flow used by team 1 to make supported decisions.

The synopsis contained a printed summary of future market and regulatory conditions. From this synopsis, the team established the likely levels of electricity demand, the RPP and STP. They determined an historical year with a similar demand and supply profile in order to establish a reference year for the electricity prices.

Next, the team made some decisions for the portfolio (controls are depicted with dials in Figure 11). For one of the initial experiments, the team deduced relationships between Financial Outcome, Electricity Prices and Swap Contract Level.

The team deduced that the possible electricity price outcomes might be much lower or higher than the baseline prediction (a range spanning 50% to 250% of predictions). Intuitively, a 1000 MW power station is best hedged with a 1000 MW swap contract. The team established what the financial outcomes looked like under an array of potential swap positions (say 0 MW, 500 MW and 1000 MW). The team then ran *price* and *hedge volume* scenarios through the model to establish a relationship diagram like Figure 12. We note that the decision support system provided only one outcome at a time, and the mission to interpret the results and generate graphs like Figure 12 was all instigated within the team.

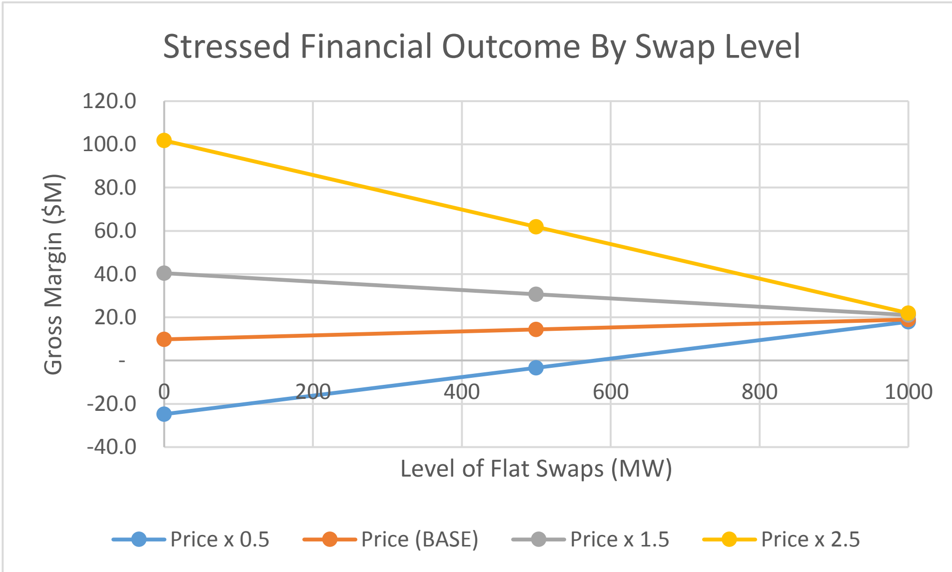

Figure 12: Relationships between financial outcome (gross margin) swap level and price multipliers.

The team deduced that under circumstances of very low price outcomes, then if the swap hedging level fell below 600 MW then the portfolio was at risk of negative outcomes, in contradiction to the board's directive. Consequently this informed the selection of contract level and the team moved on to consider the next relationship.

Similar experiments were conducted to establish relationships with other variables and other strategies. Where the team wanted to really understand what was driving the financial outcomes, we discovered that the individuals traced the formulas to understand the model (and hence market dynamics) better.

3.6 Participant Decisions and Responses

The results of the interactive component of the workshop yielded very positive results, achieving the learning objectives to appreciate the complexity of operating in the integrated energy market.

Firstly, despite the complexity of the market environment, of the portfolio attributes and the spreadsheet model which analysed the financials, each team successfully negotiated portfolio analysis to arrive at good investment and operational decisions.

On reflection, one positive design of the simulation workshop was that only one computer was allocated to a team of five persons, and this enabled the different strengths and experience of individuals to be applied in the best way. Some persons were modeling experts and suited to operating the model, while others were strategic thinkers, and others held some industry knowledge and understanding of hedging.

Secondly, the teams arrived at portfolios which were consistent with their boards' objectives The risk averse generator portfolio arrived at a position which was not highly hedged, but under none of the historical years did it turn a negative outcome. The eventual result was close with a profit margin of only around $10M off of a revenue level of around $400M.

