25 Year Optimal Generation Model

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Abstract

Synergy is expected to procure over 2000MW of electricity within the next 10 years to meet its expected future load. Additionally government policy requires at least 20% of the generation of electricity be produced from renewable sources by the year 2020. These and other constraints modify the selection of new generation facilities. The main objective of this project is to use the General Algebraic Modelling System (GAMS) to create a 25 year plan of electricity procurement options available to Synergy. GAMS is a high level modelling system used for mathematical programming and optimisation. This project involves modelling the cost of each option available to generate electricity at a minimum cost based on the uncertainty of future cost of various resources.

1. Introduction

Western Australia's electricity industry involves the North West Interconnected System (NWIS), Regional Power (RP) and the South West Interconnected System (SWIS). The focus of this project is on the SWIS. In 2006, the Western Power Corporation was disaggregated into four companies; Western Power as the network provider, Verve Energy as the generator, Synergy as the retailer and Horizon Power, the regional provider. The Independent Market Operator (IMO) has shown that the SWIS is experiencing strong electricity demand growth and forecasts household and industrial electricity demand to increase by about 4.5% and 3.4% per year respectively (Simshaunser, 2007). The main motivation for this project is to enable Synergy to produce a preferred procurement strategy for the next 25 years. This involves modelling the cost of each option available to generate electricity at a minimum cost based on the uncertainty of the future price of various resources; fuel, gas, technology advancements and changes in environmental requirements (in particular renewable resources and carbon).

1.1 CEED Client organisation

Synergy is WA's largest energy retailer participating in the Wholesale Electricity Market (WEM). Its Wholesale department is divided into five separate responsibilities: Power Procurement, Electricity, Gas, Carbon and Renewables. The project covers each of these responsibilities.

The WEM permits trading of electricity through three mechanisms – Bilateral Contracts, Short Term Energy Market (STEM) and Balancing Mechanism. Bilateral Contracts between Retailer and Generator for delivery of electricity into the long term are the mainstay agreements. Synergy therefore has a strong interest in the type of generator built and endeavours to model a solution set of generators in production over the long term.

1.2 Current State of the Electricity Market

Prior to the disaggregation, the Vesting Contract was formed between Verve Energy and Synergy to ensure adequate generation and supply is available in the SWIS. It contains a displacement mechanism requiring Synergy to expose the Vesting Contract volumes to competitive sourcing outside the Vesting contract.

As the retail corporation, Synergy is required to tender a certain amount of energy or capacity at a scheduled, orderly tender process. Synergy must enter into a tendered displacement by certain dates specified in the Vesting Contract and in accordance with a tender process set out by the ministry (Synergy 2009). These changes together with the 20% renewable target set by the Government will drive different outcomes in terms of future generating plant developments.

Coal has dominated base load power in Western Australia's SWIS electricity market. The combustion of coal, however, adds a significant amount of carbon dioxide to the atmosphere, leading to concerns of global warming. Alternative resources such as gas and renewable energy (e.g. wind, solar and hydro) have lower levels, or no carbon dioxide emissions. WA's power system would therefore make great advances in terms of environment if it substituted coal with these alternatives. When deciding which resources to be used for generating electricity, coal, as well as its alternatives, are taken into consideration.

As there was a huge supply of gas along the coastal line of WA, gas fired power plant penetration had risen to more than 30% by 2005 (Simshaunser, 2007). All that changed when the price of natural gas increased in 2007 (Fleay, 2007). In 2008 an explosion occurred at Varanus Island, cutting WA's gas supply by 30%. In this explosion, the main pipeline that sends gas through to the SWIS was affected. This had a large impact on the gas industry in WA and once again the gas prices rose. In 2005 gas was priced at roughly \$2.50 per Gigajoule (GJ), and is now priced at around \$8.00 per GJ. These price changes will drive different outcomes in terms of future plant developments.

These plants are divided into four generating types: base, peak, mid-merit and intermittent. Base plants have low marginal running cost with high fixed costs. It is expensive to be built but the fact that these plants run nearly all the time ensures that their average cost per unit of energy produced is low. Peaking plants are designed to run for a short period of time to supply the peaks demand and handle unpredictable fluctuations in demand. They are relatively cheap to build but expensive to run (Diesendorf, 2007). Mid-merit plants (also know as intermediate plants) have cost of building and running in between the base and peak load plants. These plants fill the gap in energy supply between base and peak load power (Diesendorf, 2007). Intermittent plants resources such as wind and solar provide energy from renewable sources. These plants are classified as intermittent due to uncertainty with the reliability of supply (uncontrollable wind and solar activity). These plants generally have high capital costs but little or no energy cost.

