

SOUTH AUSTRALIAN WIND POWER STUDY



Electricity Supply Industry Planning Council

March 2003

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1 EXECUTIVE SUMMARY

Governments and electricity consumers are increasingly conscious of the need for conservation and environmental sustainability. South Australia has, for many years, been supplied with a large percentage of its electricity from generators fired by natural gas and coal.

Federal Government initiatives such as the Renewable Energy Strategy and the Mandated Renewable Energy Target have increased the focus on environmentally friendly electricity generation and provided financial incentives to increase the levels of market penetration.

Wind energy is one of a number of “green” electricity generation technologies being investigated for use in South Australia. South Australia is well positioned with respect to wind generation, with a significant wind resource and relatively low population density. It is, however, potentially disadvantaged by a lack of transmission infrastructure in the areas that may be most attractive for wind development.

The impact on the electricity market, its customers, participants and related industries as a result of the introduction of wind energy into the South Australian electricity market has not previously been extensively researched.

This study is designed to provide a high level assessment of the market implications of the emerging wind power sector in South Australia and provide directions for future, more detailed analysis.

The study shows that the contribution made by wind farms to the State’s firm capacity varies considerably depending on the time basis for the analysis and the geographical separation of the sites included. Based on a statistical analysis, using modified Bureau of Meteorology data over a 6 year sample, an estimated 8% of the installed capacity of the wind farms could be considered firm. It is reasonable to anticipate that this figure would be increased slightly if a greater diversity of sites were considered.

The Planning Council found no significant correlation between temperature and wind speed although some sites exhibited moderate diurnal wind variations during summer.

The introduction of wind power into South Australia does not appear to improve the State’s load shape or load factor.

Based on the half hourly chronological modelling performed by the Planning Council, the volumes of installed wind power used in the study were able to be accommodated without significant operational impact. However, as has been noted in Europe, there appears to be a practical limit to the level of wind generation above which the operational viability of the some of the incumbent generators is uncertain and the additional complexity of market operation becomes unmanageable.

Deliberately, this study has not attempted to predict changes to wholesale electricity market prices. The introduction of wind farms will clearly alter the nature of competition in

South Australia by reducing the size of the contestable energy market and consequently increasing competition. The resulting impact on wholesale pool price is highly dependent on participant bidding behaviour. It is however important to recognise that changes to wholesale electricity price are not always reflected in prices to the electricity consumer.

The possible change to the utilisation of the gas pipeline, due to the altered role of the marginal generators in the State, has the potential to increase the pipelines' load factor and flow variability, and could adversely affect the transport cost of gas into South Australia.

The flow on affects of the changes from the wind generation could also alter the future requirements for new generation, increasing the needs for flexible intermediate and peaking generation.

The study shows that wind generation reduces national CO₂ emissions in the order of 0.52Mt per MW installed on an Short Run Marginal Cost(SRMC) basis to 0.49Mt per MW installed on an Long Run Marginal Cost (LRMC) basis. The slight reduction between SRMC and LRMC emission results are predominantly as a result of the increase in the dispatch of the gas fired units in order to manage their profitability under LRMC.

The following table shows, at a macro level, the conclusions from the Study.

MARKET ASPECT INVESTIGATED	RESULT
Firm Capacity	~8% of installed capacity
Correlation between Wind and Temperature	No specific correlation although some diurnal patterns detected
Interconnector: Net Imports	Reduced
Interconnector: hours of constrained operation	Reduced ¹
Generation levels of SA incumbents	Reduced
Changes in fuel usage	More unpredictable, higher volatility ²
Load Factor	Not improved
CO ₂ emissions	Reduced
Practical limit to wind penetration	Not determined ³

¹ Further research required on "gatekeeper arrangements"

² Could potentially result in higher transport charges.

³ Further research required to determine the parameters for failure.

2 PURPOSE OF THE STUDY

The project begins the assessment of the market implications of the emerging wind power sector in South Australia and indicates directions for future, more detailed analysis.

Specifically, the Planning Council has investigated the impact of wind farms on the following aspects of the operation of the South Australian electricity market and the NEM:-

- the contribution of wind to “firm” generating capacity;
- the predictability of wind farm output and any correlation between wind and temperature.
- the State’s load shape and load factor;
- the operation of existing generators;
- the viability of other forms of new generation in the State and the technology mix of new conventional generation;
- the operation of the Heywood interconnector and the requirement for additional interconnector capacity;
- the operation of the fuel supplies in the State; and
- reductions in greenhouse gas emissions in the NEM.

An assessment of the progress of the known wind farms in South Australia was used as an indicator of the practical, foreseeable extent of wind farm development over the short to medium term.⁴

The results of the chronological modelling performed by the Planning Council in this study can also be used to assess the likely outcome of a Regulatory Test benefits calculation. The Planning Council have performed an example Regulatory Test calculation for transmission augmentation for a hypothetical remotely located wind farm.

This study does not attempt to investigate the affects of short term perturbations in wind powers on NEM operational considerations, transient or system stability criteria. These aspects of the operation of the NEM are the responsibility of NEMMCO and should be covered in their intermittent generation study to be conducted in early 2003.

The study also does not attempt to forecast price impacts on the South Australian electricity customers.

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The results of this survey have not been included in this study as they are of a highly confidential nature.

3 WIND POWER

3.1 The Origins of Wind Power

The Earth receives approximately 1.74×10^{11} megawatts (MW) of power from the Sun and roughly one to two percent of this energy is converted into wind energy. A significant portion of this wind energy occurs in the form of geostrophic winds – winds that arise as the result of temperature, and therefore pressure, differences.⁵ The interaction of these temperature and pressure differences with the Coriolis Effect and topology creates the prevailing wind directions and speed for geostrophic winds.⁶ Prevailing wind conditions are relevant to wind turbine-siting decisions. Local geographic factors may, of course, modify any ‘rules of thumb’ that arise from applying prevailing conditions to such a decision as local geography impacts the direction and speed of surface winds.

3.2 The Physics of Wind Energy

An important aspect of the science of wind energy is harnessing the potential energy of these winds. A wind turbine obtains power input by converting wind force acting on the rotor blades into a turning force, *i.e.* a torque. The quantity of energy that the wind transfers to the rotor depends on three primary factors: *i)* wind speed, *ii)* air density, and *iii)* rotor area. In brief, the energy potential per second, *i.e.* the power, of wind varies in proportion to the cube of the average wind speed, *e.g.* if the wind speed doubles, it contains eight times as much energy, all else remaining equal. Kinetic energy in a moving body is proportional to its mass. Consequently, the wind’s kinetic energy depends on the density of air, *i.e.* its mass per unit volume. The rotor area determines the quantity of energy that a turbine is able to harvest from the wind. The rotor area increases with the square of the rotor diameter and, as a result, a turbine that is twice as large is able to receive four times as much energy.

However, there is a limit to the amount of the kinetic energy in the wind that a turbine can convert into mechanical energy. This limitation arises since, as a turbine extracts more kinetic energy from the wind, the wind is increasingly slowed as it exits the turbine. In the extreme, if the turbine attempts to extract all of the kinetic energy from the wind then the wind would possess speed zero and be unable to leave the turbine – the turbine would extract no energy. Alternatively, if the turbine allows the wind to pass through it completely unhindered then the turbine would also extract no energy. Betz’s Law dictates that an ideal wind turbine slows wind down by two-thirds of its original speed. At

⁵

Solar energy heats the areas around the Earth’s equator relatively more than areas away from the equator. The hot air from this process rises above the relatively cooler air to an altitude of approximately 10km and then disperses to both the North and South. As the wind rises, low pressure areas close to the ground level attract winds from the North and South. At about thirty degrees latitude in both hemispheres, the Coriolis Effect causes the wind from moving significantly farther away from the equator. At this latitude, high pressure areas force the air to start sinking downward. At the same time, high pressure areas at the poles will result from the cooling of any air.

⁶

The Coriolis Effect is an inertial force described by the 19th-century French engineer-mathematician Gustave-Gaspard Coriolis in 1835. The effect of the Coriolis force is an apparent deflection of the path of an object that moves within a rotating coordinate system. The object does not actually deviate from its path, but it appears to do so because of the motion of the coordinate system. It is significant in the earth sciences because the Earth is a rotating frame of reference, and motions over the surface of the Earth are subject to acceleration from the force indicated.

this point, the maximum value for the power the turbine extracts from the wind is 0.59 or 16/27 of the total power in the wind.

3.3 Wind Power and Turbine Output

WIND SPEED VARIABILITY

Characteristics of Wind Speed Variations

Short term, wind speed always fluctuates and this fluctuation or gusting creates small scale variations in the energy content of the wind. The magnitude of this variability depends on several factors including weather and surface conditions. Gusting is typically spherical in nature and its affect on power generation varies with the size of the gust.

Wind speed is also subject to diurnal patterns. Weather and temperature conditions typically cause most locations world-wide to experience conditions that are 'more windy' during the day than during the night. Two primary reasons explain this diurnal variation: *i*) temperature differences between sea and land surfaces are usually larger during the day than at night, and *ii*) the wind is usually more turbulent and changes direction more frequently during the day than at night.

Quantifying Wind Speed Variations

The ability to describe wind speed variations quantitatively is important in facilitating improvements in wind turbine design and in forming expectations of wind power and ultimately, wind generation revenues. The calculation of the average wind speed at a site, however, is not indicative of the expected average power from the site. Variations in wind speeds occur with different probabilities at a given site; therefore, the wind power implied by each wind speed must be associated with an appropriate wind speed probability.

Typically, the measurement of winds speeds at a given site over a year shows that moderate winds are common while strong, gale force winds are rare. These patterns are best characterised statistically by the Weibull distribution. Since wind speed patterns at different locations vary by temperature and weather conditions, as well as by local geography, the Weibull distribution varies by shape and mean value.

CONVERTING WIND POWER INPUT TO TURBINE OUTPUT

Wind Power Relationships

In order to obtain the total energy output from a turbine, it is necessary to use the Weibull distribution of wind speeds in conjunction with the wind turbine power curve. The power curve represents power output as a function of wind speed. Power curves are formulated from data obtained by field measurements.⁷ The sum of probability-weighted values from the power curve yields the mean power output from the turbine. Figure 3-1 summarises

⁷

Measurements are typically taken with an anemometer that is located on a mast within a reasonable distance of the wind turbine. The anemometer is never placed too close to the turbine because turbulence from the turbine rotor will likely cause measurements to be unreliable.

the relationship between total power input and turbine power output, based on a site with mean wind speed = 7 m/s and a Weibull shape parameter of 2.

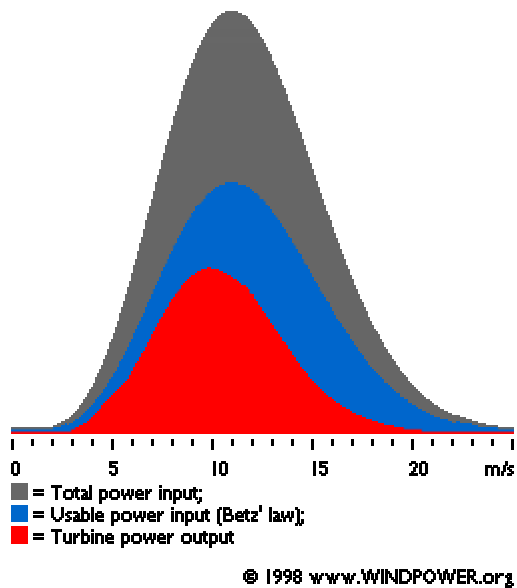


Figure 3-1: Wind Power Relationships

The height of each vertical segment in the total power input curve is the power (watts / sq. meter) for that particular wind speed. As a result, the area under the curve is the total wind power per sq. meter of wind flow at the particular site. The area under the middle curve is the fraction of the total power input that is actually usable, *i.e.* convertible to mechanical energy according to Betz's Law. Finally, the area under the bottom curve is the fraction of usable power input that a particular wind turbine will produce at this site, based on its power curve.

Measuring Wind Turbine Output

Output from a wind turbine is measurable by the calculation of its capacity factor. Capacity factor is defined as the annual energy output divided by a unit's theoretical maximum output under the assumption that the unit operates at its rated maximum capacity during every hour of the year.

Relatively large capacity factors are not necessarily economic in the context of wind power. It may be more economic to build a large generator (implying a smaller capacity factor) with the same rotor diameter as a smaller generator, depending on the nature of wind conditions at a given site and generator costs. In general, trade-offs will exist between relatively stable wind output with a high capacity factor or high, variable energy output with a relatively lower capacity factor.

3.4 Implications for Modelling Wind Power

Since the characteristics of wind power imply that it is both stochastic and non-storable, wind generators generate only when there is sufficient wind and they cannot control the timing and amount of generation.

International experience with the integration of wind farms into interconnected networks shows that generation from wind farms alters the operation of more conventional stations particularly where other forms of renewable energy, such as Hydro or pump storage, cannot offset the wind farm generation. Similar to other countries, the dispatch rules in the Australian NEM are structured such that generation from wind farms displaces generation from market-scheduled sources. The behaviour of the existing generators under these circumstances is very difficult to predict with any accuracy. Where the generation from wind farms causes more conventional generators to operate at lower levels of output, their efficiency is reduced. By operating less efficiently the cost per unit output and emission levels from the conventional generators are normally increased, offsetting some of the emission reductions from wind generation. In large interconnected networks, such as in Europe, the short term variations in output from the wind turbines are compensated for by a large number of conventional and hydro generating units, via a strong interconnected network. In Australia, because of the larger distances and more fragile interconnection, the ability of the rest of the market to absorb these variations may not be as effective and may need to be compensated for by more significant regional responses. This response could be in the form of a larger number of starts of some of the peaking plant or by holding more spinning reserve increasing the cost of market operation.

Wind generators, because of their intermittent nature, are considered by the National Electricity Code (NEC) to be non-scheduled and are not currently required to submit "bids" into the market nor do they receive dispatch instructions from NEMMCO.

Subject to changes in the NEC, wind farms will generate when the wind resource is available and their energy contribution will be accounted for in the NEMMCO dispatch process as a reduction to the total system demand. As a consequence the wind farms cannot set the pool price, they are price takers and receive pool revenue in accordance with their generation.

4 STUDY DATA

The Planning Council's initial investigations into the development status of the wind power industry proposed for South Australia highlighted that there are numerous potential projects under serious consideration. On the bases of this potential, the Planning Council has chosen to examine 3 wind power development scenarios against a neutral base case. These cases will essentially cover a range of development of the wind power industry in South Australia from approximately 150MW up to 1000MW

The Planning Council has also attempted to examine the variation of the impact experienced across these scenarios by varying other parameters such as meteorological conditions and participant behaviour. The modelling has been based on a core of constant parameters as discussed in the following section.

4.1 Wind Industry Data

The analysis performed by the Planning Council utilised wind data from the wind farm proponents, the Bureau of Meteorology (BoM) and the South Australian Wind Energy Program 1984-1988, available from the South Australian Government.

Data from the proponents was usually too limited in scope for use in the chronological model but has been used to provide a benchmark for the conversion of the BoM data.

The most comprehensive, long term wind data available was that from the BoM, providing half hourly wind speed and direction data for the last 6 years. Unfortunately, the sampling points were not always co-located with the proposed wind farm developments or at a height sufficient to eliminate terrestrial interference. It provided a consistent chronological and spatial wind data array that, with appropriate manipulation could be used as an approximation of the wind resource. Given the nature of this Study it is considered that there is little disadvantage in using the BoM data appropriately modified such that the power output of the wind farms conformed to the wind farms design output as provided by the proponents.

While the South Australian Wind Energy Program 1984-1988 provided wind speed and power readings on a 20 minute basis from 20 metre towers close to the proposed wind farm locations there was a considerable amount of missing data and its frequency made it unsuitable for later use nor did it chronologically match other data to be used in the study. However, it provided a valuable benchmarking reference for the final preparation of the BoM data.

The process for the conversion of the BoM data to that required by the dispatch model was as follows:

- complete the wind data sets with interpolated data.
- based on information from proponents calculate the capacity factor of the wind farm installation.

- using the appropriate power curve for the wind turbines selected by the proponent, convert the wind data to energy.
- scale (ie multiply by a constant) the source wind data to produce the capacity factor claimed by the proponent for the entire period of the wind data. Because this capacity factor targeting is done for the duration of the wind data available there will be some annual capacity variation.

While this method does not account for variations in the efficiency of the wind farm due to changes in wind direction and the configuration and geographical layout of the turbines that will make up a wind farm in total, it is sufficiently accurate for the proposed study.

European experience in wind analysis suggests that there can be up to a $\pm 15\%$ variation in the total wind resource annually. While most of the South Australian sampling points examined exhibited smaller variations than this, the time frame over which data has been examined is not sufficient to exhibit the full range of variation. The BoM data collection point chosen to represent Tungketta Hill had some unexplained data inconsistencies and a considerable period where no data was available. Together, these factors reduced the viable wind data for that site to the last 2 years. In order to generate the 6 years of data required for the model, consistent with all of the other locations, the valid data was repeated 3 times.

4.2 Electricity Industry Data

The generator seasonal capacity and availability, levels of Demand Side Participation, and regional peak demand and energy forecasts for the NEM used in this study are from the NEMMCO 2002 Statement of Opportunities (SOO). Other station performance parameters, reliability and transmission network constraints are consistent with those used in the 2002 NEMMCO reliability assessment.

The medium economic growth and 50% Probability of Exceedence (POE) peak demand forecast have been used throughout this study as listed in the 2002 SOO.

SUPPLY-SIDE

Generator Ratings and Capabilities

Assumptions concerning specific station performance parameters not included in the NEMMCO 2002 SOO are based on information provided by the South Australian participants and general engineering knowledge, these assumptions covered station performance parameters including

- Generic heat rate data.
- Generic used in house information.
- Generic heating and cooling rates, start up times and fuel usage.

Generator maintenance and forced outage rates are based on those used for the NEMMCO reliability assessment.

The wind turbine manufacturers provided typical wind turbine performance information such that the Planning Council could convert the chronological wind data into normalised power readings.

Hydro generation energy limitations were extracted from the information provided by NEMMCO to the NEM during the SNI analysis.

The Planning Council has also assumed that the new SEAGas pipeline has been commissioned and is fully operational removing any need for oil firing at Torrens Island Power Station and that the two pipelines together are capable of delivering the required quantity of gas in all circumstances.

TRANSMISSION

Interconnectors

In the NEM model, the notional interconnector provides a simple ‘link’ representation of the complex mesh of individual transmission lines that forms the actual, physical interconnection between two regions. Figure 4-1 provides a notional, market representation of the existing regions and inter-regional links in the NEM; it is not a physical representation. Both the proposed South Australia–New South Wales Interconnector (SNI) and Basslink are excluded.

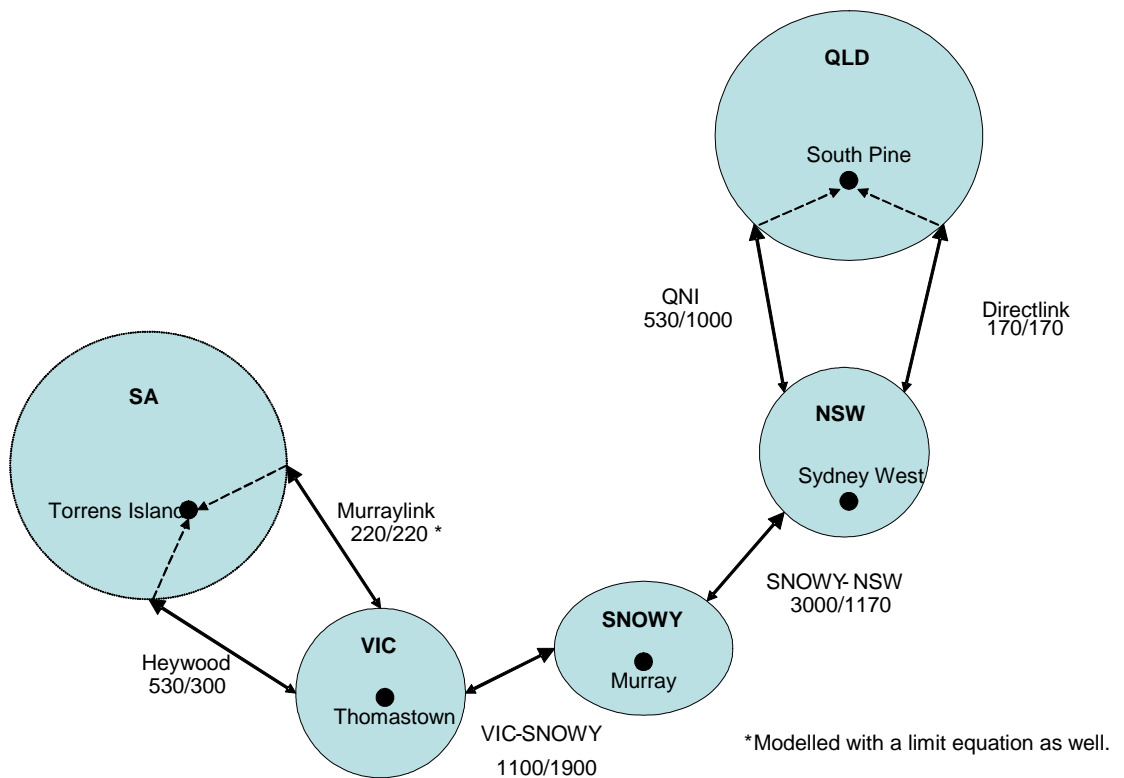


Figure 4-1 Interconnector representation in the NEM

Interconnectors may carry flow in either direction, and in Figure 4-1, the larger arrow on each interconnector indicates the direction of flow that the NEM model defines as notionally positive. For example, flow from Victoria to South Australia on V-SA is notionally positive, while flow in the reverse direction is notionally negative. In Figure 4-1, the rating of each line is given below the line name, with the rating for the positive direction of flow given first. For example, the rating of V-SA is 530MW from Victoria to South Australia (positive) and 300MW from South Australia to Victoria (negative).