The portfolios targeting a more aggressive profit target indeed found methods to do so and achieved significant profits. One of the most impressive results arose in one of the teams where participants observed that the relationship between the flat cap and the peak cap contract prices contained a small inconsistency (which also appears in the electricity derivative market from time to time). By selling peak cap contracts and buying flat cap contracts, the historical years demonstrated a consistent pattern of profitability. The simulated business instituted the speculative trades and contributed significantly to a higher profit.

Development of bid profiles proceeded on an experimental basis. The genesis of each teams' bid profiles was on the basis of a notional SRMC. However, the restart costs arising from the number of starts, and the stepped tranches of fuel led to final bid profiles refined slightly from the original input.

Thirdly, the use of the Excel models revealed the high degree of modeling literacy in the workshop participants. The spreadsheets were delivered in a form permitting full access to formulas and the 'under-the-hood' model calculations. We observed that participants actually opened up the formulas and plotted intermediate results as a device to learn about the content. In other words, rather than teaching the theory and using the model as an illustration, participants opened up the model to understand the theory. That outcome was not expected.

A final reflection relates to timing in the workshop's experimental stage. The reader probably appreciates the vast breadth of content conveyed in the workshop, and it is fortunate that we delivered the content to participants who already had an industry background. Participants were assigned a period of around 1.5 hours to conduct the model experiments and arrive at their final decisions on contract positions and operational profiles. This is longer than originally planned, however, the extended periods allowed participants a solid feel for the model, greater opportunities to probe alternative market and portfolio scenarios, and enabled the participants to land on excellent investment and operational decisions. In hindsight, the notion of providing opportunities for reflection and consolidation were certainly rewarded with a positive workshop outcome.

3.7 Participant Feedback

Participants were surveyed using a generic instrument regarding the effectiveness of the workshop to meeting their needs and relevance for their roles in the sector. There were 13 participants and 6 respondents. The survey consistent of quantitative satisfaction responses and free-form feedback. Two key findings are that (i) appreciation of the content resonated when it could be directly tied to individuals day-to-day work and (ii) the active learning experience was positive in reinforcing the key messages and negotiating a complex environment, delivering more benefits than the lecture-style presentation of theory and the post-simulation discussions.

How do you find the topics presented at the training relevant to your work and why? Please provide examples.

- This was an excellent training course with particular relevance to the majority of work that I do in the Gas and Markets Team. The training course was a great way to build on the knowledge I have had to acquire on an ad hoc basis. The course was particularly helpful in building my understanding of what is taken into consideration when a generator places their bid and rebid and how they manage their risk and return.
- Bidding behaviour discussion, relevant to potential modelling inputs. Contract behaviour discussion, relevant to understanding key drivers of plant behaviour for both Vertically Integrated and Merchant Generators.
- Modelling is very relevant in my quantitative analyst position.
- Very relevant if I do any [Government Department] related work, otherwise just beneficial for keeping my knowledge of the electricity market up-to-date.
- Highly relevant to day to day work.
- The training provides insight into how different components relate within the industry.

Which part of the training you most enjoy and why?

- The Scenario
- The hands on practical side, as I felt some of the market background was already known. Also the hands on stuff was a good opportunity to consolidate understanding.
- Gaming / modelling against real world data.
- The Game Round. Beneficial to apply the theory to a practical situation.
- The exercise.
- The activity.

Which part of the training you least enjoy and why?

- No Part.
- Market background, as I felt I already knew most of it. Although I understand this may not have been the case for all present.
- Theory is a little heavy, but nonetheless relevant and interesting.
- Enjoyed it all.
- Nil.
- The speed of the course, perhaps 2 days would allow slower coverage of the material.

4 Conclusions

By reviewing the various constituent parts of the integrated energy market, a dependency map shows the complex relationships between fuel, environmental and power markets, domestic and international gas markets and Carbon linkages.

A simulation of the investment, trading and operating decisions reinforced that businesses operate within an environment requiring 360 degree analysis of exposures on both input and output commodities.

A professional development workshop has been developed which successfully conveyed the relationships between market exposures by simulating virtual businesses with exposures to multiple markets.

Participant feedback showed that significant benefits were achieved and learning outcomes reinforced by engaging in an active learning approach through a game-based learning framework. The use of a decision support software suite which resembled commercial risk management and modeling software enabled students to appreciate market relationships, to develop and test strategies and to manage financial risk. Participants were observed to analyse market relationships by delving into the underling operations of the decision support model.