2. Optimisation

Optimisation is used to minimize or maximize an objective function. With regards to electricity generation, the objective function is designed in a way to minimise the total cost of the set of generation available over a period of time while supplying enough electricity and capacity to meet the required demand and capacity reserve. Various optimisation softwares are available for modelling purposes.

The objective function to be minimized, C_y, is the total cost for supplying the required electricity for a specific year, subjected to certain constraints. C_y is defined as the sum of the costs for the electricity supply from each of the N generators. The costs incurred by a given generator are defined as fixed and variable costs. Fixed costs, F_i are the costs that are paid regardless of how much energy is supplied, and the variable costs, V_i are costs that are directly related to the electricity supplied, $G_{i,y}$ by the generator in year y.

$$C_y = F_1 + V_1.G_{1,y} + F_2 + V_2.G_{2,y} + F_3 + V_3.G_{3,y} + ... + F_N + V_N.G_{N,y}$$

$$= \sum_{i=1}^{N} F_i + V_i.G_{i,y} \qquad (1)$$

where : $i = 1,2,3,......N$

The essential constraint on the operation of the system is that the sum of the electricity supplied in a specific hour, $G_{i,h}$, for all generators must equal the load demand for that specific hour, $Load_k$.

$$\sum_{i=1}^{N} G_{i,h} \geq Load_h \qquad (2)$$

Generators are built with different capacities. Therefore, the power output of each unit must be greater than or equal to the minimum power permitted, $G_{i(min)}$ and must also be less than or equal to the maximum power permitted, $G_{i(max)}$ on that particular unit.

$$G_{i(\min)} \leq G_i \leq G_{i(\max)} \qquad (3)$$

Thus the objective function, as detailed in equation (1), must be minimized in respect to the constraints in equations (2) and (3).

The optimisation package being used in this project is the General Algebraic Modelling System (GAMS). GAMS is a high level modelling system mainly used for mathematical programming and optimisation. It consists of a language compiler and separate solvers, each of its own methods and benefits.

2.1 Modelling in GAMS

This project aims to create a preferred procurement strategy available to Synergy for the next 25 years. Currently, Synergy is using an optimisation program called ‘Whirlygig’ which was created by the Frontier Economics Consultancy. The reference case is a set of assumptions that is applicable to the market now and is used as the benchmark for this project.

However, concerns have been raised regarding Whirlygig’s black box methodology in modelling the reference case and scenario testings. Therefore, another reason for this project is to design a model in GAMS that duplicates the reference case modelled by Whirlygig. This will allow Synergy to have a program of its own, consisting of algorithms and mathematical equations that are understandable and accessible, eliminating the uncertainty of Whirlygig’s black box methodology. The GAMS model also provides Synergy the flexibility of being able to update the model in the future to reflect changes in the energy sector. The optimal solution set is the most suitable generator mix, (base, peak, mid-merit or intermittent plant) across the 25 years.

The initial part of this project is to come up with a suitable database in GAMS, equivalent to Synergy's reference database. This database will then be used as inputs into the modelling performed by both Whirlygig and GAMS. Research into the energy sector will be used to create the constraints on electricity demand, fuel cost and availability, generator costs and limitations, reserved capacity requirements, renewable energy targets and proposed carbon reduction schemes. By changing the levels of these constraints we will be able to create a range of possible scenarios for the energy sector. Under each of these scenarios, sensitivity analysis will be conducted to determine the impact each of these has on the energy sector. The model in GAMS is divided into SQL statements, constant declaration statements, variables, equations and output.

The creation of a database in Microsoft Access consists of generator names, the size of each generator, its fixed and variable cost, the year in which it is available to be used up until the year it retires, etc. This data is stored in its individual tables for better understanding. They are then extracted out into GAMS using SQL statements. The output of the model is shown in the listing window. This listing window is generated after each GAMS run. The listing window also shows the generated SQL files which have been earlier been extracted out from Microsoft Access through SQL statements and stored in separate files.