Losses

Intra-regional losses are accounted for using static Marginal Loss Factors as published annually by NEMMCO.

Inter-regional losses are represented in accordance with the loss equations that represent the virtual interconnectors as described in the previous section. NEMMCO publish a full set of Marginal loss equations in conjunction with the marginal loss factors.

It should be recognised that the use of static Marginal Loss Factors and Marginal Loss Equations for determining losses for the study could over account for actual losses.

Constraints

Only one intra-regional constraint has been included in the market modelling of South Australia. Currently ElectraNet SA, the South Australian transmission network service provider, provides a “gate keeper” equation for the south east of the State. This equation describes transmission capacity limits between the South East of the State and the Adelaide Load Centre accounting for the regional load and generation. The results of the modelling will show the number of periods for which this constraint is binding and indicate the relative merits of upgrades to the transmission network for its removal.

During the analysis of the SNI and SNOVIC regulated interconnectors, NEMMCO published the results of the IOWG network analysis, which contained a full set of interconnector constraint equations. The most significant of these equations, that have bearing on this study, are those that affect the capacity of Murraylink, Heywood and the Victoria - Snowy interconnector. These equations have been implemented in the wind power study.

ENVIRONMENTAL ISSUES

Fuel emission rates for the various types of fuels used by generators in the NEM have been extracted from the most recent National Greenhouse gas inventory published by the Australian Greenhouse Office.

The Planning Council has included a form of Carbon Tax as a scenario in the analysis.

5 METHODOLOGY

The modelling of the impact of wind on the South Australian electricity market was constructed using a detailed chronological NEM model. The NEM model used by the Planning Council is PLEXOS by Drayton Analytics.

In conjunction with the data collected by the Planning Council, PLEXOS also requires some additional assumptions, principally covering the behavioural aspects of the participants and the level of detail required in the results.

5.1 Generator Bidding Strategies

Without doubt the most complex aspect of modelling the NEM is attempting to understand the business drivers of the generation companies in the NEM and translating that understanding to offer patterns that represent them. In this study, rather than attempt to reproduce offers for the future based on the historical behaviour of the generators the Planning Council has chosen to use a uniform approach to all generators based on their short run and long run marginal costs. The Planning Council has attempted to build on previous work and utilise the PLEXOS model's ability to optimise the offers for the generators within an organisation such that each organisation recovers all of its financial and operating costs. The Planning Council used the generator cost information published by NEMMCO as part of the Regulatory Test analysis for SNI as a basis and re-engineered the fuel and operating costs, debt and equity ratios and an assumed WACC to calculate new assets values. These values in conjunction with all of the other station performance data, were provided to the model with the objective of creating a viable market where the generating organisations operate profitably while maintaining efficient dispatch and producing the lowest possible market price. This analysis reflects a version of a viable market based on the long run costs of generation operations.

The Planning Council has also investigated the theoretically most economic efficient dispatch by offering all of the generators at their short run marginal cost.

5.2 Interconnectors

Network modelling and DC power flow analysis

While it would be possible to implement a full DC power flow representation of the Australian market in PLEXOS for the wind study, there seems to be little advantage in the significant additional complexity that the development of such a model would require. Based on the structure of the proposed scenarios, the wind farm projects will either require no augmentation of the existing network or would require specific extensions to the network, targeted to the output of the Wind Farm (rather than just its nameplate capacity) and predominantly dedicated to their output. A rudimentary high level Regulatory Test analysis of the augmentations required to support the new Wind Farms on the west coast will be performed as an example of the potential hurdle that such augmentations may face.

South Australia – Victoria interconnector (Heywood)

As indicated in Figure 4-1 the chronological model of the NEM includes the Heywood interconnector between South Australia and Victoria.

Murraylink

Murraylink, the DC entrepreneurial interconnector between Victoria and South Australia has been included in the base case. As an entrepreneurial interconnector its commercial operation could be simulated in a number of different ways.

- using a wheeling charge that would imitate its actual NEM offers.
- using a wheeling charge representing the losses on the DC link
- using an estimate of its costs and financing charges to allow the model to maximise the profit by the operation of the link.

Considering the objectives of this study are to investigate the potential impact of wind power on the South Australian electricity market the simplest (i.e. the first) method has been adopted.

South Australia – New South Wales Interconnector (SNI)

As market prices continue to equalise across the NEM, South Australia is likely to remain a low level net importer of electricity. Intuitively, the introduction of wind power into South Australia is likely to further reduce the net imports into the State. The Base Case model includes the 2 existing interconnectors, Murraylink and the Heywood interconnector as indicated in Figure 4-1 the modelling does not reveal significant levels of interconnector constraint then the inclusion of SNI is not likely to make a significant difference to market dispatch. If however there were a significant number of periods of constraint on the interconnectors then the additional interconnector capacity from SNI would be beneficial to the market. Results of a scenario for all cases with SNI included in the data set are in Appendix 1.

5.3 Study Period

There are many factors that are likely to affect the impact of the development of wind power in South Australia, some of which will occur in other states in the NEM. These included factors such as :

- a) peak load growth in all states and the shift of NSW from a winter to summer annual peak; and
- b) changes to the supply demand balance and the opportunities for reserve sharing leading to the need for additional generating capacity and/or changes in transmission infrastructure.

The Planning Council has chosen to simulate the period covered by the NEMMCO load forecasts in the 2002 SOO, up to the end of the 2012 financial year to allow factors such as these to develop.

The BoM data for this study only covers the 6 years from 1996 to 2002 and was repeated to accommodate the longer period.

The entry of new conventional generation will be driven by the need to maintain the prescribed NEMMCO reliability standards.

5.4 Cases Modelled

BASE CASE: NO WIND PENETRATION

This case is the reference case, intended to map out the development of the electricity industry in South Australia as it could occur if there was no investment in wind power. It therefore contains an amount and type of typical new entry, additional transmission capacity and future interconnector projects. Since these assumptions would drive the Base Case market share, import/export, fuel, and emission figures, against which the wind cases and sensitivities are measured. This is also the base case against which the Regulatory Test assessment for the west coast transmission developments will be calculated. Several sensitivity versions of the base case have been developed where critical market or participant behavioural parameters are varied and re-assessed against the chosen wind penetration cases. These aspects include changes to participant bidding behaviour and fuel prices.

CASE 1: LOW WIND PENETRATION

This case provides an indication of the impact of a low level of wind based generation and utilises a selection of wind farm projects that utilise the available transmission network in their implementation, therefore requiring the minimum of investment in additional transmission or distribution capacity. This case installs wind farms on 3 locations across South Australia.

LOCATION	CAPACITY
Starfish Hill	34.5MW
Lake Bonney	80MW
Central Eyre Peninsula	54MW
Total MW	168.5MW

CASE 2: MEDIUM WIND PENETRATION

In addition to the wind generation from the low wind penetration case, case 2 extends the existing Lake Bonney Wind Farms and introduces some capacity at Tungketta Hill, increasing the number of locations considered across South Australia to four.

LOCATION	CAPACITY
Starfish Hill	34.5MW
Central Eyre Peninsula	54MW
Lake Bonney	200MW
Tungketta Hill	200MW
Total MW	488.5MW

CASE 2A: MEDIUM WIND PENETRATION

The initial project assessment phase of this study revealed significant quantity of potential wind generation concentrated in a single area on the west coast of South Australia. Should all of this development proceed, it would require a considerable transmission network upgrade on the Eyre Peninsula. Determining the cost allocation of such an upgrade between the proponent and the South Australian public would require considerable analysis and negotiation. The performance of a Regulatory Test calculation on the transmission augmentations required to support the development of wind farms on the west coast of South Australia provides a starting point for such an allocation process by contrasting the potential contribution that the development would make with respect to the “no wind development” base case. Case 2a includes all of the proposed wind farm developments at Tungketta Hill and all of the developments from the low wind case and has been used for such a comparison. Installing a large quantity of wind generation in one area will increase the dominance of the relative wind profile of that location, negating some of the distributed advantages of a wider geographical spread.

LOCATION	CAPACITY
Starfish Hill	34.5MW
Central Eyre Peninsula	54MW
Tungketta Hill	380MW
Total MW	548.5MW

CASE 3: HIGH WIND PENETRATION

To test the performance of the network with what could be considered a high level of penetration of wind generation in South Australia, the Planning Council developed a case where all of the projects highlighted in the initial project investigation were included. While installing wind farms on 5 sites, this approach concentrates development in 2 main areas of South Australia, the South East at Lake Bonney and Tungketta Hill on the Eyre Peninsula.

LOCATION	CAPACITY
Starfish Hill	34.5MW
Central Eyre Peninsula	54MW
Lake Bonney	380MW
Tungketta Hill	380MW
Port Lincoln	170MW
Total MW	1018.5MW

5.5 Wind analysis

Before any chronological modelling could be performed it was necessary to assess the contribution that wind power would provide to firm capacity in the State, any correlation between temperature and wind power and the State's load factor. It is important to note that the analysis performed by the Planning Council does not consider the perturbations in the wind over a time scale less than half an hour.

ANALYSIS OF THE FIRM CAPACITY OF WIND

It should be noted at the outset that the Planning Council has not included a forced outage rate for any of the wind farms. Each wind farm is composed of a relatively large number of discrete wind turbines, each with a low forced outage rate, the loss of a single turbine in an array would not therefore make a material difference to the modelled output of the farm. The Planning Council considered that the inclusion of a forced outage rate for each wind turbine would not make a material difference to the results of the analysis compared to other more significant factors and would add an unwarranted level of complexity. This approach implicitly assumes the absence of any "Type" fault that affects multiple turbines at the same time.

Typically, large wind farms are connected to the grid by means of a series of distribution feeders, marshalled together and connected to the transmission network by means of one or more step-up transformers. Smaller wind farms may have less complex connection arrangements directly into local distribution networks. An outage of a

distribution feeder or step-up transformer could have a significant impact on the availability capacity of the wind farm. The typical reliability of these elements is quite high and the Planning Council considers that while this effect should not be ignored it is likely to have a very small impact on the overall long term performance of the wind farm compared to the variability of the wind resource and is included in the equivalent forced outage rate of the wind farm.

While conventional generation in the NEM is considered relatively firm in the supply demand balance analysis, all generators have some level of unpredictable failure or Forced Outage Rate (FOR) that could remove them from service at any stage. Consistent with the ESAA published figures, it is reasonable to assume that the forced outage rates for the existing generators provide State averages equivalent to 4% of the period hours. Implicit in the reliability of conventional power stations is the assumption of the continuous unlimited availability of their fuel resource. For some stations in the NEM this is not true and their declared market availability should reflect this scarcity. Hydro generators may be limited in their capacity to generate electricity due to the quantity of water that they have available in storage. By controlling the time and rate of release of the water resource, stations such as the Snowy Mountains Hydro scheme are able to ensure that they have sufficient reserves available to provide their full capacity to the NEM as it is required. "Run of River" hydro stations are not able to control their releases and their declared capacity varies with the availability of water.

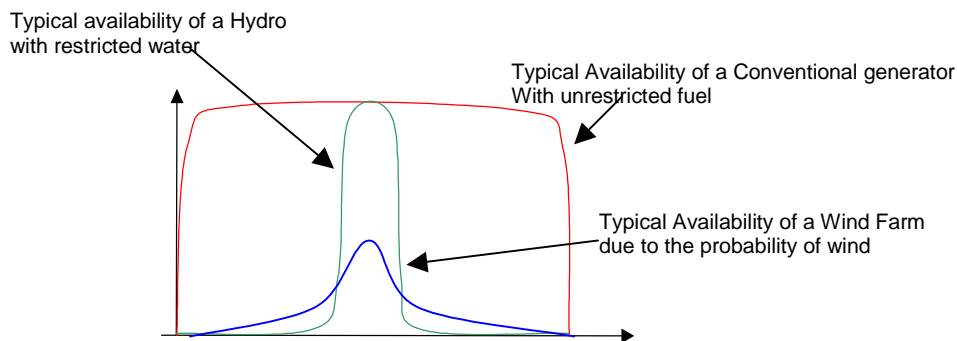


Figure 5-1 Typical probability curve of plant availability.

Figure 5-1 is a simplistic representation of the probability basis for different types of generators. The probability of a conventional generator with unrestricted fuel being available during peak periods is dependant only on the forced outage rate for that generator. By controlling the timing of the release of the available water, a hydro generator can optimise its capacity. A wind generator cannot control the availability of the wind so their availability at any particular time is dependent on the probability of the wind.

The supply demand balance during peak periods is calculated based on the declared availability of the generators in the NEM for that time. Since the wind resource is neither storable nor predictable, the Planning Council believes that the available capacity should be calculated based on that which is available for at least 95% of the time. This provides the wind farms with a comparable level of unavailability based on the unreliability of their "fuel" resource as the conventional generators would have from forced outages. That is,

the Planning Council has assumed that the firm capacity of a wind farm is that percentage of its installed capacity that is statistically available for at least 95% of the time.

In the calculation of the level of firm capacity provided by the wind farms and their periodic variability, the Planning Council performed a number of statistical analyses on the chronological wind power output levels calculated for each case.

A frequency analysis on the individual and 3 hour rolling period output from the wind farms in each case reveals results as shown in Figure 5-2 to Figure 5-5⁸. On a cumulative basis, this frequency analysis produces a generation duration curve for the combined wind farms in each case. From the predictions considering all of the half hourly data, it is clear that for all cases there is some percentage of half hourly periods over the 6 years of wind data, where there was no power output from any of the wind farms. This percentage was highest for the low penetration case and decreased as more wind power was introduced. It is theoretically feasible, although not tested in this analysis, that with a larger geographical distribution of wind farms that this figure would decrease to almost zero.

Historically, South Australian peak demand occurs on working days during summer months between the hours of noon and 7pm. To better assess the contribution that the wind farms may make to firm capacity during the peak hours of the day and the peak hours during summer the Planning Council extended its analysis, separating these periods. This significantly increases what could be considered firm capacity, from 3-5% to 6-13% of the installed capacity of the wind farm. It must be stressed that this assessment of the firm capacity is based on predictions using only the 6 year data set as described previously.

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These figures show the percentage of hours that the combined output of the wind farms from all locations was at or above a particular level.