The use of peer support by conducting team based learning enabled participants to leverage on the strengths of individuals in modeling, market and risk management expertise. Participants shared insights within the team as the game proceeded and across all teams in the valuable reflections session at the conclusion of each round of the game.

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6 Glossary of Terms and Acronyms

AEMO: Australian Energy Market Operator, being the manager of electricity and gas markets in Australia operating as the physical system operator and financial clearing house

ASX: Australian Securities Exchange, being an exchange for trade of futures contracts on electricity and some environmental certificates.

AUX: The auxiliary consumption of electricity from a power station to enable its own operations. It is typically in the range 2%-5% for gas fired generators and 5%-10% for coal generators.

Baseload: A profile of electricity production or consumption which is consistent across all seasons and times-of-day.

Cap Contract: A financial derivative written on the electricity spot price delivering a payoff only during times when prices exceed $300/MWh. It has the ability to cap liabilities when held in conjunction with a load exposure to electricity.

Carbon Tax: The fixed cost of emissions governed through the CEF legislation

CEF: Australian Commonwealth legislation termed the Clean Energy Future Act which instituted a price on carbon dioxide emissions from Australian large industry and power generators.

CER: Clean Energy Regulator, being the entity responsible for Australia's carbon and renewable regulation

CO2: Carbon dioxide, being the underlying commodity of emissions abatement under the Clean Energy Future legislation and Kyoto framework.

DWGM: Declared Wholesale Gas Market being an interval market operated by AEMO for gas in Victoria

Flat: Synonymous with Baseload.

Forward Contract: A contractual arrangement to take position of a commodity at a future date at a price agreed now. This contract is the dominant transaction for hedging purchases and sales of environmental certificates.

GEC: Gas Electricity Certificate, being a tradable certificate affirming 1 MWh of gas-fired generation dispatched into the Queensland region of the NEM.

GJ: Gigajoule, being the typical unit of measurement for the energy content of fuel

LGC: Large scale Generation Certificate, being a tradable certificate affirming generation of 1 MWh from a large scale renewable generator such as a wind turbine.

LNG: Liquefied Natural Gas, being a compressed form of natural gas in a form suitable for bulk transport in specialized ships.

MLF: Marginal Loss Factor, being a numerical value assigned to generators and loads to represent the losses associated with transporting electricity to and from the Node respectively.

MW, MWh: Megawatts and Megawatt hours, being standard measures of electricity power and energy.

NEM: National Electricity Market, being Australia's physical electricity market spanning the East Coast.

Node: The electrical centroid of a region in the NEM, being a position at which generation or a load creates no additional losses to the grid. Placement at other locations in the grid means that transport losses are invoked and are quantified by the MLF.

NSP: Network Service Provider being an operator who on-charges the energy distribution costs to an electricity retailer to incorporate into their electricity charges to consumers.

Peak: A predefined period within the day during which elevated power consumption is observed in electricity markets. In the NEM it is defined as 7:00am to 10:00 on working week days.

Pool Price: The spot price for electricity in the physical market (NEM).

QGS: The Queensland Gas Scheme, being a State Government initiative to foster gas fired generation in Queensland

RPP: renewable power percentage, being the percentage in regulation pertaining to the number of LGC certificates which must be surrendered for each MWh of electrical consumption load.

Spot Price: The market price for a transacting a commodity with immediate delivery.

SRMC: Short Run Marginal Cost, being the variable costs of production for a power station which scale approximately linearly with levels of output. Excludes fixed costs including capital costs.

STC: Small Technology Certificate, being a tradable certificate relating to renewable generation arising from small scale renewable generation, such as rooftop solar installations.

STP: small technology percentage, being the percentage in regulation pertaining to the number of STC certificates which must be surrendered for each MWh of electrical consumption load.

STTM: Short Term Trading Market, being a daily market operated by AEMO for gas in Queensland, NSW and South Australia

Swap Contract: A financial derivative being a contract for difference written on the electricity spot price. It has the ability to act as a perfect hedge for a similarly profiled generation or load exposure to electricity.

tCO_2: Tonnes of CO_2, being the standard unit of measure for quantities of carbon emissions.