2.2 Practical Issues

The results of the modelling were similar between GAMS and whirlygig. The small differences in the results are likely to be due to different solvers and optimization accuracies being used in the programs. The GAMS modelling has given Synergy comfort in the results of the Whirlygig modelling, and given the time constraints (and the solving time for GAMS) the sensitivity analysis will be performed using Whirlygig rather than GAMS.

3. Results and Discussion

Each model produces a solution set for 25 years based on a set of assumptions regarding current, fixed and variable prices for each resource in the electricity market. This predicted generation plant mix for the reference case is shown in Figure 1**,** which shows the generator type for both existing and new plant in the electricity market over the 25 year period.

Figure 2 below shows the investment for new generating plants to meet future load demands. The need to build new plants is due to increasing load demand and to replace generators which are subjected to retire. The modelling shows a large increase in gas plants (Open Cycle Gas Turbine, OCGT, and Combined Cycle Gas Turbine, CCGT) compared to coal plants. This is likely to be due to the inclusion of the proposed Carbon Pollution Reduction Scheme and the peak load increasing proportionally more to the base load, requiring more peaking plant (OCGT is a peaking plant).

The relationship between generating capacity requirements and capacity utilization is shown in Figure 3. This shows the total energy (in Gigawatt hours, GWh) across each year and how much energy each generating plant provides to meet this. Due to the nature of OCGT plants, although there is a large capacity available of these plants (Figure 1), only a small proportion of the total electricity supply comes from OCGT plants. This is because OCGT plants are only used for short periods of time.

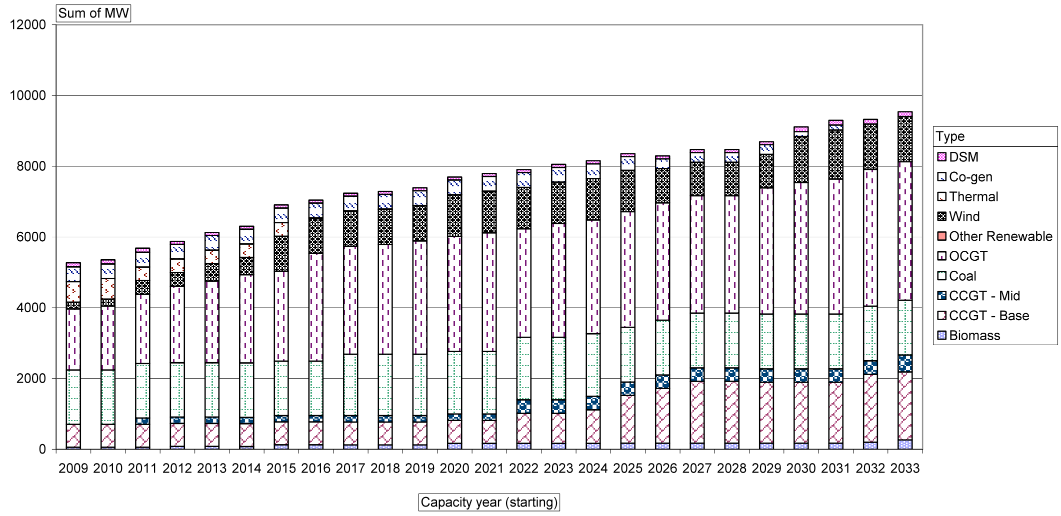

Figure 1 Investment of respective generators for each particular year.