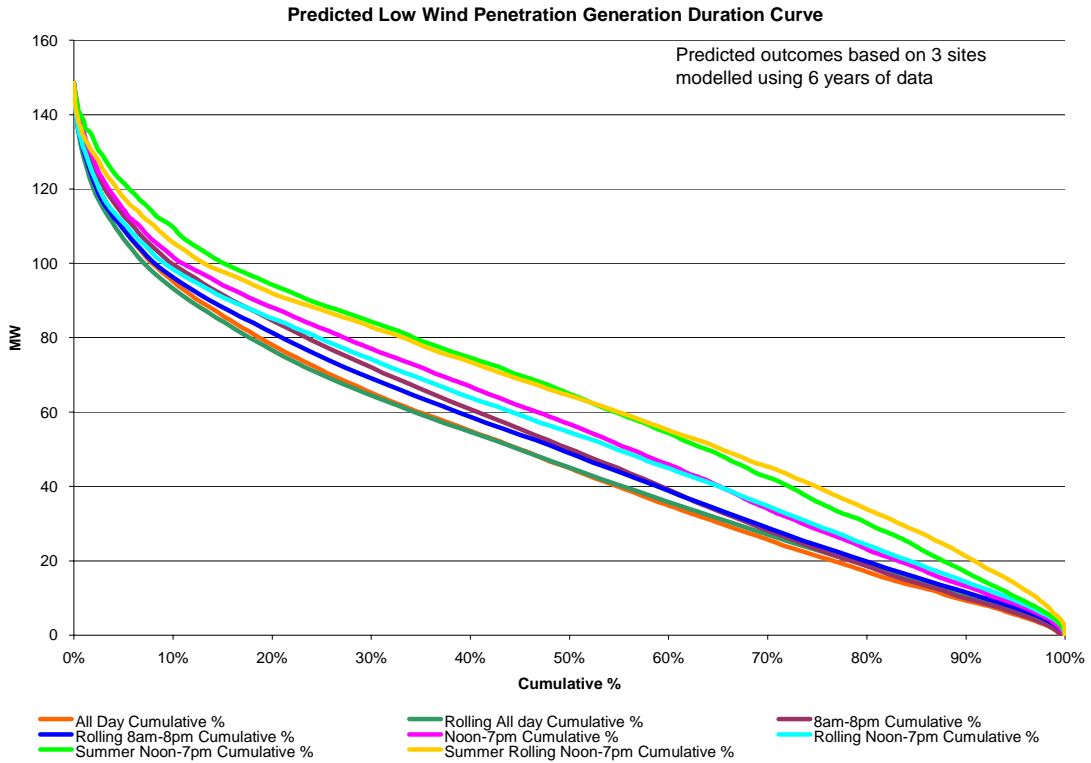


Figure 5-2 Low penetration generation duration curve

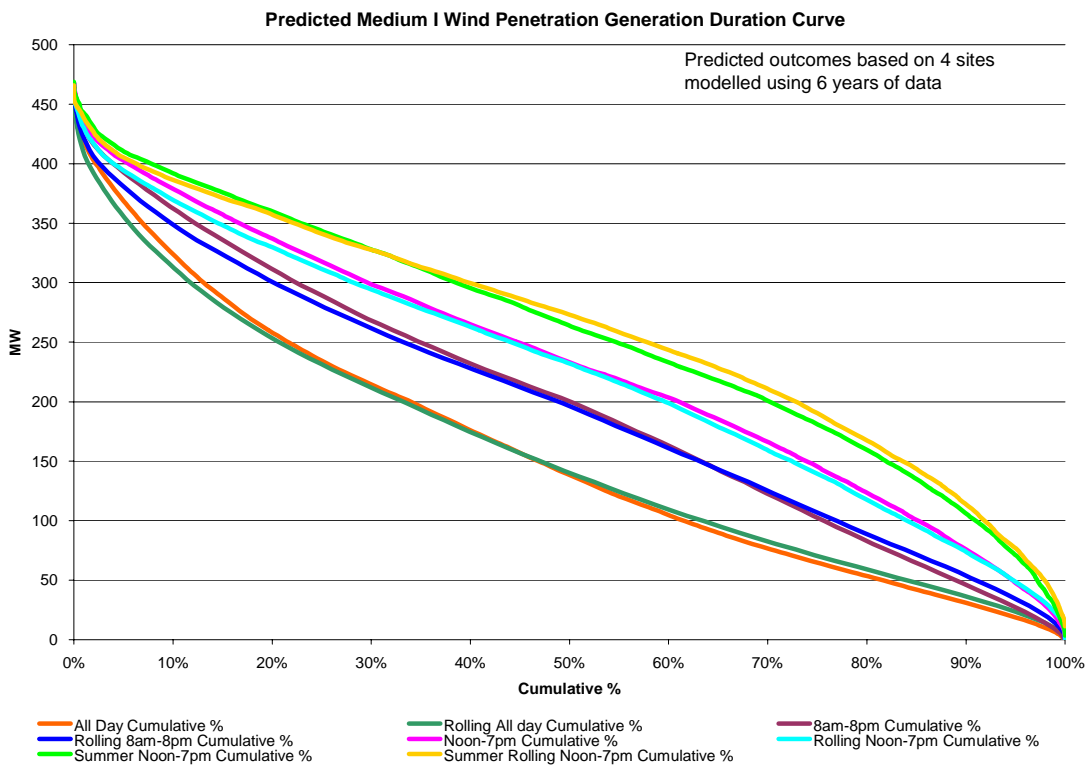


Figure 5-3 Medium penetration I generation duration curve

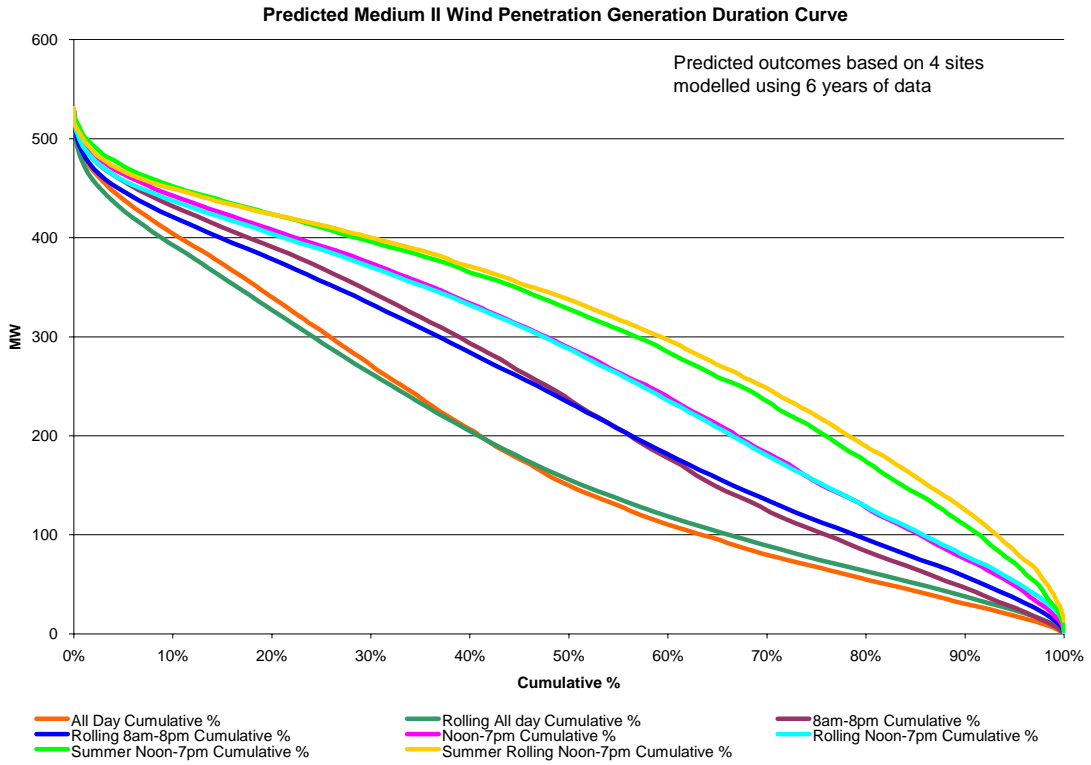


Figure 5-4 Medium penetration II generation duration curve

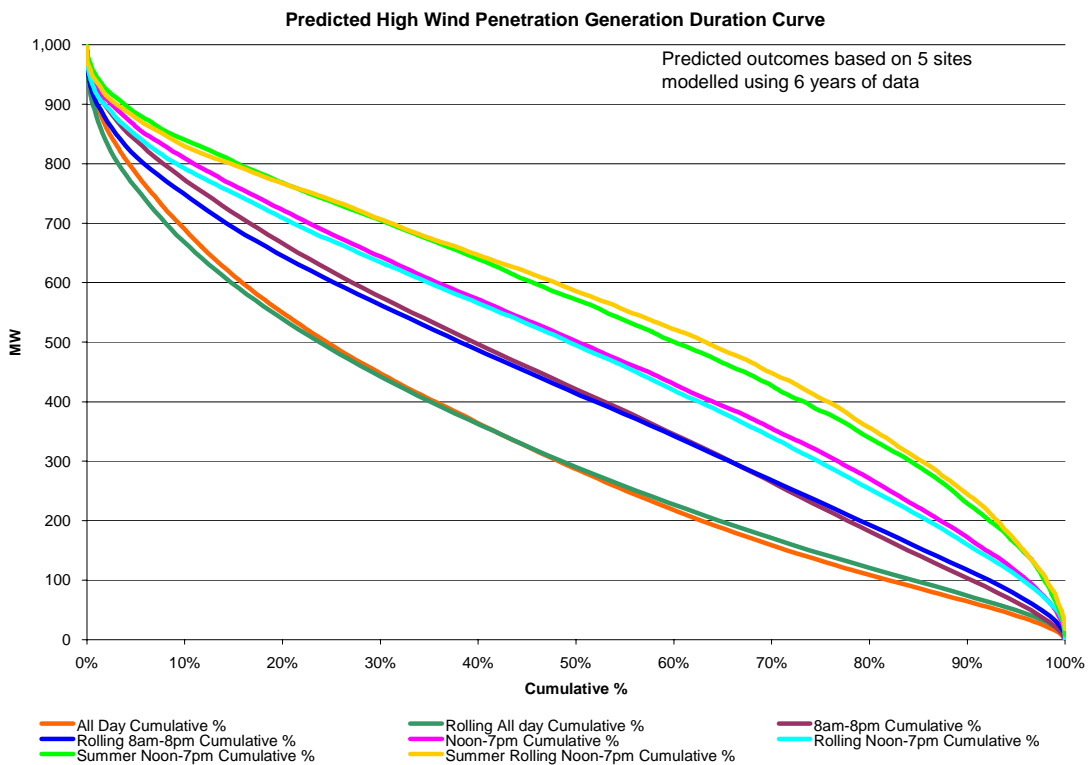


Figure 5-5 High penetration generation duration curve

PREDICTABILITY OF WIND

Critical to scheduling conventional generation in the NEM while accommodating the changeability of wind capacity will be the ability of wind generators to provide the National Electricity Market Operator with some “forecast” of their output. While the BoM data was not of high enough resolution to determine the short time frame perturbations of the wind related to gusting, it was adequate to provide some predictability or trajectory for the coming periods. Figure 5-6 shows that, based on the data provided by the BoM, the analysis indicates that 99% of the time the relative variation in wind speed from one half hour to the next is less than 15% of the installed capacity of the wind farm. Figure 5-7 shows a similar relationship between the relative variations in wind speed over an hour, 99% of the time the relative variation in wind speed from one hour to the next is less than 18% of the installed capacity of the wind farm. It should be noted that the medium II case correlation between the periods is lower than that of the other cases. This would appear to be as a result of the concentration of wind generation from a single location. It is anticipated that if more wind sites were considered that this predictability would be improved to some extent.

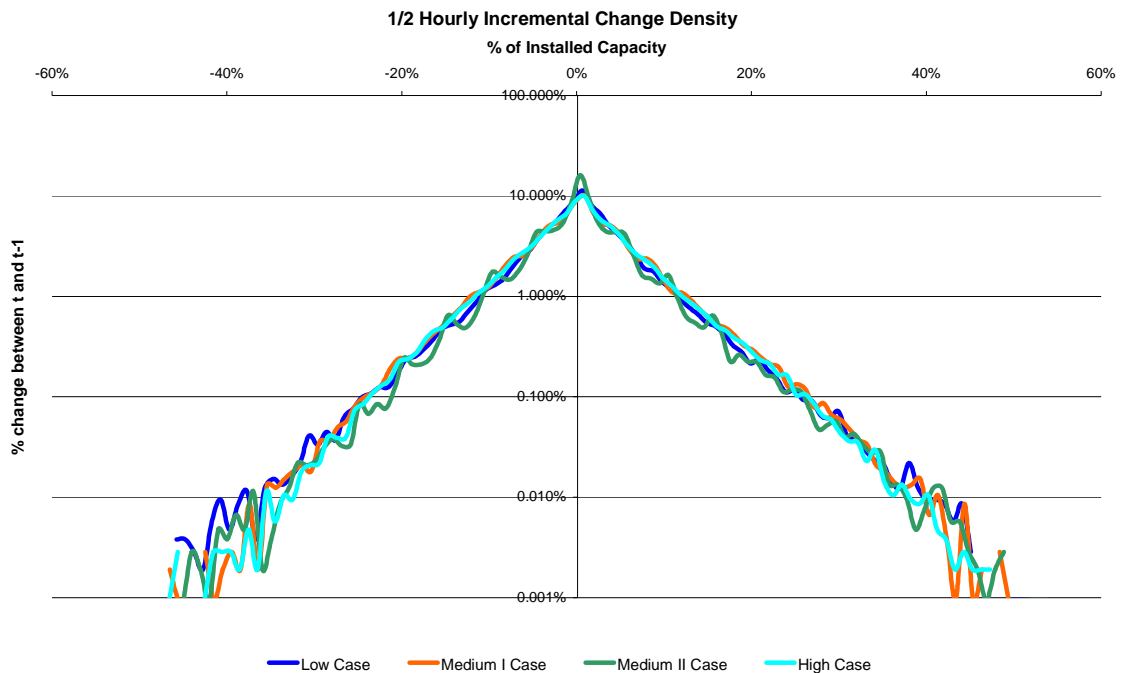


Figure 5-6 Relative change in power output between consecutive periods.

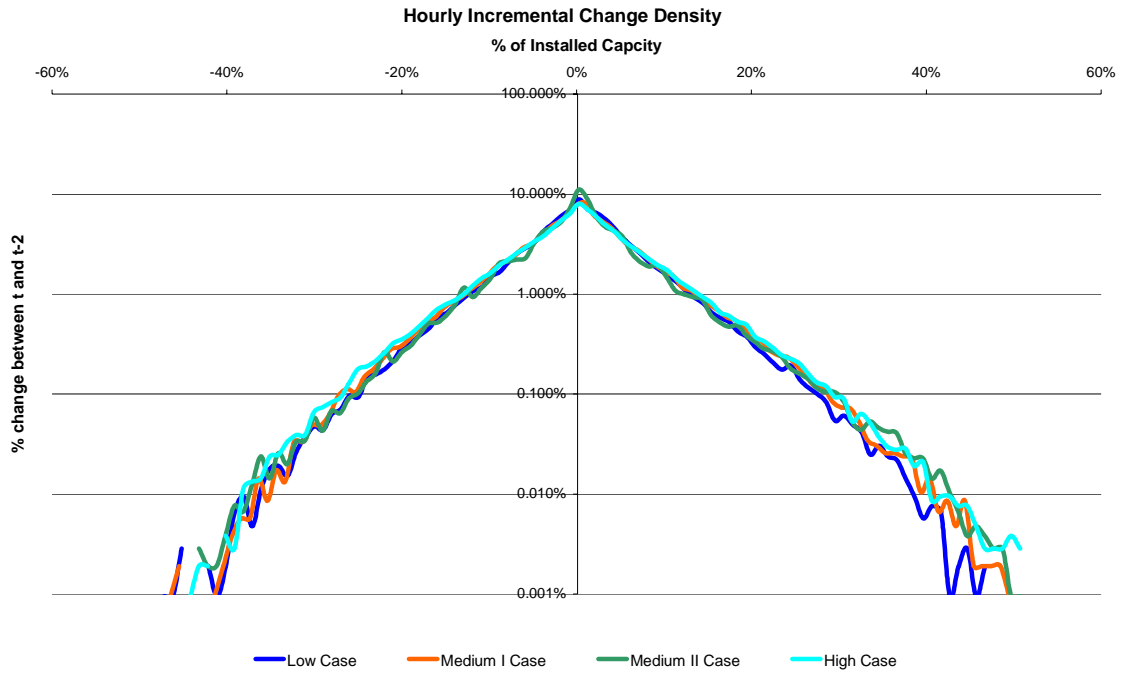


Figure 5-7 Relative change in power output across 2 periods.

ANALYSIS OF THE CORRELATION BETWEEN WIND AND TEMPERATURE

The Planning Council investigated any potential relationship between temperature and wind. Utilising only the data provided by the BoM, the Planning Council concluded that there was no significant relationship between the prevailing temperature and the strength of the wind.

SHAPE OF THE LOAD DURATION CURVE AS A RESULT OF WIND POWER.

South Australian demand is dominated by temperature sensitive loads where short periods of very high temperature lead to very high loads. However as discussed earlier, the Planning Council found no relationship between temperature and wind. Without the dominance of industrial loads that are evident in the eastern states, off peak loads can be quite low. Consequently the State has a load factor of 0.51⁹ and a load duration curve that has a high-level, short duration peak (or needle peak) where the top 30% of demand occurs for less than 10% of the year and a very low absolute minimum load.

As a full NEM participant, electricity demand in South Australia is included as part of the total national requirement. It is not, therefore, strictly accurate to consider that the South Australian wind farms will only reduce South Australian demand as South Australia is part of the NEM interconnected network. However, to indicate the potential impact of wind farms on South Australia, the Planning Council has assessed the reduction in the State's load factor from wind farm generation.

⁹ The Load Factor is defined as the division of the average load by the peak load

During the detailed analysis of the wind data provided by the BoM, the Planning Council detected some diurnal pattern, particularly during the summer months. This initially appeared to indicate that the wind farms may contribute more energy during peak periods than off-peak periods, potentially improving the State's load factor.

Using the full 6 year wind data set, the Planning Council correlated the changes to the South Australian load as a result of wind generation for each case preserving the chronological and spatial relationships that existed between State demand during that period and wind generation. To make the comparison more representative these figures were normalised with respect to the peak load in each financial year.

Figure 5-8 shows the States normalised load duration curve for the 1998 financial year and the corresponding contribution made by the wind generation in the high penetration case. This figure maintains the chronological relationship between the demand and the wind contribution at that time and hence the wind generation produces a band of points. Also marked on the chart are the ranges for which more detailed generation duration curves (labelled GDC band 1 to 6) have been provided. This has been done to further investigate the contribution from wind farms to the State's load factor.

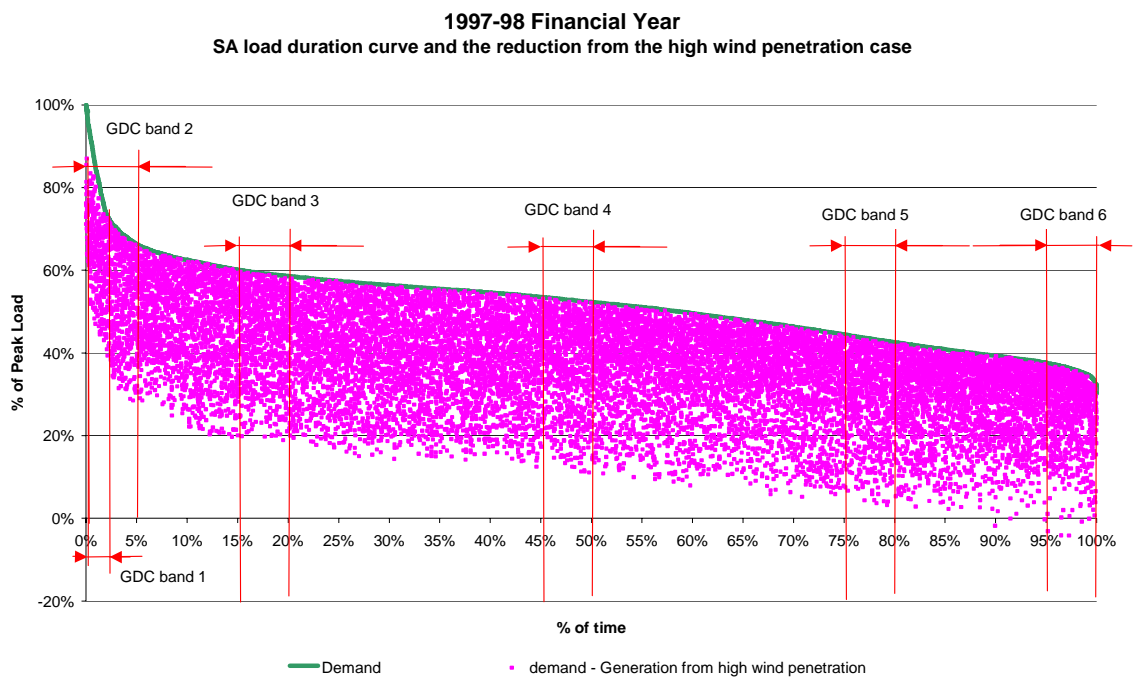


Figure 5-8 Normalised South Australian load duration curve for the 1998 financial year

The wind power generation duration curves for the GDC bands ranges shown in Figure 5-8 are shown on Figure 5-9 to Figure 5-14 and have been calculated using the normalised full 6 year wind data set.

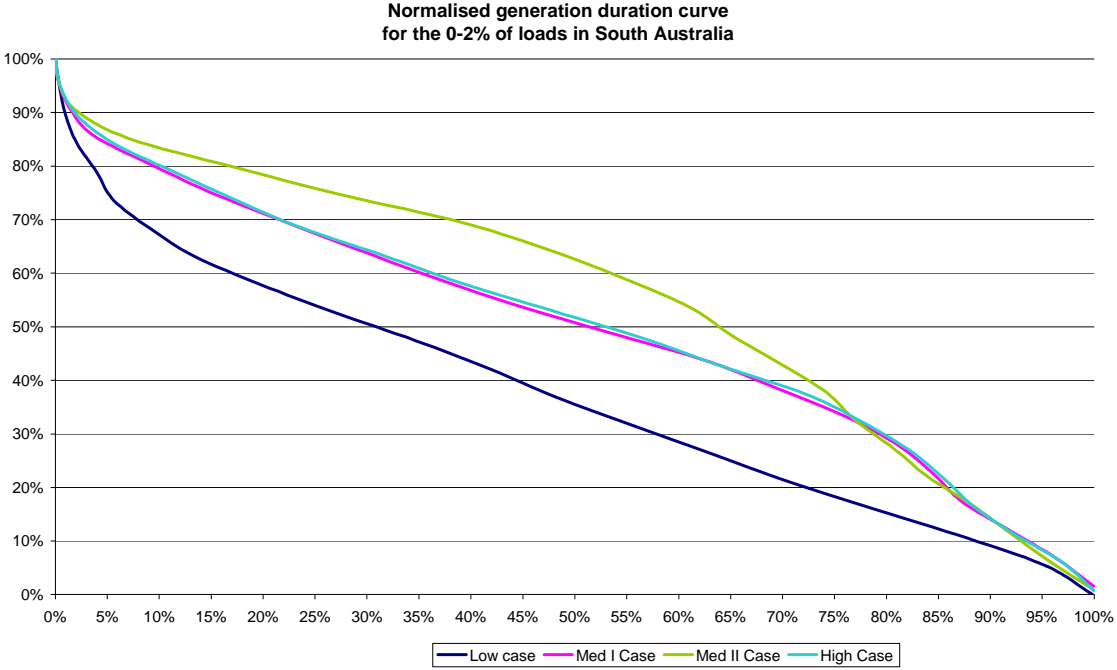


Figure 5-9 Normalised generation duration curve for loads occurring for the top 2% of the year

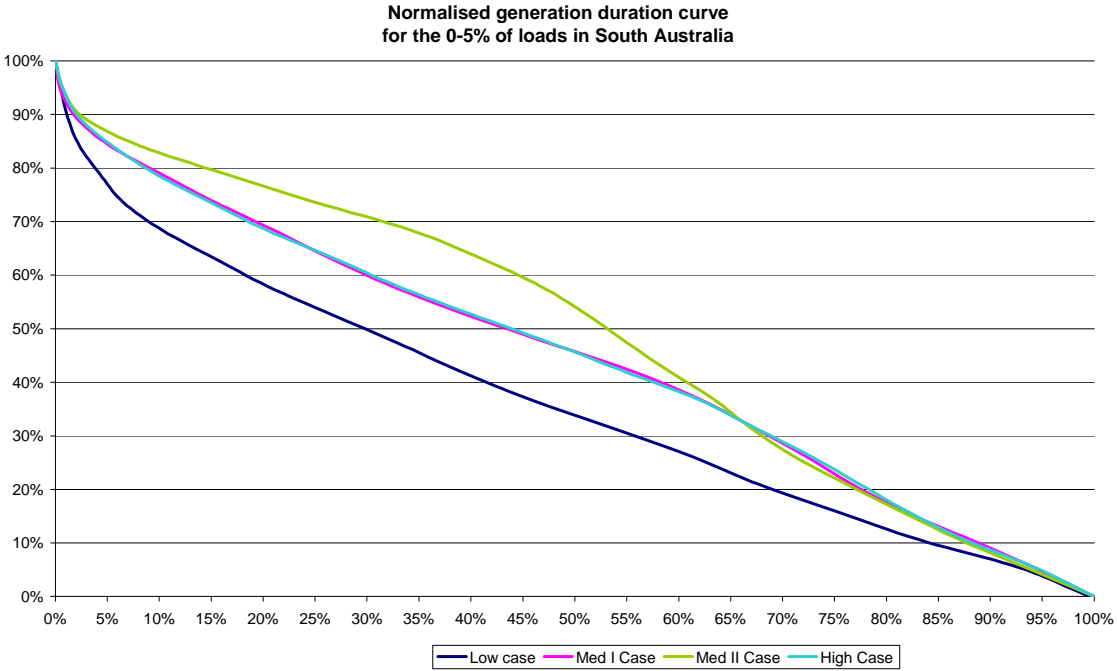


Figure 5-10 Normalised generation duration curve for loads occurring for the top 5% of the year

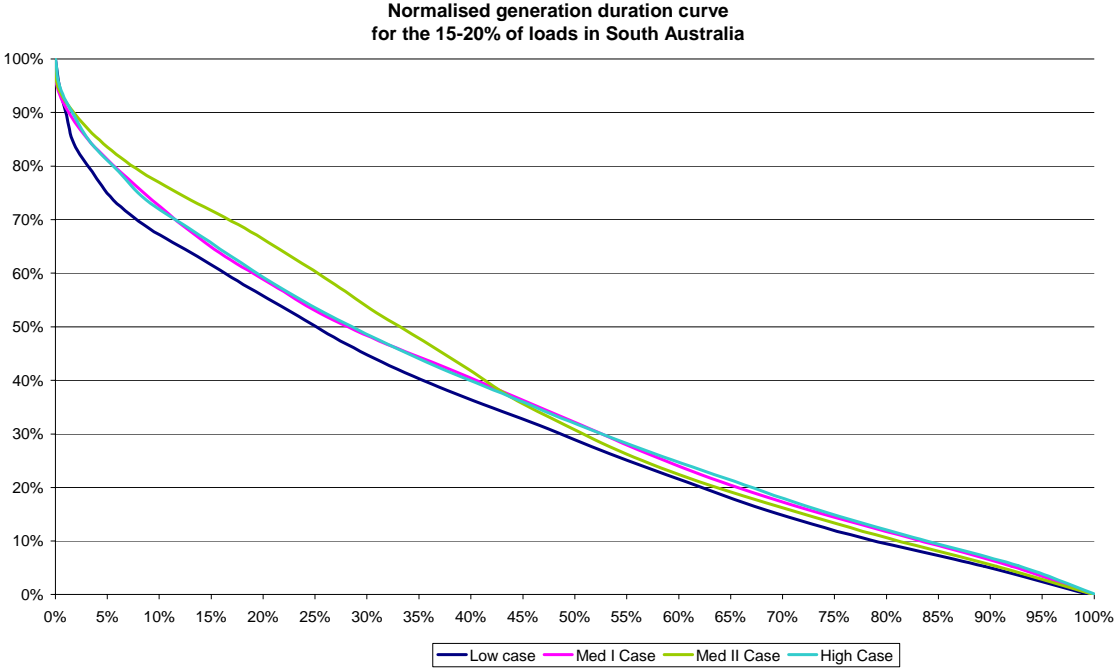


Figure 5-11 Normalised Generation Duration curve for loads occurring for the top 15 and 20% of the year

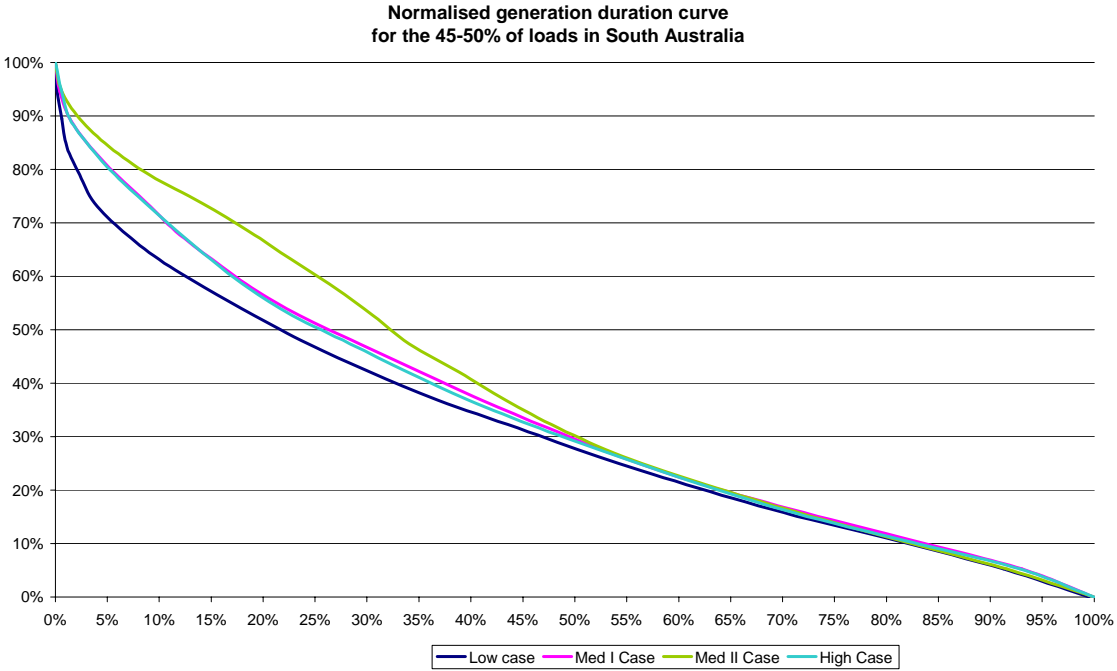


Figure 5-12 Normalised Generation Duration curve for loads in between 45 and 50% of the Peak South Australian Load

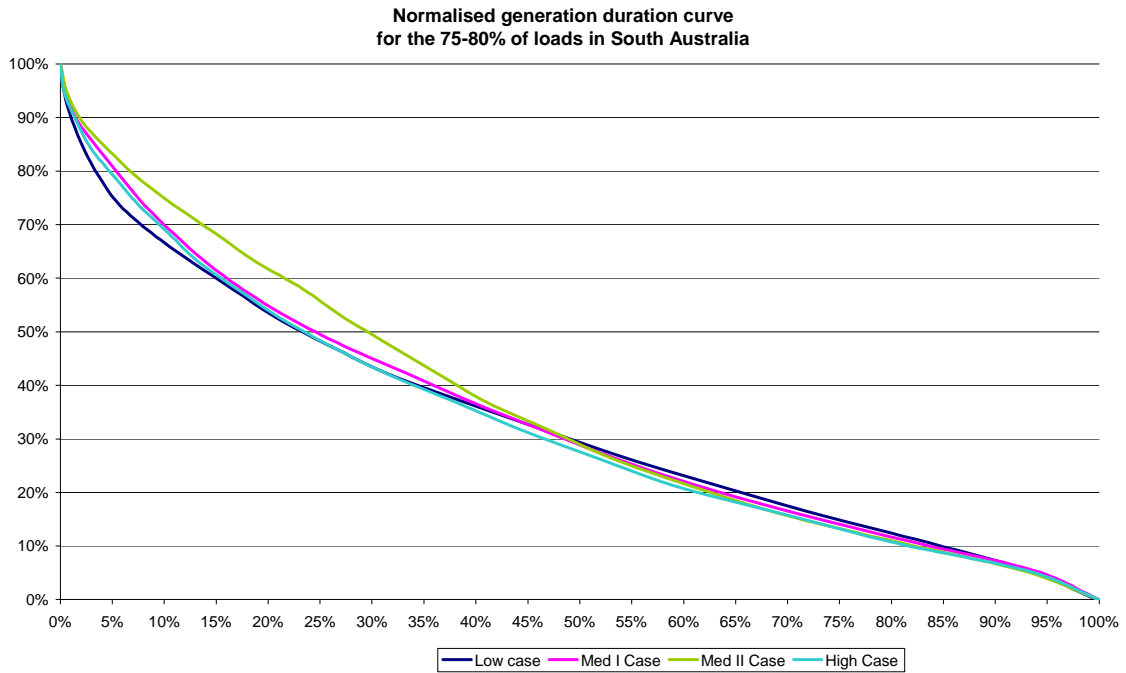


Figure 5-13 Normalised Generation Duration curve for loads occurring 75 to 80% of year

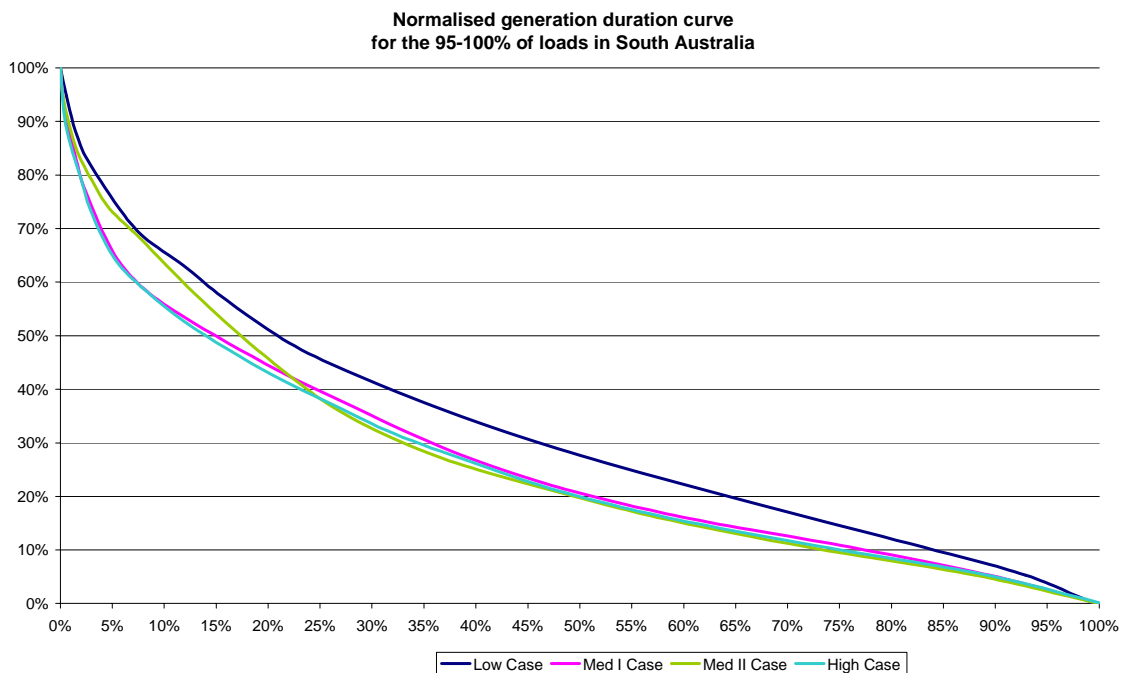


Figure 5-14 Normalised Generation Duration curve for loads in between 95 and 100% of the Peak South Australian Load

These curves show that during peak load periods, the dependable wind capacity is not significantly greater than that which was shown to have been available from an all hours analysis, as shown earlier, and lower than that which was predicted by the Summer peak hours analysis. Together this analysis shows that while the average output from the wind

farms is higher during the summer peak hours it does not necessarily provide more power during the periods of peak load.

These outcomes are consistent with the Planning Council conclusion that there was no significant relationship between the wind speed and temperature and would appear to indicate that while the contribution from wind generation during the peak hours of the summer months is likely to provide a higher average level of generation it still cannot be relied upon sufficiently to be considered firm. On the basis of these results it would appear that on the basis of the data used the calculation methodology and definition created for firm capacity the contribution of the wind farms is likely to be in the order of 8% of their installed capacity. It is also clear that the inclusion of wind power does not improve the State's load factor.

5.6 Chronological Model Results

The following is a summary of the results from the chronological model analysis of the operation of the NEM from the introduction of wind power. As with the statistical analysis the Planning Council ensured that the PLEXOS model used chronologically and spatially consistent data for its future load forecasts.

CHANGES TO THE EXISTING GENERATION

Using the firm capacity contributions as calculated for the wind farms as previously discussed, the PLEXOS model calculated the additional fossil fired capacity required to maintain the Reserve Standards as prescribed by the Reliability Panel. Figure 5-15 shows annual increase in the total installed capacity in the NEM including the nameplate capacity of the wind farms for each case while Figure 5-16 separates the additional fossil fuelled capacity in the NEM. This new capacity schedule was the same for all of the cases considered.

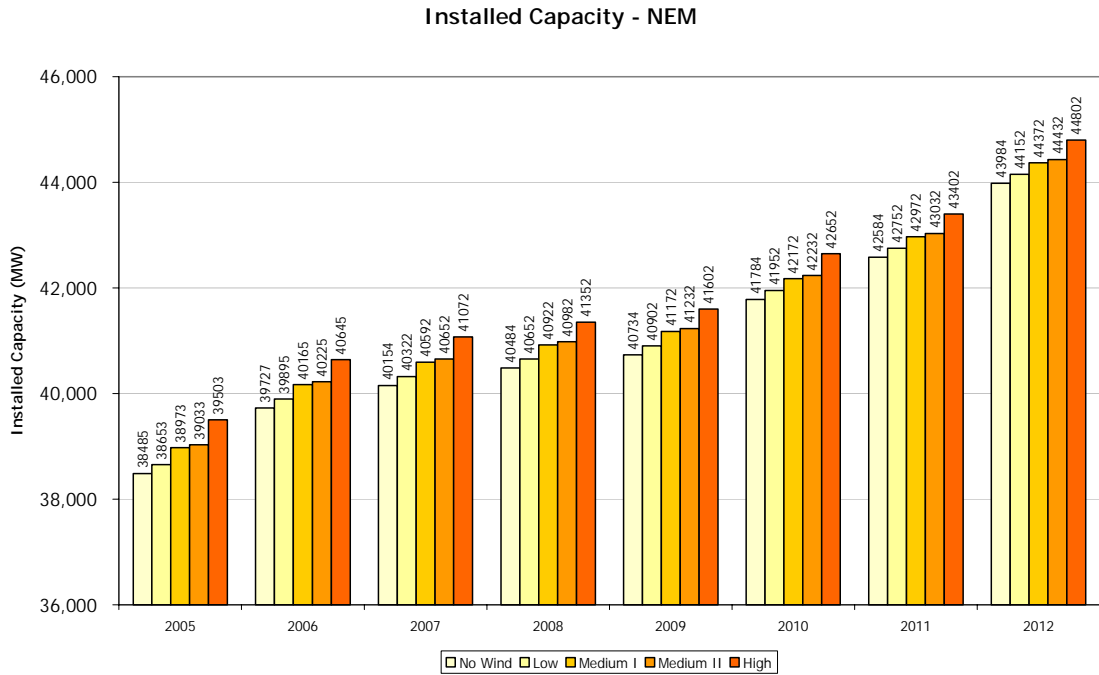


Figure 5-15 Installed Capacity in the NEM

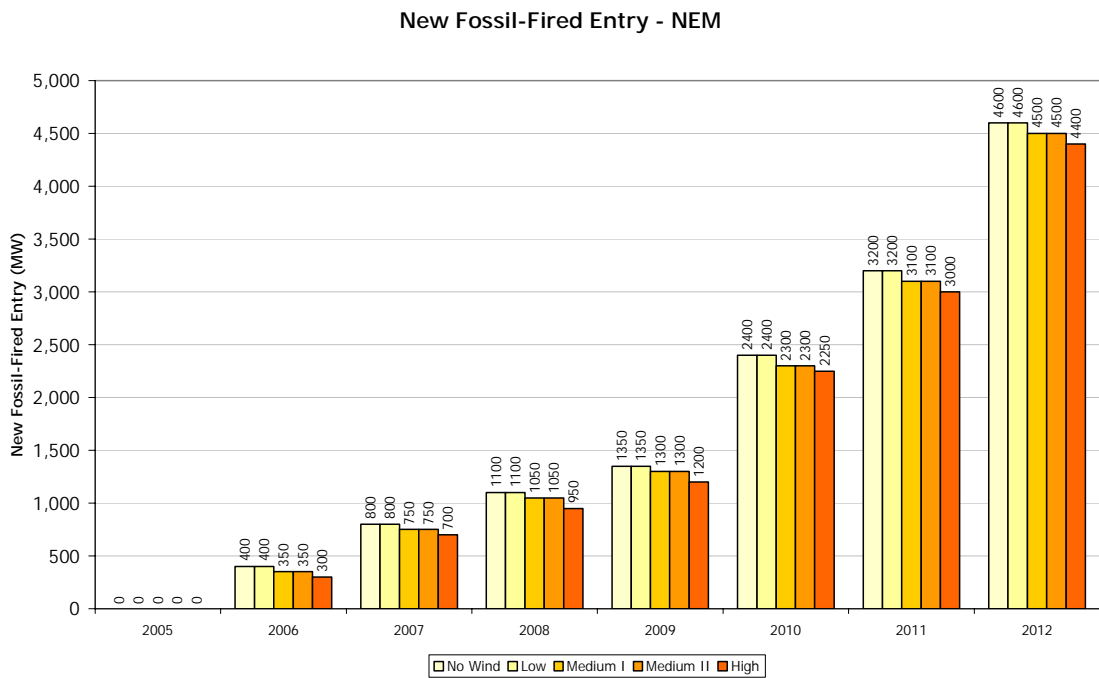


Figure 5-16 New fossil fired capacity in the NEM

CHANGES IN GENERATION IN SOUTH AUSTRALIA

On the basis of the wind data used Table 5-1 shows the annual energy contribution from the wind farms for the cases considered.

FINANCIAL YEAR	LOW CASE (GWH)	MED I CASE (GWH)	MED II CASE (GWH)	HIGH CASE (GWH)
30-Jun-05	494	1,452	1,689	2,996
30-Jun-06	481	1,448	1,735	3,000
30-Jun-07	463	1,394	1,659	2,916
30-Jun-08	473	1,426	1,733	2,948
30-Jun-09	514	1,497	1,710	3,082
30-Jun-10	454	1,422	1,708	2,880
30-Jun-11	494	1,452	1,689	2,996
30-Jun-12	483	1,454	1,742	3,013

Table 5-1 Wind energy contribution by case

The LRMC bidding scenarios indicate that wind generation in the State reduces the total generation from fossil fuels in the State and with time decreases the levels of net imports. The total South Australian generation and South Australian fossil fuelled generation results of the LRMC simulations for all cases are shown in Figure 5-17 and Figure 5-18 and for the SRMC simulations for all cases in Figure 5-19 and Figure 5-20. The differences between the generation levels for the SRMC and LRMC scenarios are, at times quite small because the Planning Council's approach to the allocation of fixed and variable costs is such that a majority of operating costs for the South Australian generators are considered variable.

In these simulations while the introduction of wind generation increases the total energy generation in South Australia, there is a significant reduction in generation from fossil fuels. That is, a large percentage of the energy generation from wind farms is offset by reductions in generation from the incumbent South Australian generators, and the rest is from reductions to net imports.

With an objective of long run marginal cost recovery for all of the participants in the NEM as opposed to the simple Fuel cost + Variable O & M offers used in the SRMC analysis, the South Australian generators generate more energy. This is primarily due to the significant fixed costs imposed on the interstate generators from their higher sale prices and scale.

A loss of market share by the South Australian generators such as in the LRMC cases may well result in a behavioural change that this Study has not attempted to predict. The impact of the wind generation on the incumbent South Australian generators could possibly be reduced to some degree with some staging of the wind farm developments. However because of the wind farms do not contribute significantly to the firm capacity in the State, a delay in their implementation would still require some level new entry.