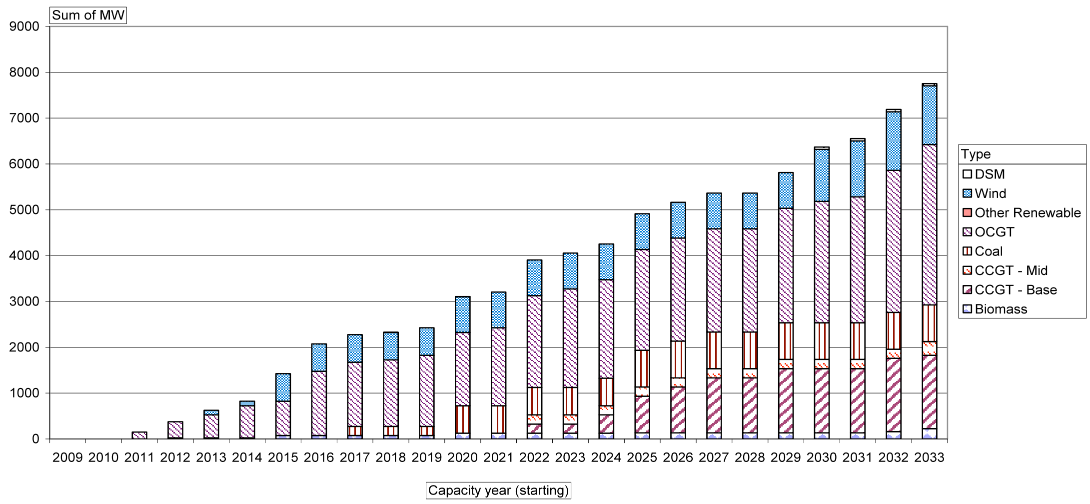

Figure 2 Investment of new generator plants for future years

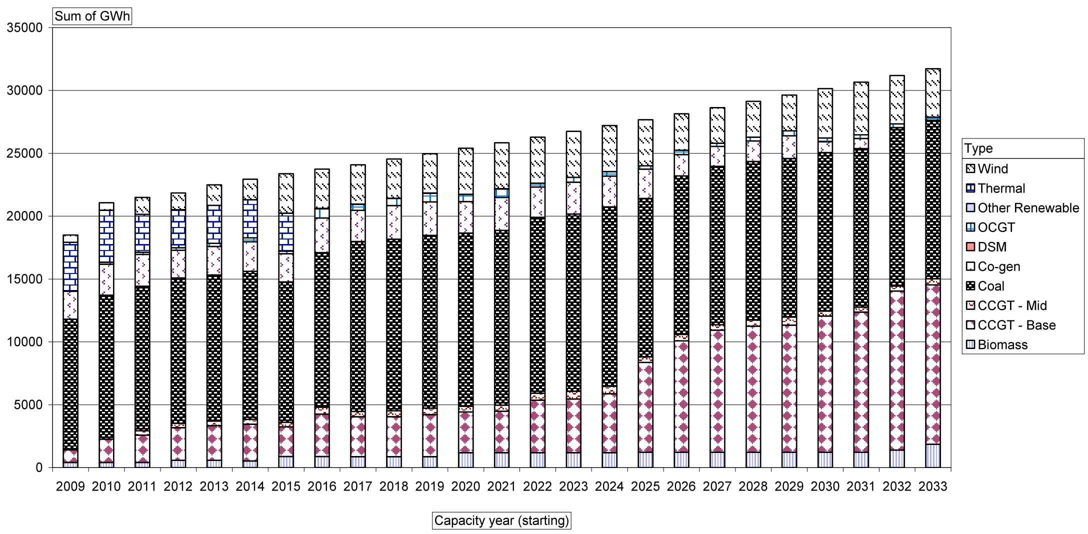

Figure 3 Generator output showing total energy supplied for each year.

It is important to plan the capacity requirements (in terms of quantity as well as the generator mix) years ahead of time because generator plants will retire and also there is uncertainty as to what the electricity market will be like in the future due to changes in the existing conditions (fuel, policies, technology etc.) By performing sensitivity analysis on the assumptions of the reference case, we obtain a set of different scenarios that will provide Synergy with a solution set applicable to a range of possible future electricity markets.

4. Conclusions and Future Work

The modelling undertaken in this project will provide Synergy's with a procurement solution over 25 years. Because there is uncertainty as to what the electricity market will be like in the future due to changes in the existing conditions (fuel, policies, technology etc.) it will be important to undertake sensitivity analysis. By performing sensitivity analysis on the assumptions of the reference case, we obtain a set of different scenarios that will provide Synergy with a solution set applicable to a range of possible future electricity markets. This will allow Synergy to choose the most appropriate generator needs for the future given the uncertainties. These solutions will allow for the design of bilateral contracts with generating companies available to meet Synergy's future load demands.

The working GAMS model built allows Synergy to manipulate and update the model with changes in the assumptions and future changes in the energy sector. The capability of Synergy having a generalised model reduces their financial risk and allows space for flexibility as the model can be adjusted to match future energy requirements.

After the completion of the sensitivity analysis, if sufficient time is available, other aspects of the market will be investigated, such as carbon sinks to overcome carbon restrictions. A carbon sink is a process whereby carbon dioxide is removed from the atmosphere and stored indefinitely. With this technology, it will be profitable to Synergy to have a long run coal generating plant as coal is cheaper than other resources.

5. Acknowledgements

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