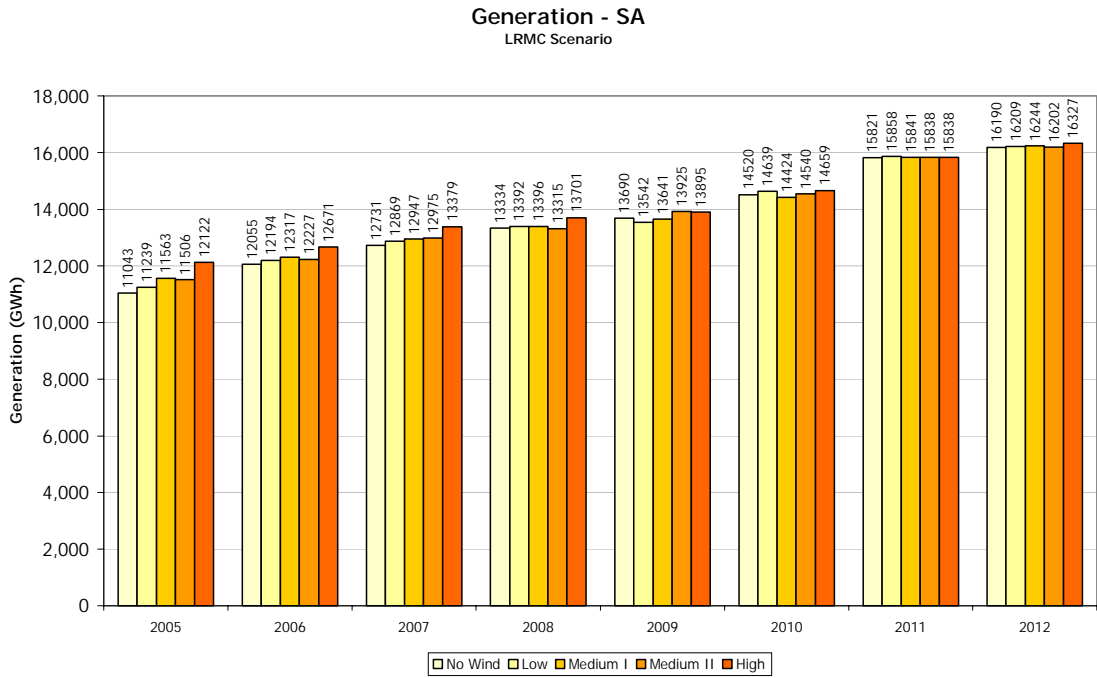


Figure 5-17 Total South Australian generation (LRMC)

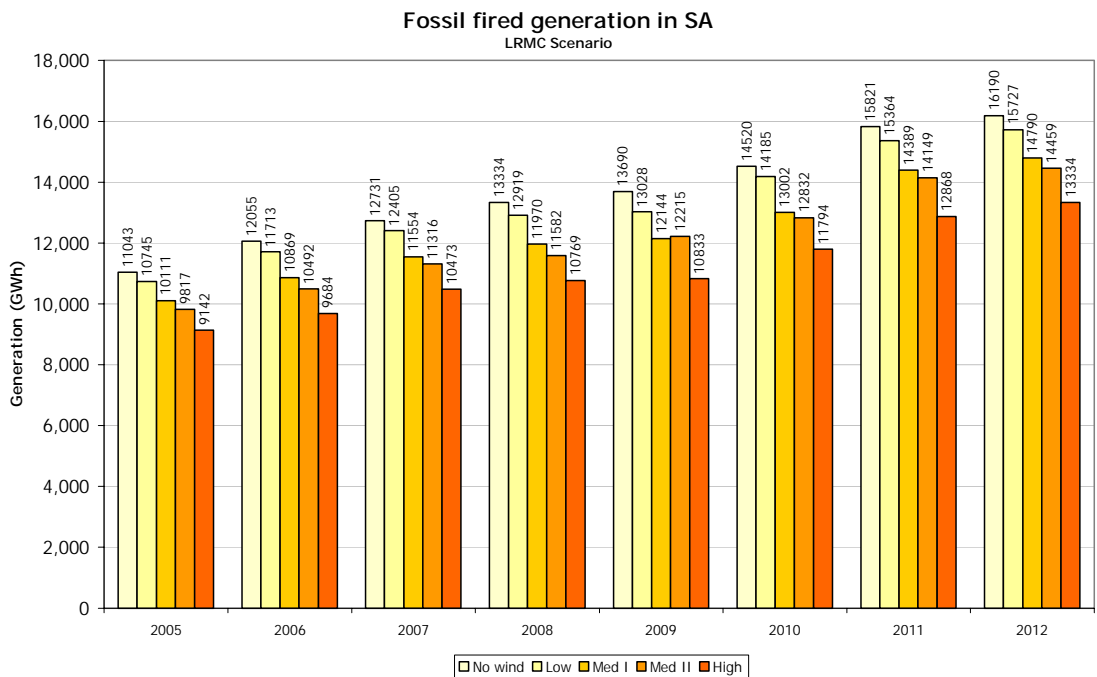


Figure 5-18 South Australian fossil fired generation (LRMC)

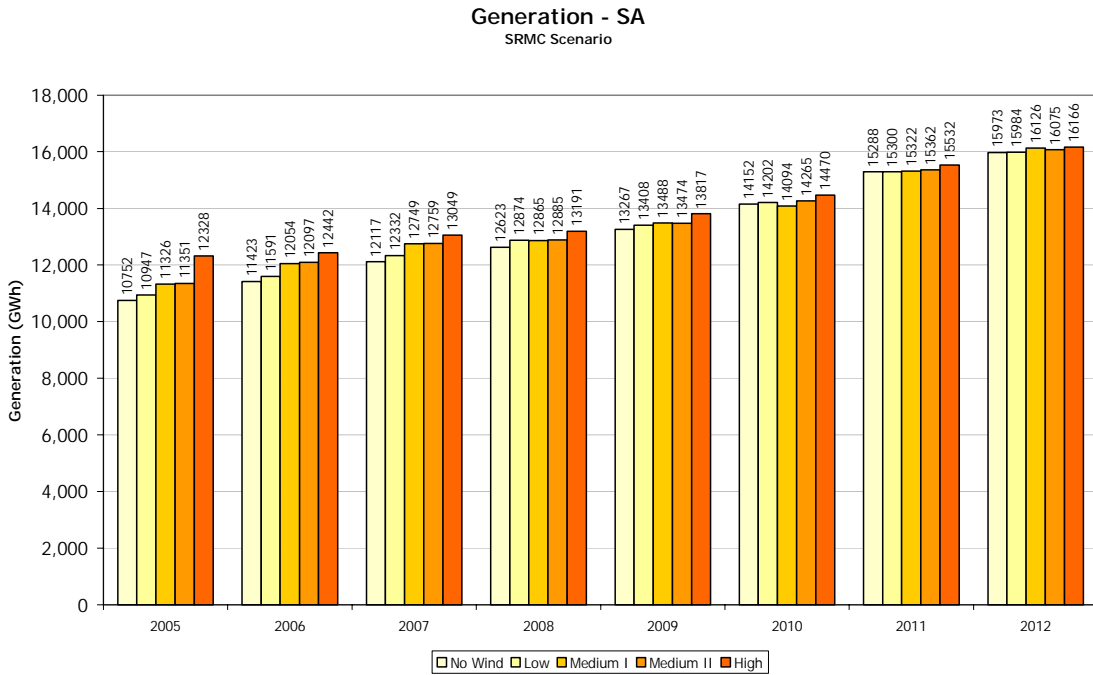


Figure 5-19 Total South Australian generation (SRMC)

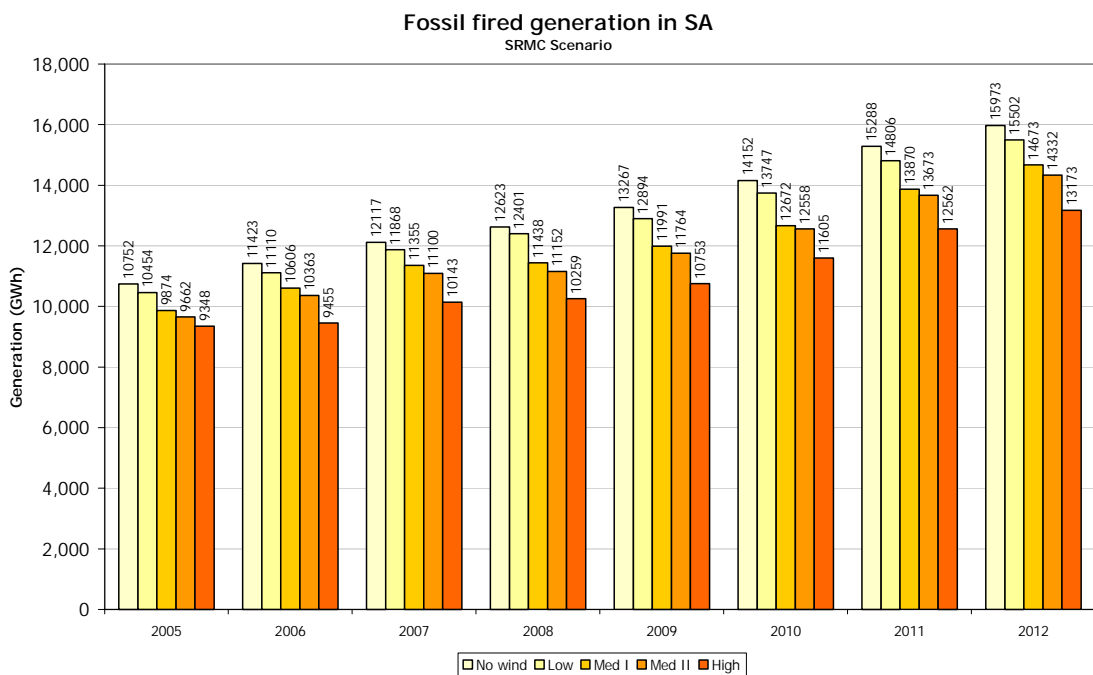


Figure 5-20 South Australian fossil fired generation (SRMC)

CHANGES INTERCONNECTOR OPERATION.

As discussed earlier the introduction of wind generation into the South Australian market does not just affect South Australia. The total generation and fossil fuelled generation results indicate that while wind generation displaces South Australian generation there is also a net reduction in net import levels into the State. It is significant here that the majority of the energy produced by the wind farms is lost from South Australian

generators. Base load generation in South Australia is largely unaffected by the introduction of wind power. The bulk of the reductions are seen in the more marginal gas based electricity production.

The change in the net imports into South Australia flows on the interconnectors for the LRMC scenario is shown in Figure 5-21 and the SRMC scenario in Figure 5-22. This indicates with time that the South Australian generators' market share is recovering to some degree, as the levels of reserve capacity in other regions reduces. As would be expected there is a considerable difference in net interchange with South Australia under the SRMC and LRMC bidding scenarios.

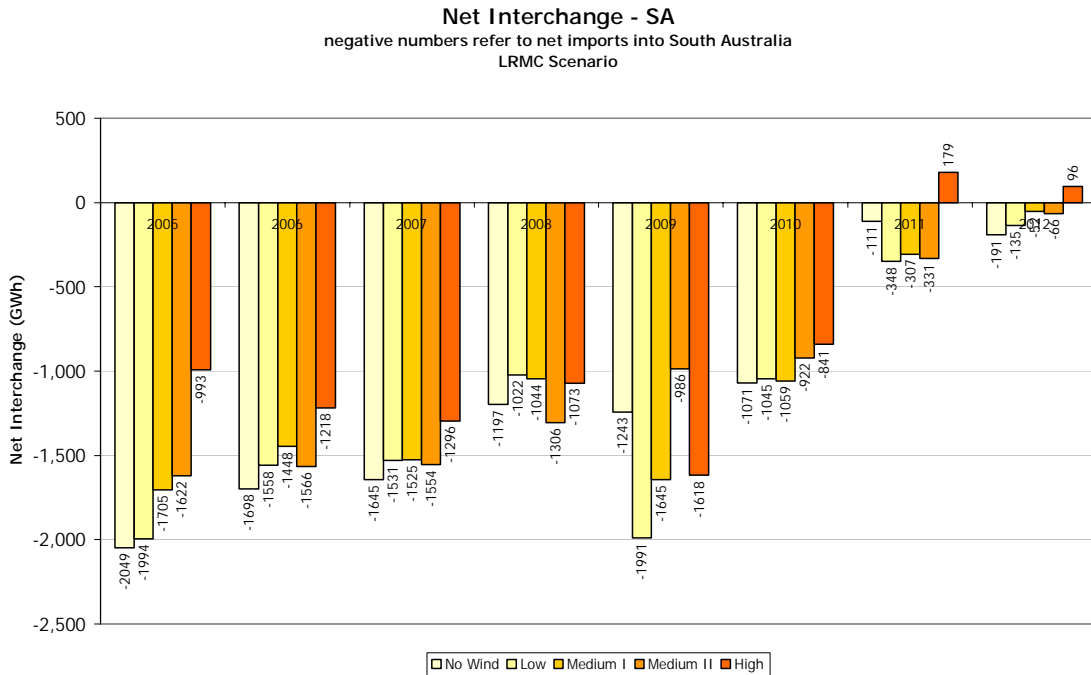


Figure 5-21 Change in the net interchange (LRMC)

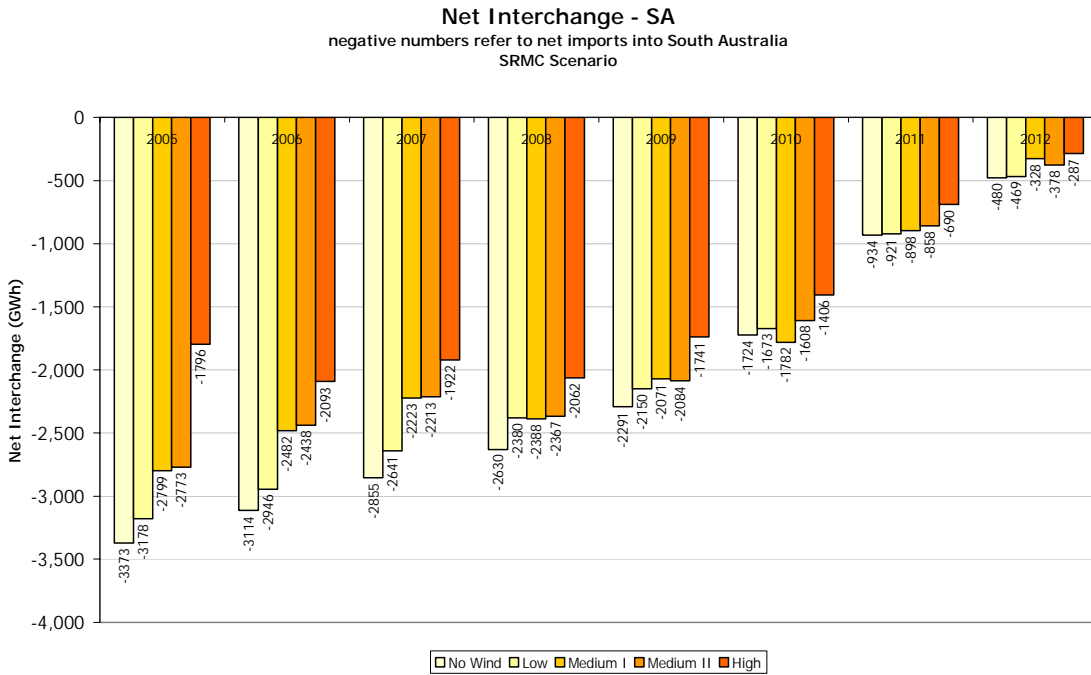


Figure 5-22 Change in the net interchange (SRMC)

Figure 5-21 and Figure 5-22 show the changes in the utilisation of the Heywood and Murraylink interconnectors in to South Australia.

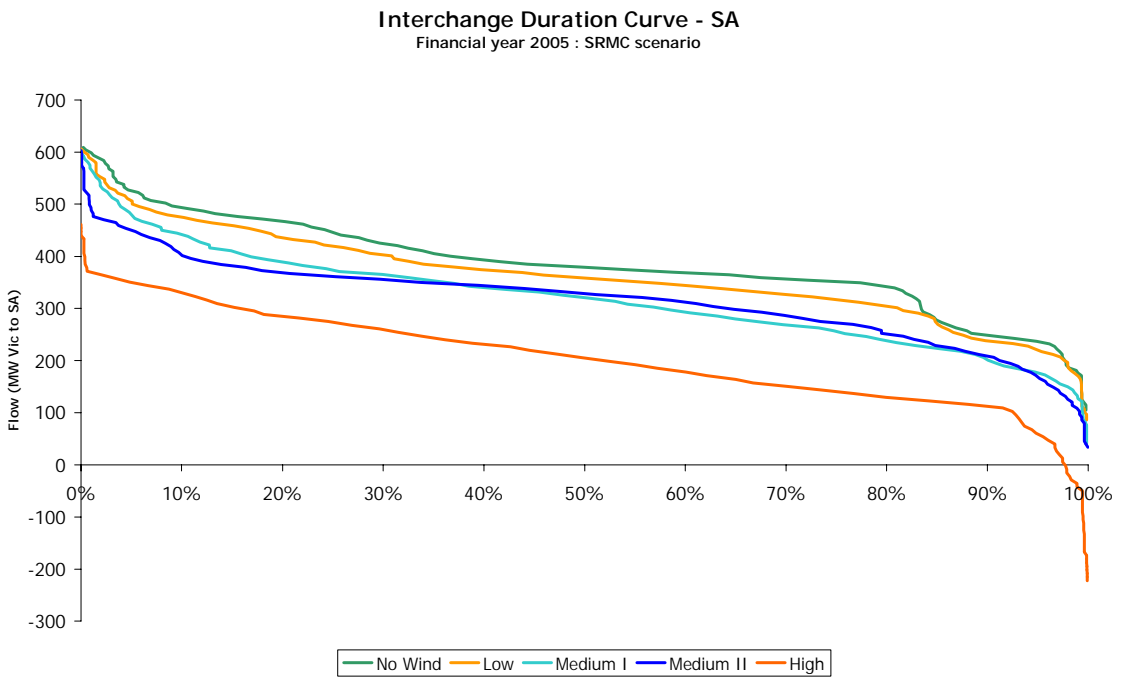


Figure 5-23 Net interchange flow duration curve (SRMC)

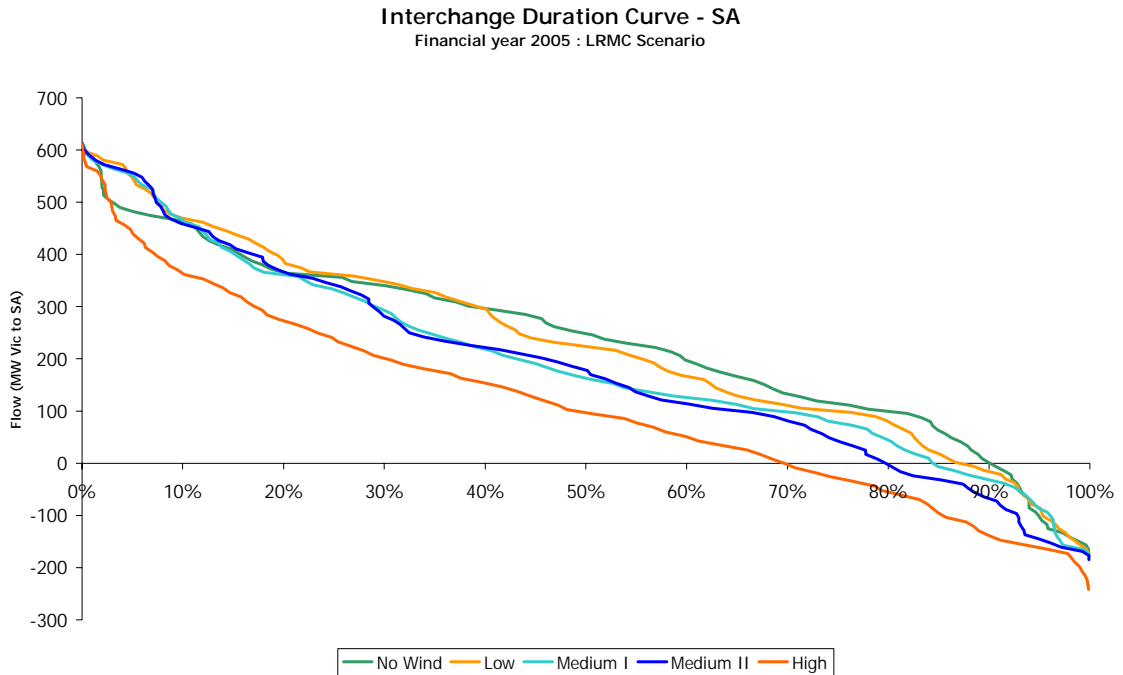


Figure 5-24 Net interchange flow duration curve (LRMC)

CHANGES IN GAS UTILISATION

Changes to the utilisation of fuel in South Australia, particularly natural gas, is seen by the Planning Council as one of the critical aspects of the impact of wind generation. The natural merit order in South Australia makes the natural gas fired generators in the State most likely to be affected by the introduction of wind power. The consequential changes to fossil fuelled generation as a result of variations from wind power could result in reduced output and increased variation in operation, affecting the total quantity, certainty and predictability of natural gas demand. This effect is clearly evidenced in the changes to the daily and hourly gas duration curves for the LRMC and SRMC scenarios are shown in Figure 5-25 to Figure 5-28. This could potentially increase the transport cost of gas and increase the difficulty in effectively managing receipts and deliveries into the gas network.

Increases in the variability of demands on the gas producers could exacerbate the complexities in scheduling of production and transport, however the net reduction in utilisation of gas as a result of wind could extend the life of the available reserves.

Daily Gas Duration Curve - SA
Financial year 2005 : LRM Scenario

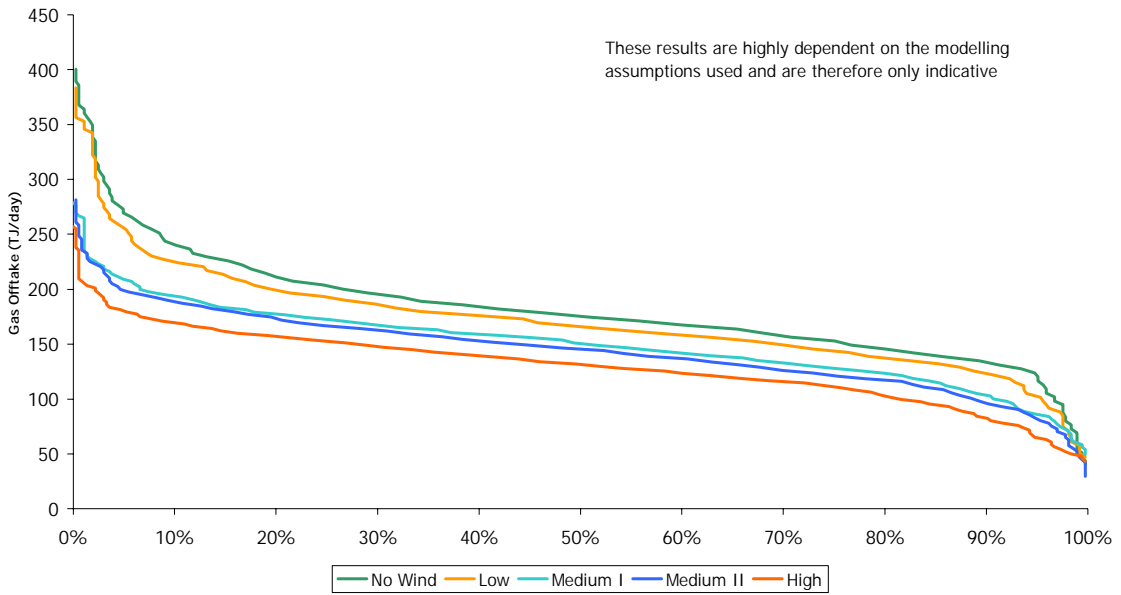


Figure 5-25 South Australian daily gas duration curve (LRMC)

Hourly Gas Duration Curve - SA
Financial year 2005 : LRM Scenario

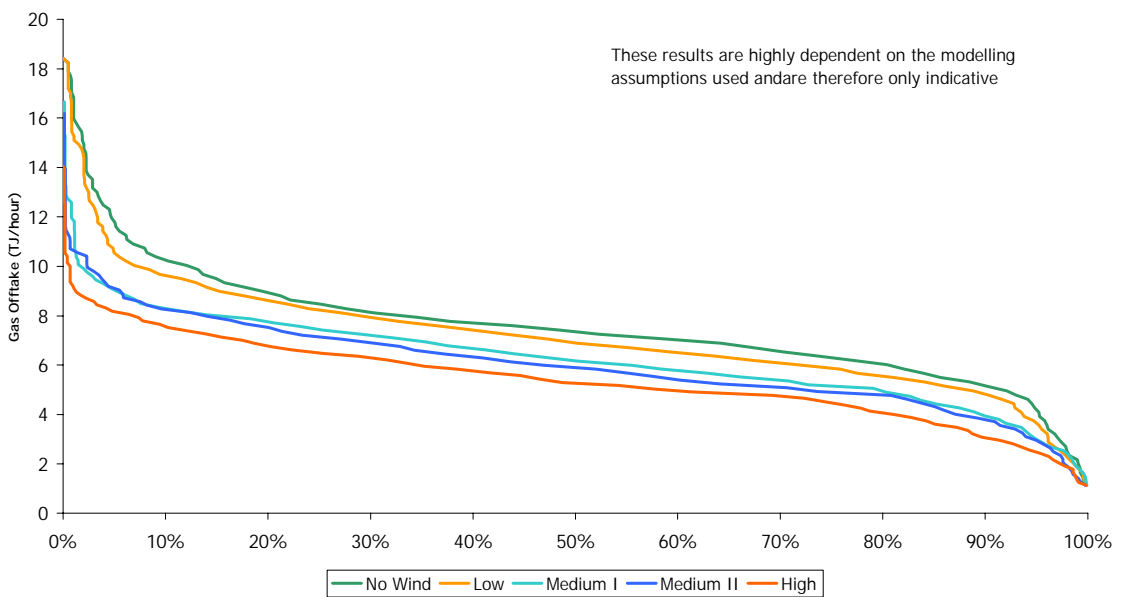


Figure 5-26 South Australian hourly gas duration curve (LRMC)

Daily Gas Duration Curve - SA
Financial year 2005 : SRMC Scenario

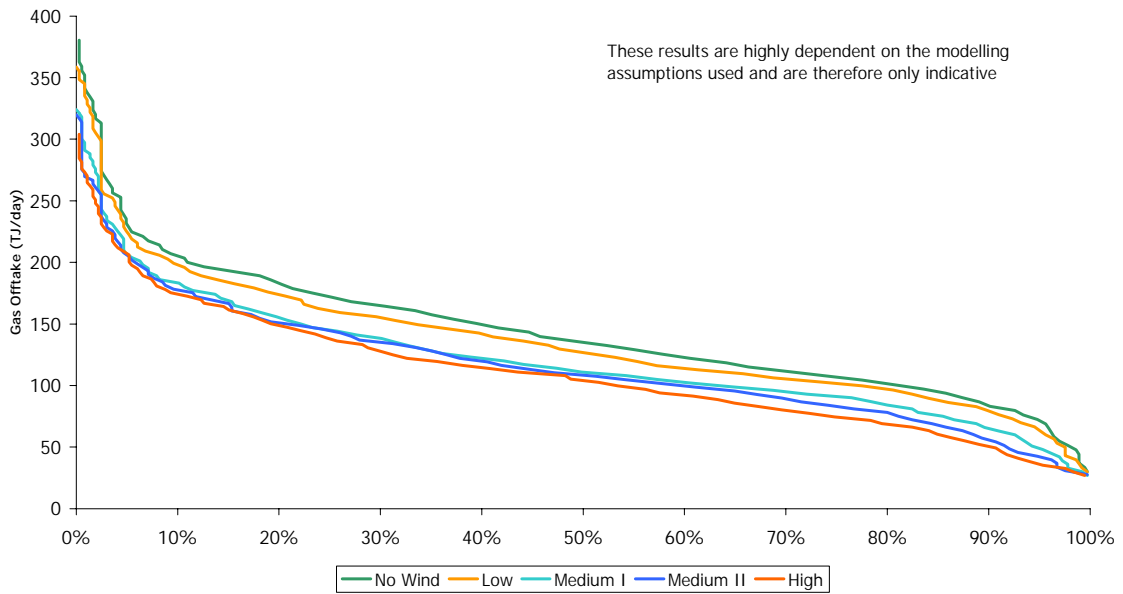


Figure 5-27 South Australian daily gas duration curve (SRMC)

Hourly Gas Duration Curve - SA
Financial year 2005 : SRMC bidding

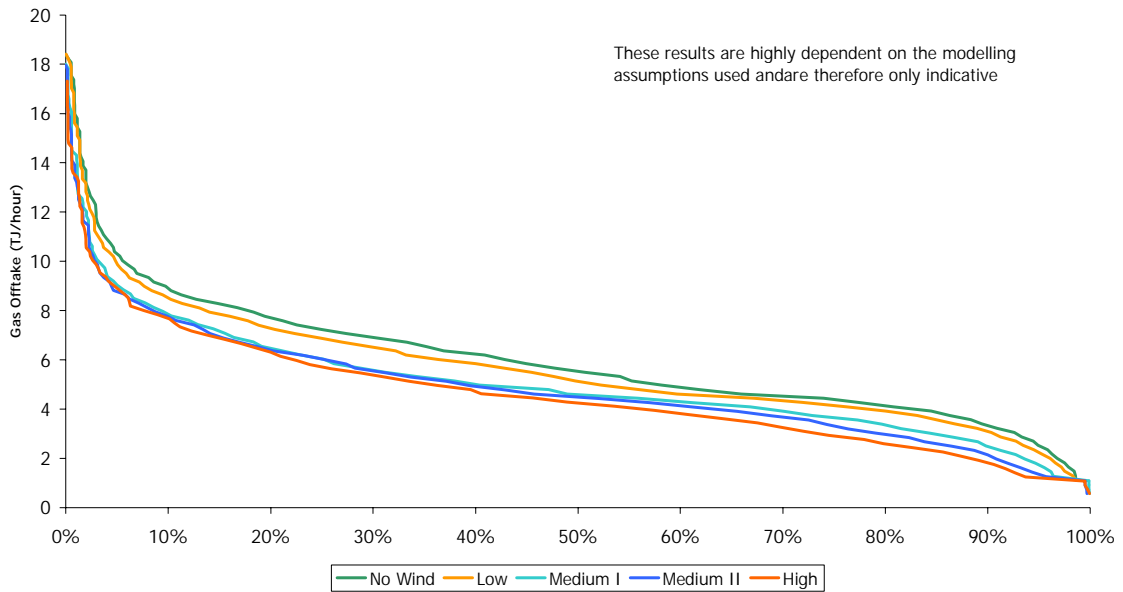


Figure 5-28 South Australian hourly gas duration curve (SRMC)

CHANGES IN CO₂ EMISSIONS

Significant to the introduction of wind power is the consequential reduction in greenhouse gas emissions. It is normal for the wind proponents to quote reductions in Greenhouse gas emissions based on their energy contribution to the NEM and the average CO₂ emission rates as published by the Australian Greenhouse Office in their National Greenhouse Inventory. By accounting for the operational constraints and performance

degradation of the fossil fuelled generators in the NEM the Planning Council’s modelling has provided a more accurate assessment of the reduction in Greenhouse gas emissions that could be expected. Figure 5-29 to Figure 5-32 show the Planning Council forecast of the reduction in greenhouse gas emissions for each case considered. Variation in the levels of reduction is related to the types of new entrant needed in the market and potentially the strength of the wind resource in that year. CO₂ reductions were smaller in the SRMC case, reflecting the increased generation from sources such as coal, with higher emission rates, this result is consistent with increased imports and reduced local generation.

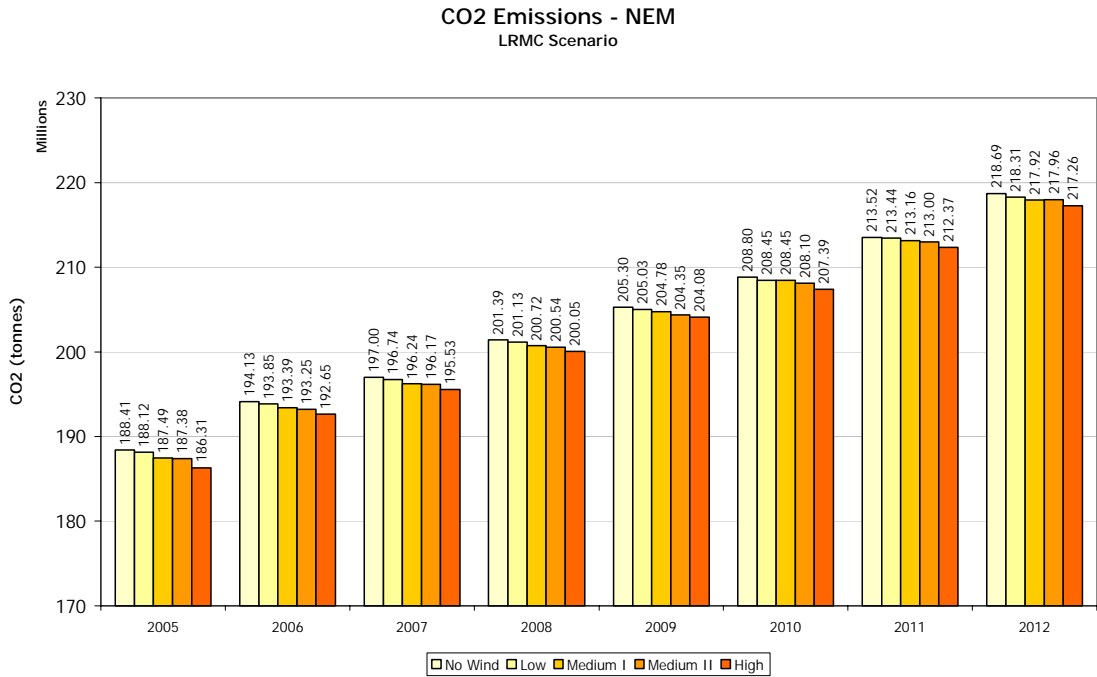


Figure 5-29 Greenhouse gas emissions across the NEM (LRMC)

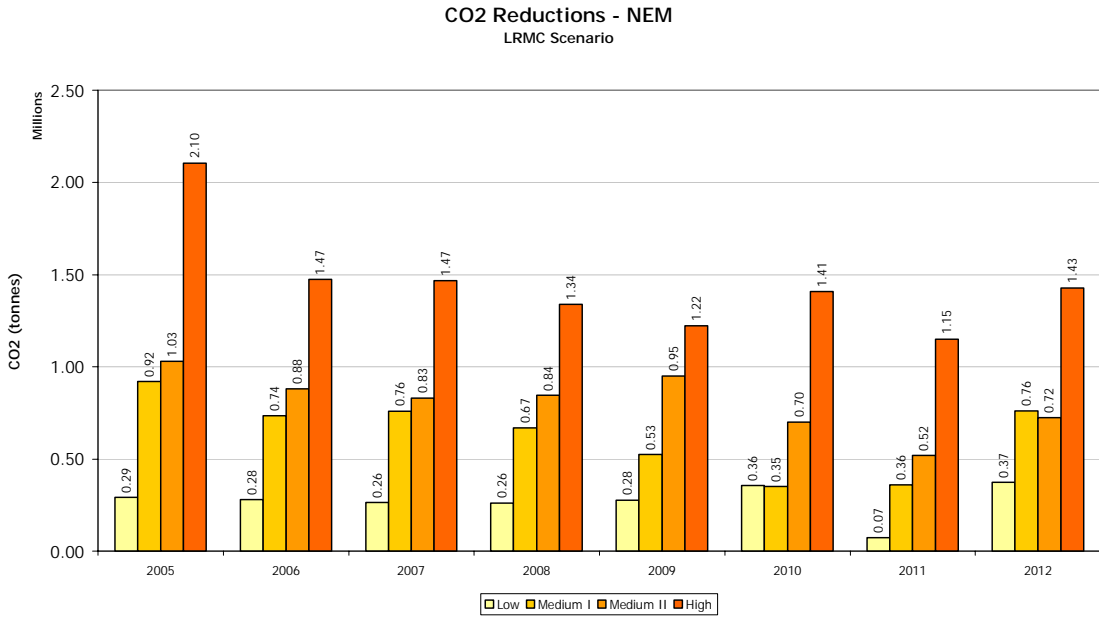


Figure 5-30 Change in greenhouse gas emissions with respect to the base case (LRMC)

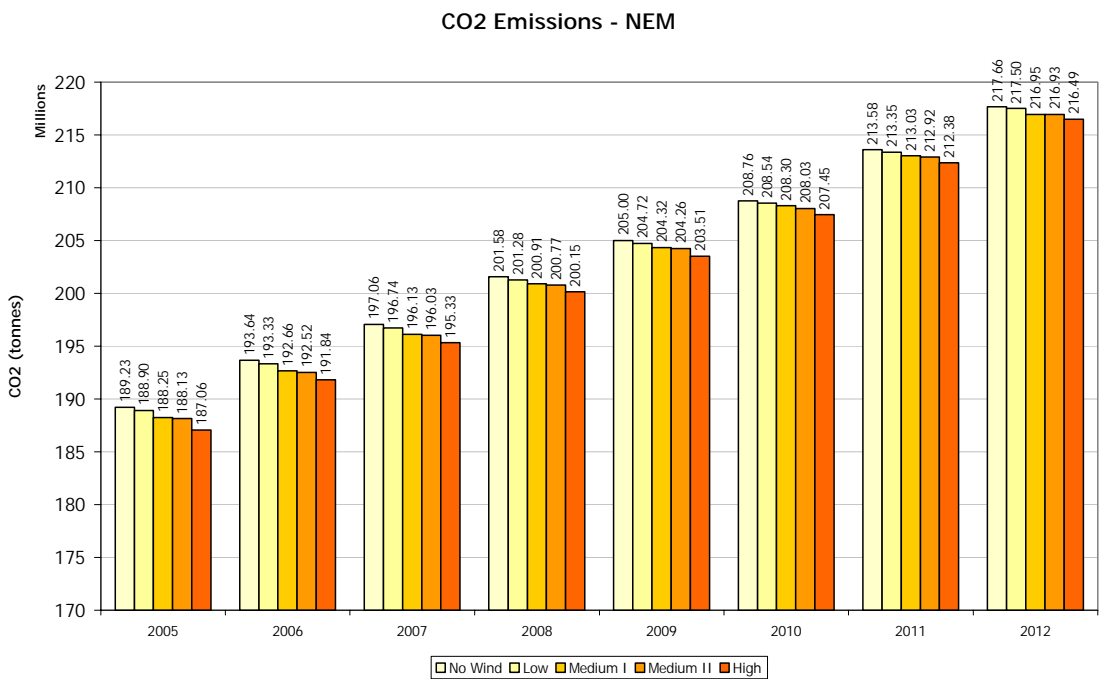


Figure 5-31 Greenhouse gas emissions across the NEM (SRMC)

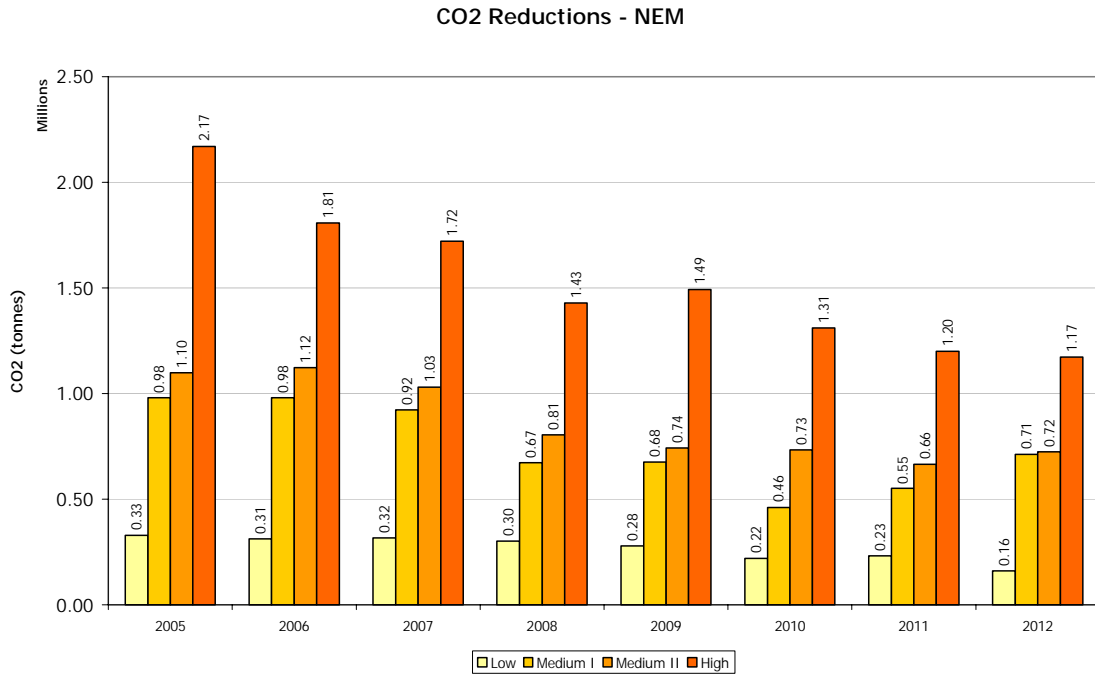


Figure 5-32 Change in greenhouse gas emissions with respect to the base case (SRMC)

Losses in the Network

As stated in the assumptions section of this report intra-regional transmission lines and constraints have not been included in the analysis. The model does however model the inter-regional transmission network including loss functions for the notional interconnectors. On a total generation basis, the results of the analysis indicate that for the LRMC cases the inclusion of wind power increases the losses in the NEM, while for the SRMC cases the outcome is less conclusive. This situation with increased network losses would appear to reduce during the study period, reaching a point where the net generation in the network is reduced. Without significant additional research the cause for this affect is unknown. It may, however, be related to the chronological load and wind data used in the study or the re-evolution of the location, role, technology and size of the new entrants in the market.

APPENDIX 1: CARBON TAX SENSITIVITY RESULTS

The Planning Council also investigated the sensitivity of the results with respect to the inclusion of a carbon tax. On discussion with the Australian Greenhouse Office and using greenhouse gas production figures from the latest National Greenhouse Inventory, the Planning Council applied a cost penalty equivalent to \$10/ton CO_{2eq} produced by each station in the NEM. CO_{2eq} represents the combination of the emissions of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and perfluorocarbons (PFCs) on the basis of the respective Global Warming Potentials (GWP) of each chemical. This is calculated by multiplying the actual mass of emissions by the appropriate GWP factor published by the Intergovernmental Panel on Climate Change (IPCC 1995). While the GWP's may vary as environmental research continues and with the time horizon under consideration the GWPs used in this document are 1 for carbon dioxide, 21 for methane, 310 for nitrous oxide, 6500 for the PFC perfluoromethane (CF₄) and 9,200 for the PFC perfluoroethane (C₂F₆).

The new generation construction schedules for the carbon tax sensitivity analysis are the same as those used in the preceding analysis. Trends in generation patterns were similar to those from the initial analysis, however have been some increases in the total quantity of generation in South Australia reflecting a slight shift in the merit order as a result of the imposition of the Carbon Tax.

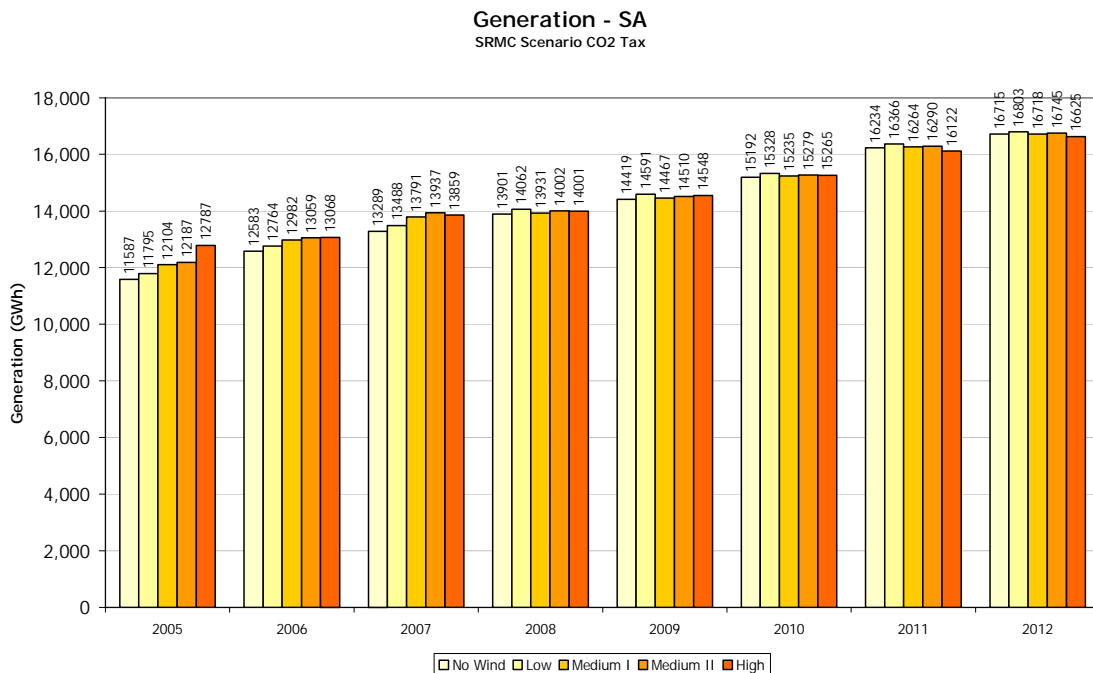


Figure 5-33 Total South Australian generation with CO₂ Tax (SRMC)

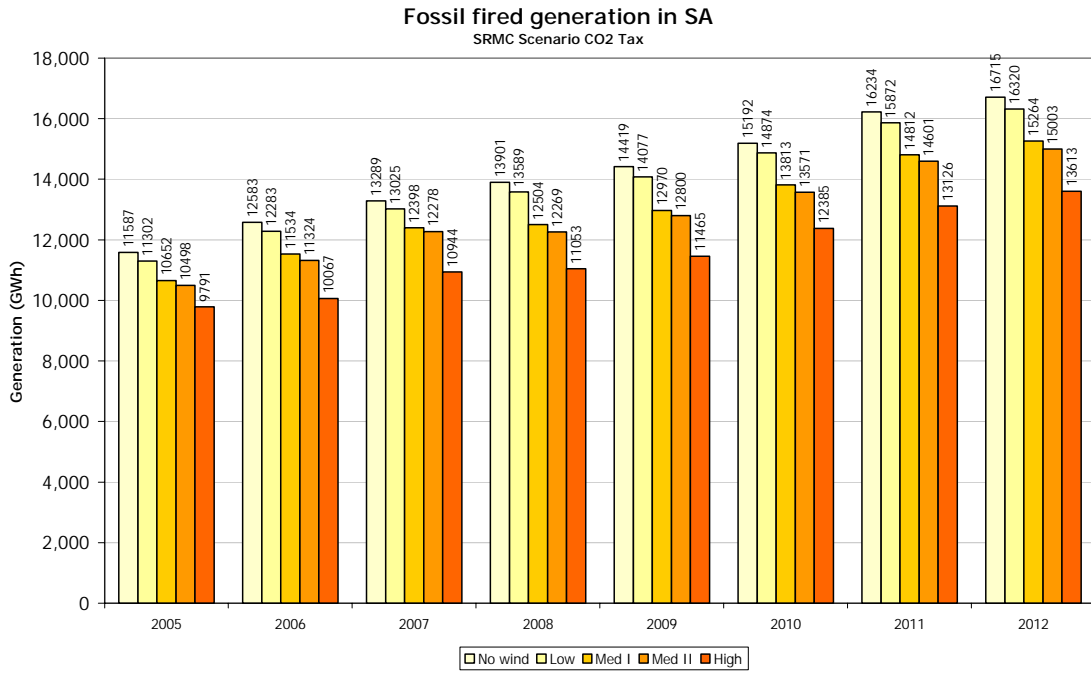


Figure 5-34 South Australian fossil fired generation with CO₂ Tax (SRMC)

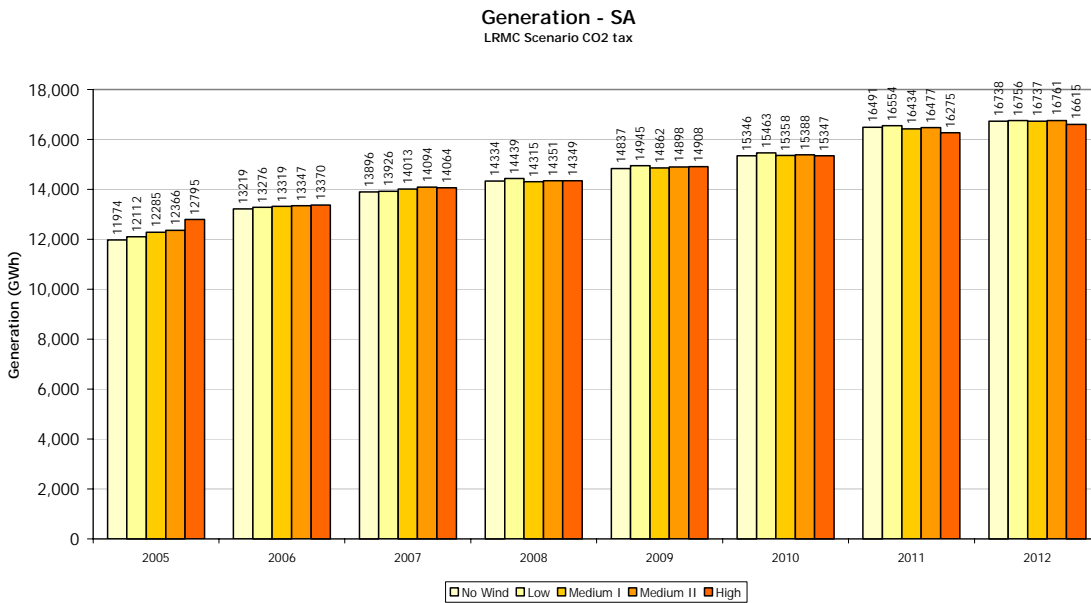


Figure 5-35 Total South Australian Generation with CO₂ Tax (LRMC)

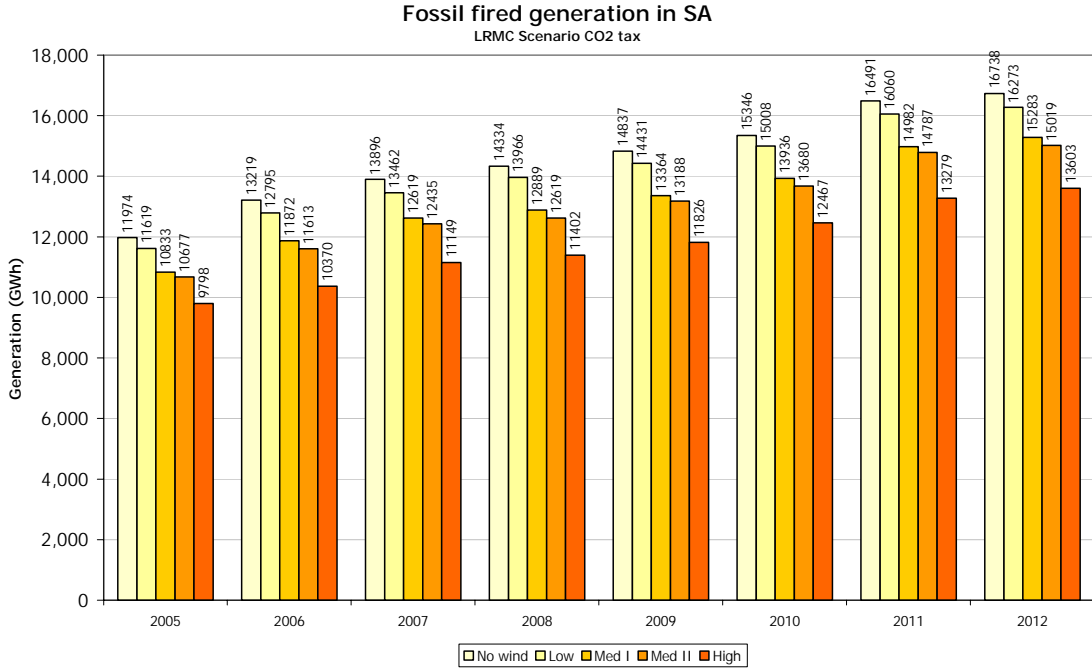


Figure 5-36 South Australian fossil fired generation with CO₂ Tax (LRMC)

The impact of the carbon tax on net imports is not quite the same with the marginal position of the natural gas plant emphasised but the annual variations.

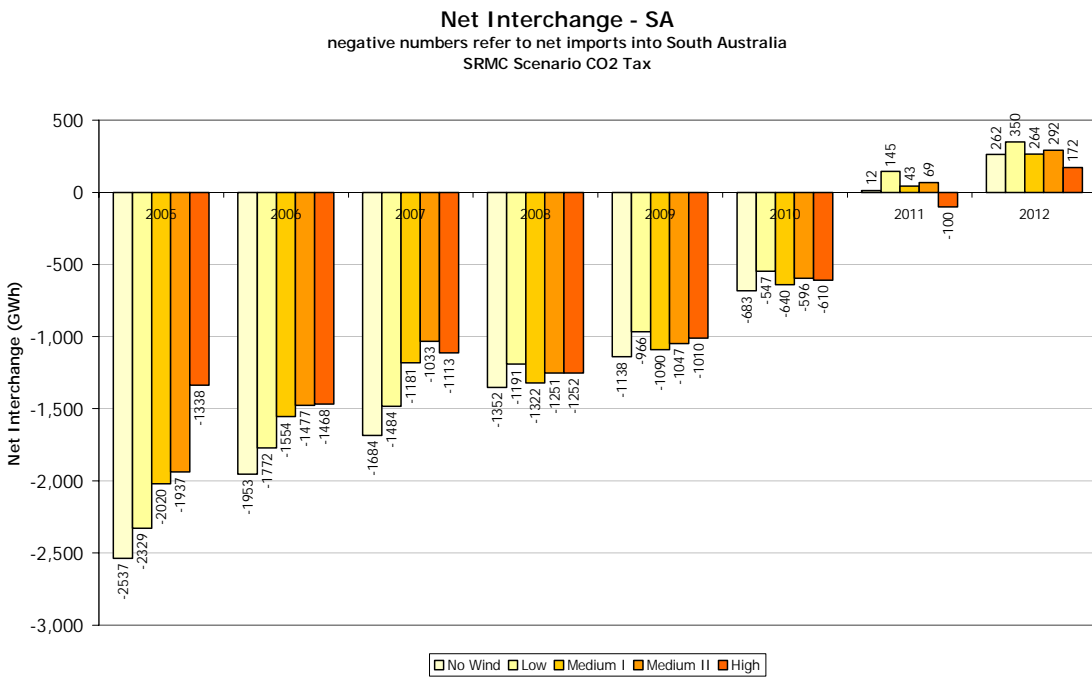


Figure 5-37 change in the net interchange to South Australia with CO₂ Tax (SRMC)

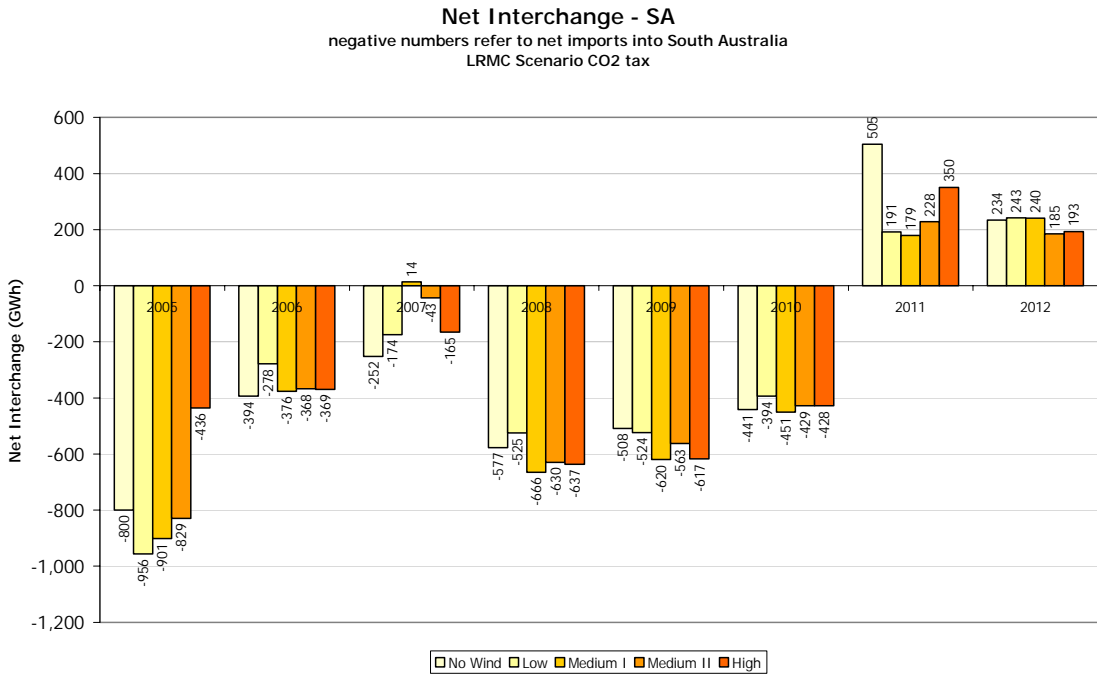


Figure 5-38 change in the net interchange to South Australia with CO₂ Tax (LRMC)

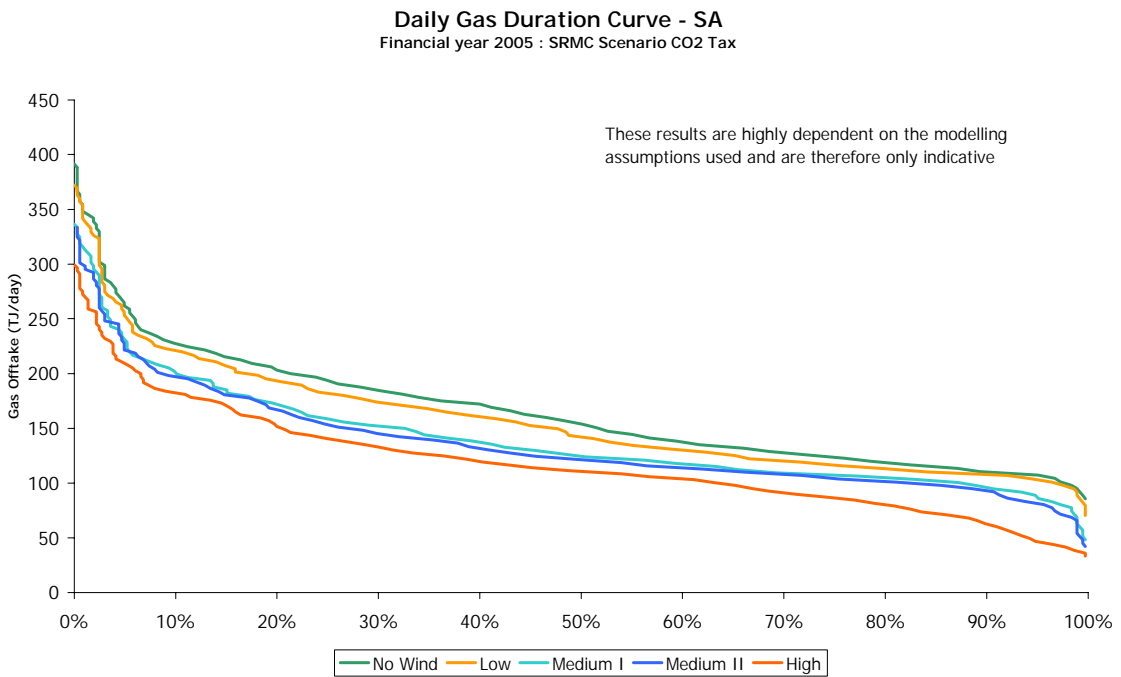


Figure 5-39 South Australian daily gas duration curve with CO₂ Tax (SRMC)

Daily Gas Duration Curve - SA
Financial year 2005 : LRMC Scenario CO2 tax

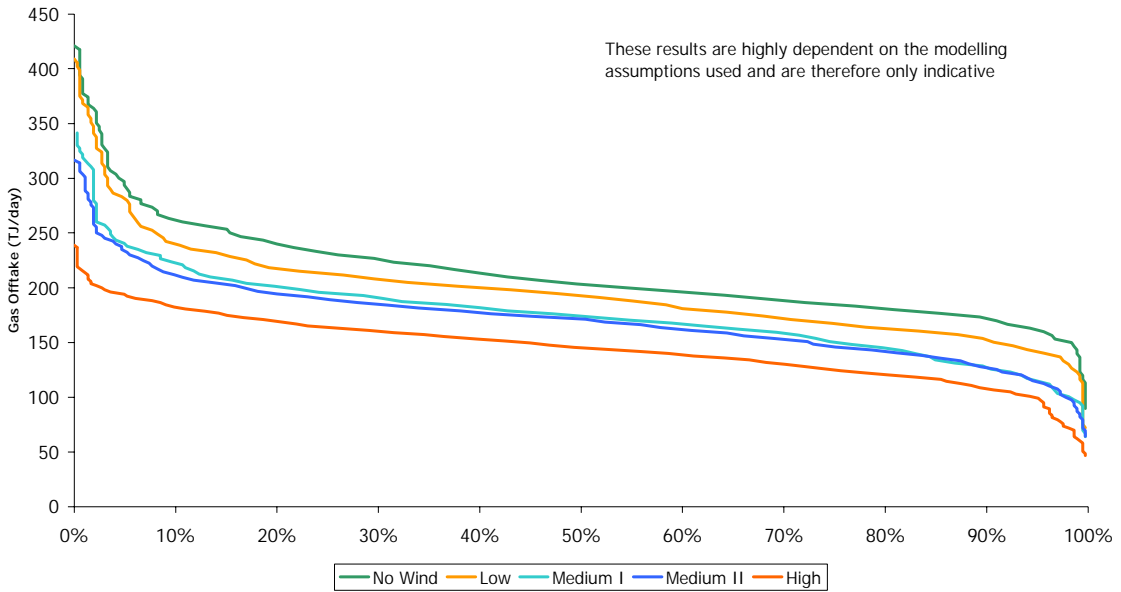


Figure 5-40 South Australian daily gas duration curve with CO₂ Tax (LRMC)

CO2 Emissions - NEM
SRMC Scenario CO2 Tax

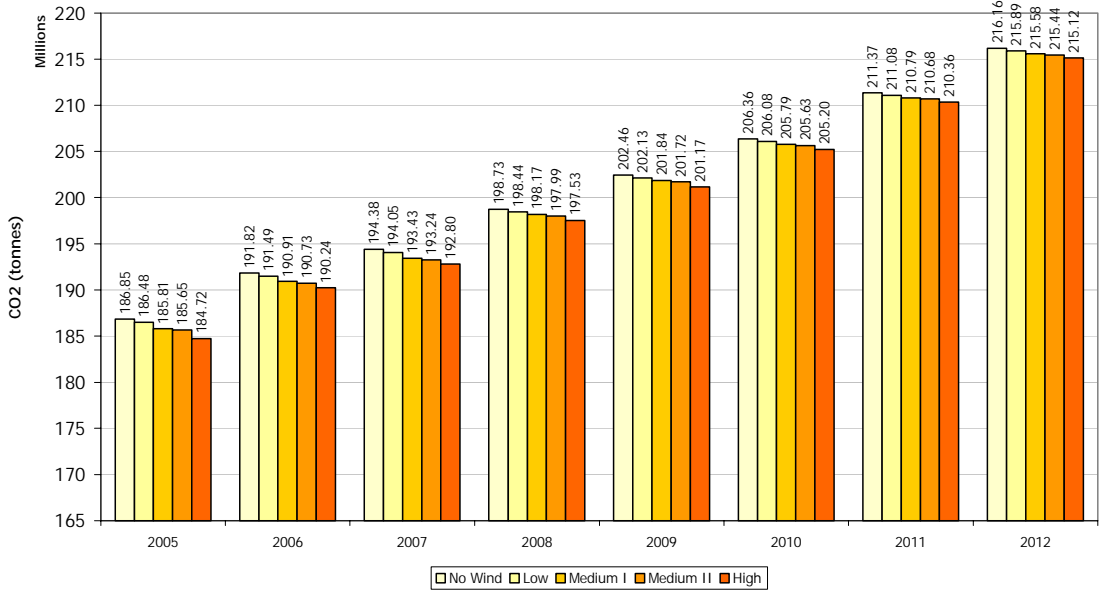


Figure 5-41 Greenhouse gas emissions across the NEM with CO₂ Tax (SRMC)

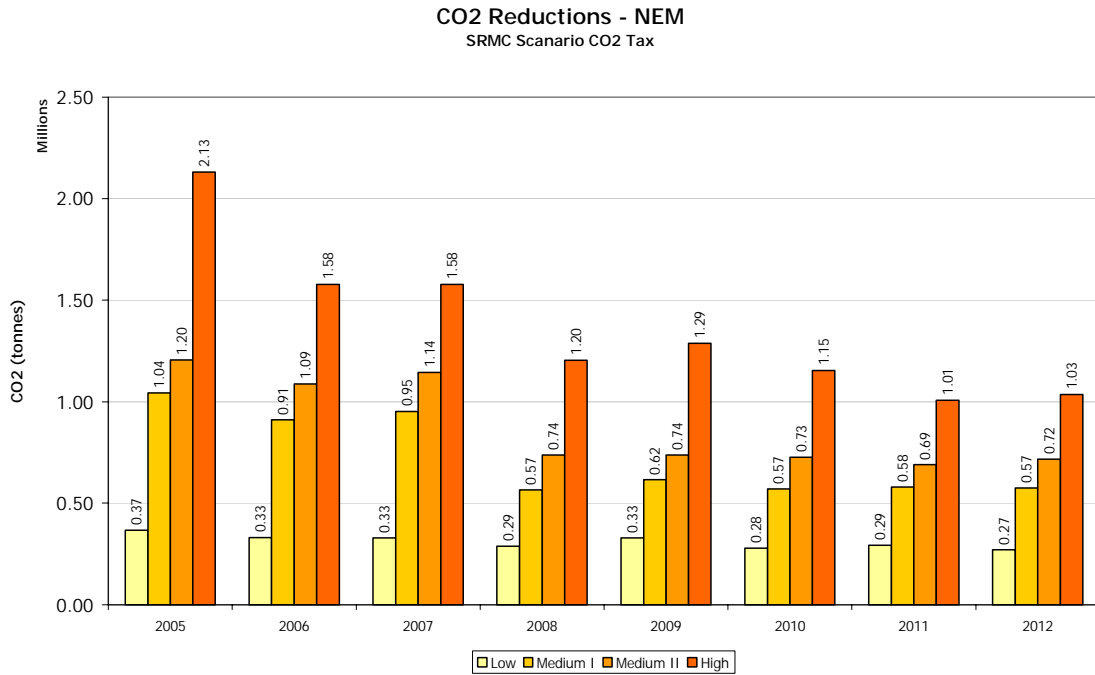


Figure 5-42 Change in greenhouse gas emissions with respect to the base case with CO₂ Tax (SRMC)

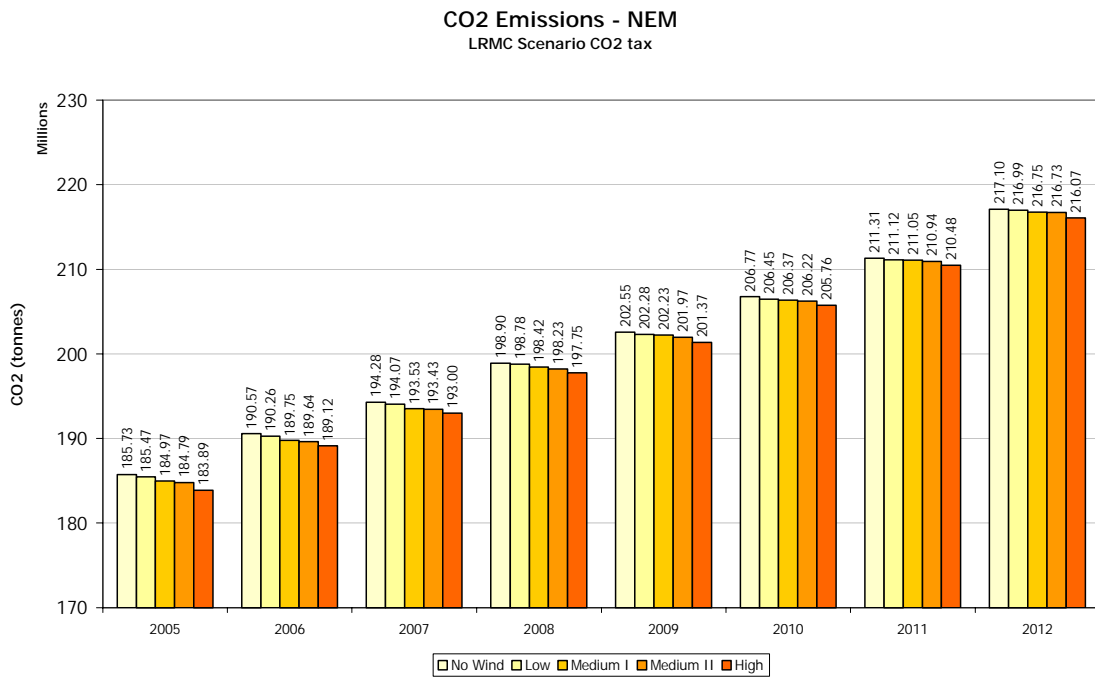


Figure 5-43 Greenhouse gas emissions across the NEM with CO₂ Tax (LRMC)

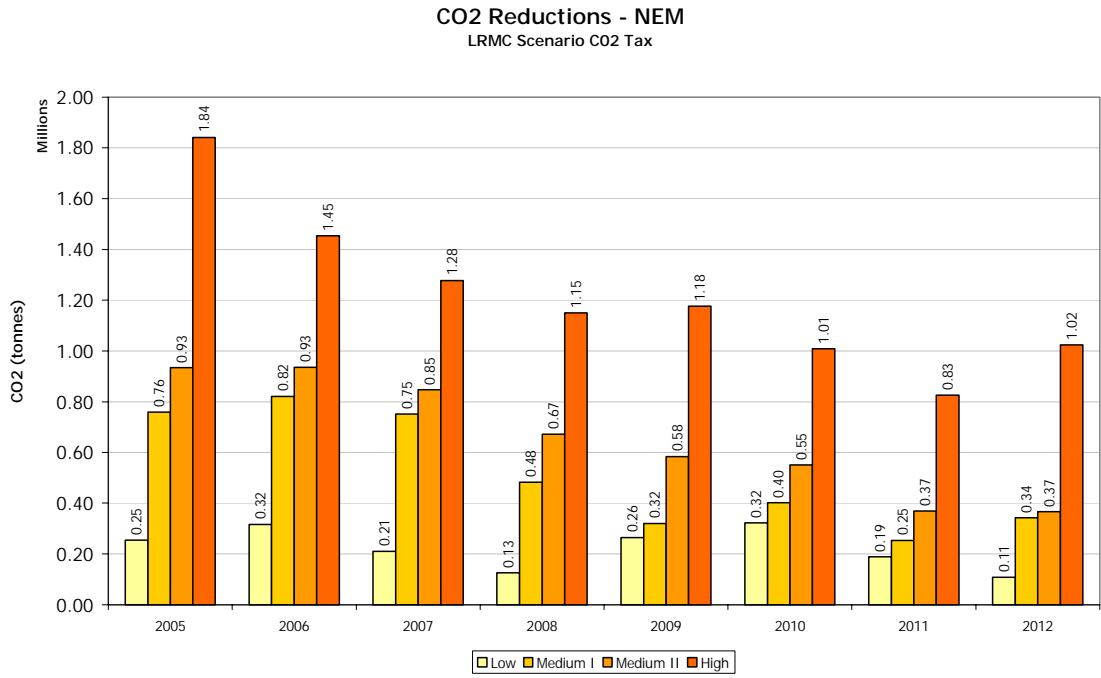


Figure 5-44 Change in greenhouse gas emissions with respect to the base case with CO₂ Tax (LRMC)

APPENDIX 2: INTERCONNECTOR CAPACITY

LINE ID	FROM	NODE TO	MAX FLOW (MW)	MAX FLOW BACK (MW)
Murraylink	Victoria (Thomastown)	South Australia (Torrens Island)	220	220
Directlink	NSW (Sydney West)	Queensland (South Pine)	170	170
QNI	NSW (Sydney West)	Queensland (South Pine)	530	1000
SNOWY	Snowy Mountains (Murray)	NSW (Sydney West)	3000	1170
Heywood	Victoria (Thomastown)	South Australia (Torrens Island)	530	470
V-SN	Snowy (Thomastown)	Snowy Mountains (Murray)	1100	1900

While the figures in the above table were used as the absolute maximum capacities of the interconnectors, the Planning Council also implemented the constraint equations as described in the NEMMCO 2002 Statement of Opportunities.

APPENDIX 3: THE REGULATORY TEST

5.7 Role of the Regulatory Test

The purpose of the Regulatory Test is to assess the merits of potential investments in the transmission system.

The Australian Competition and Consumer Commission (ACCC) determination holds that an transmission investment proposal satisfies the Regulatory Test if it maximizes the net present value of the market benefit, with respect to a number of alternative projects, timings, and market development scenarios.¹⁰ It is primarily a cost-benefit style test to assess the economic benefits of a proposed project against the project's reasonable alternatives (including a "do nothing" or base-case scenario).

Should a network project proposed by a Transmission Network Service Provider pass the Regulated Test, it is able to apply to the ACCC to have the value of that project included in its regulated asset base and thus earn a regulated return over the life of the project.

Occasionally, the NEM's use of a regional pricing model, as opposed to a locational (nodal) model, prevents potential investors from capturing the full benefits of their investment(s).¹¹ Consequently, it is possible that investments in the network should proceed from a market-wide, assessment of benefits and costs, but would not proceed from the perspective of the potential investor because the latter does not capture all of the benefits of the investment under regional pricing.

An investment proponent may still propose a potential investment project and fund it privately, relying on market revenue to cover the investment.

5.8 Key Aspects of the Regulatory Test¹²

COSTS AND BENEFITS

An assessment of the Regulatory Test considers the electricity market as a closed system, accounting for net changes to the cost of inputs and outputs to the market as a whole. As such it does not consider the impact of internal wealth transfers between participants in the market resulting from changes to pool price.

¹⁰ If the purpose of a proposal is to meet an objectively measurable service standard associated with the technical requirements of schedule 5.1 of the Code, the proposal must minimise the net present value of the cost of meeting those standards.

¹¹ An excellent example is transmission investment in the NEM. In a locational pricing model, the value of interconnection is captured by the rental (settlement surplus) that accrues from operation of the new line. If the rental earned is sufficient to cover the cost of the new line then augmentation is efficient. The owner, therefore, would possess the incentive to build it and the market would enable the owner to capture the full benefits. Under the regional pricing regime, the regional price is referenced to a single node. In this case, the new augmentation may not result in a pool price change sufficient for the owner to capture the benefits. From a market perspective, assume that the total cost of market operation, with the investment, provides benefits. Consequently, the investment should proceed from a market perspective, but the owner does not possess the financial incentives to make the investment.

¹² For a complete and comprehensive description of the Regulatory Test, see Regulatory Test for New Interconnectors and Network Augmentations (ACCC, December 1999).

In conducting the Regulatory Test, therefore, the following cost benefit elements are typically considered:

Regulatory Test Elements

- The costs and timing of Project capital;
- The costs and timing of other new entrant capital;
- Net changes to overall market operating and maintenance costs;
- Fuel Costs;
- Ancillary services;
- Changes to energy not served.

These elements are calculated as changes relative to the Base Case and may move in either direction.

The calculation of the net benefit is based on the cost of market operation as calculated by PLEXOS during the analysis and includes Planning Council estimates of the financial costs of all of the generators in the NEM.

However, the Regulatory Test, as it currently stands, does not take account of:

- Competition benefits;
- Environmental impacts such as Greenhouse emissions;
- Pool Price.

PERFORMING THE REGULATORY TEST

Given the complexity of the market and the need to forecast the future operation of commercial investment and bidding decisions, the Regulatory Test requires a number of sensitivities to be explored by way of market development alternatives. This normally involves consideration of the following:

- Credible forecasts of:
 - Electricity demand;
 - The value of energy to customers, as captured by the level of VoLL.
- Alternative project options such as:
 - Demand side management opportunities;
 - New entrant technologies and fuel sources;
 - Comparable conventional generation or transmission options, including market network service provision.

- Operational variations for the market such as:
 - Different participant bidding behaviours. These can be as simple as SRMC or LRMC or as complicated as Nash-Cournot Equilibrium bidding;
 - model projects under two paradigms:
 - *least-cost expansion* - includes new modelled projects based on a least-cost planning approach, similar to conventional central planning, i.e. the project would be included in the market if the net present value of the benefits, such as fuel substitution and reliability improvements, exceeds the costs; and
 - *market-driven expansion* - mimics competitive market processes by modelling spot price trends based on existing generation and demand and includes new investment on the same basis as would otherwise result from private development, i.e. when the net present value of spot price revenue exceeds the net present value of investment costs.

5.9 Wind Specific Application

In considering the viability of wind farm projects, the costs of transmission infrastructure is significant. As such, the Planning Council has considered whether wind farm transmission augmentations could be the subject of a Regulatory Test application. In doing so, the following assumptions were made:

PROJECT COSTS

The cost of construction of the wind farms is not insignificant. The Planning Council has assumed, based on market research, that the capital cost of a typical wind farm installation is in the order of \$1550/kW.

Transmission or distribution connection requirements will vary on a project-by-project basis depending on location and scale of the wind farm.

Although the purpose of these transmission assets is to connect the proposed project(s) to the transmission network, the project developers may not be exclusive recipients of the potential benefits from connection. Specifically, potential benefits to other market participants may reduce transmission support costs and regional network losses

NEW ENTRANT CAPITAL COSTS

The Planning Council has assumed that the capital costs of new entrants in the NEM are in the order of \$450/kW for a Gas Turbine and \$950/kW for a Combined Cycle Gas Turbine plant.

OPERATING AND MAINTENANCE (O&M) COSTS

The Planning Council has assumed that the Operating and Maintenance costs for a wind farm are in the order of 1.6% of the capital cost per annum.

GENERATION COST (I.E. FUEL COST) SAVINGS

Reductions in generation costs result from fuel savings arising from wind supplanting higher cost generation. It is significant from all of the previous analysis that while coal consumption is relatively unaffected, significant fuel savings accrue from reductions in the consumption of expensive natural gas and distillate. The fuel cost savings are therefore likely to be significant.

DEFERRAL OF NEW ENTRY

This category captures benefits and costs of new project construction and timing relative to the Base Case. For example, assume that in the non-wind Base Case, an X MW gas unit enters the market in year two of the study at cost \$A. In Wind Case I, however, Y MW of wind are present in year zero at cost \$B. In this situation, the test would need to account for:

- any difference in project costs, including capital and O&M costs;
- the net present cost to Wind Case I of incurring cost \$B; and
- the net present benefit to Wind Case I of deferring capital cost \$A.

Any fuel savings benefits from the deferral of the gas unit will also be counted in the Generation Cost (Fuel Savings) category.

This study concluded that, statistically, the firm capacity of the wind farms is likely to be quite small and hence deferred construction benefits are likely to be correspondingly reduced compared to a more conventional form of generation. However the energy contribution from wind farms is not insignificant and could alter the mix of new capacity required in the market, potentially reducing the need for expensive combined cycle plant for cheaper and more flexible peaking units.

INCIDENCE OF ENERGY NOT SERVED

Any reduction in ENS in the NEM is a benefit, appropriately discounted depending on the year.

EMISSIONS

The Regulatory Test as it has been defined by the ACCC does not allow for any benefits from the reduction of Greenhouse gas emissions.

DISCOUNT RATE

The Planning Council has chosen an 8% pre-tax real discount rate for the analysis, consistent with that used by NEMMCO in their analysis of SNI and SNOVIC.

5.10 Regulatory Test Example Calculation for a Typical Wind Farm

The Planning Council has performed an example Regulatory Test calculation based on the development of a hypothetical 380MW wind farm located some distance from major transmission infrastructure.

Based on \$1550/kW the capital cost of this wind farm would be in the order of \$590M. The Planning Council has assumed that the cost of the transmission upgrade to connect the farm is in the order of \$120m.

Table 5-2 and Table 5-3 show the results of a high level Regulatory Test assessment of the wind farm development and transmission upgrade based on LRMC and SRMC bidding.

COSTS OF PRODUCTION	BASE CASE (\$M)	REMOTE WIND FARM (\$M)	"BENEFIT" (\$M)
Variable Costs			
Generation Cost (fuel + VO&M)	\$50,651,200	\$50,141,700	\$509,500
Fixed Costs			
Fixed O & M	\$12,600,900	\$12,589,100	\$11,800
Debt	\$18,978,100	\$18,937,200	\$40,900
Equity	\$16,946,800	\$16,879,700	\$68,100
Cost of ENS	\$101,000	\$116,000	-\$15,000
Cost of new entrant/capital deferral			
CCGT	\$554,600	\$441,700	\$112,900
GT	\$1,207,400	\$1,225,000	-\$17,600
Wind Farms			
Capital Cost		\$589,000	-\$589,000
O&M Cost		\$138,000	-\$138,000
Transmission upgrade			
Capital Cost		\$120,000	-\$120,000
O&M Cost		\$16,500	-\$16,500
Regulatory Test outcome			-\$152,900

Table 5-2 High level Regulatory test (LRMC Scenario)

COSTS OF PRODUCTION	BASE CASE (\$M)	REMOTE WIND FARM (\$M)	"BENEFIT" (\$M)
Variable Costs			
Generation Cost (fuel + VO&M)	\$49,780,600	\$49,323,600	\$457,000
Fixed Costs			
Fixed O&M	\$12,606,400	\$12,594,700	\$11,700
Debt	\$18,988,200	\$18,947,200	\$41,000
Equity	\$16,963,400	\$16,896,100	\$67,300
Cost of ENS	\$99,200	\$108,500	-\$9,300
Cost of new entrant/capital deferral			
CCGT	\$554,600	\$441,700	\$112,900
GT	\$1,207,400	\$1,225,000	-\$17,600
Wind Farms			
Capital Cost		\$589,000	-\$589,000
O&M cost		\$137,800	-\$137,800
Transmission upgrade			
Capital Cost		\$120,000	-\$120,000
O&M Cost		\$16,500	-\$16,500
Regulatory Test outcome			-\$200,300

Table 5-3 High level Regulatory test (SRMC Scenario)

This analysis shows that while there are significant fuel savings made as a result of the construction of this hypothetical wind farm and transmission upgrade there is still a net cost to customers. This analysis assumes that there are no other benefits to customers as a result of reduced losses or network support costs. It also assumes that there are no benefits derived from the deferral of other network developments that may be required in the future.

The results of this type of analysis are sensitive to changes in assumptions and should not be taken as conclusive, it is however, indicative of the difficulties facing the emerging wind industry where significant transmission infrastructure is required. The Planning Council would like to highlight that although this analysis indicates that the transmission augmentation may not pass the Regulatory Test this does not mean that the project cannot proceed. Rather it implies that the cost of the transmission augmentation would need to be funded by the proponent.