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ENERGY MODELLING EXPERTISE

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Interim Report (Imo00015) to

imo
Independent Market Operator

Scenarios for Modelling Renewable Generation in the SWIS

3 March 2010

VERSION HISTORY

Version History				
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0.5	2009-12-03	Joel Gilmore	Ian Rose	Preliminary
0.8	2010-01-18	Joel Gilmore Jenny Riesz	Ian Rose	Draft results
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0.9	2010-02-19	Joel Gilmore Jenny Riesz	Ian Rose	Revised report incorporating comments from REGWG participants
1.0	2010-03-03	Jenny Riesz	Ian Rose	Interim Report pending revisions coming from subsequent work packages

EXECUTIVE SUMMARY

In this package of work ROAM has identified the likely scenarios for the future generation mix in the SWIS as a result of State and Federal Government policies and regulations and other key drivers and constraints.

Key drivers

ROAM considers the following Commonwealth policy outcomes to be important in determining the mix of renewable generation in Australia and the SWIS to 2030: The expanded Renewable Energy Target (RET), The Carbon Pollution Reduction Scheme (CPRS), The Solar Flagships Program, The CCS Flagships Program and The Geothermal Drilling Program. The details of these and their likely impacts are discussed in Section 3).

Western Australia has considerable renewable resources, particularly wind, solar, biomass, geothermal and wave resources. A review of the status of each of these technologies and the resource available in the SWIS is provided in Section 4).

The SWIS market Rules may also play an important role in encouraging or discouraging the development of renewable technologies in WA.

Transmission constraints should be taken into consideration as a driving factor. In this study it is assumed that the Pinjar to Geraldton 330kV transmission line is installed within a timeframe sufficient to allow uninhibited generation development in the Mid-West region.

Other factors of high importance include the demand projection (high, medium or low), the development of the gas market (degree of growth in the LNG export industry and the resulting increase in gas prices towards international parity), and the rate of development of carbon capture and sequestration (CCS) technologies.

Scenarios for modelling

Upon detailed consideration of the above described key drivers, ROAM has developed four possible scenarios that are both realistic but also explore a range of potential futures for the SWIS. A summary is given in the table below.

Summary of Scenarios						
	Description	**CPRS**	**Demand Growth**	**Gas price**	***CCS***	**Renewable technologies**
1	Strained network	CPRS -15	Low	High	*Not available*	Wind
2	Minimal change	CPRS -5	Medium	Moderate	*Not available*	Wind
3	Low emissions	CPRS -25	Low	Moderate	*Available*	Mix
4	Coal development	CPRS -5	High	High	*Available late*	Wind

More detailed descriptions of these outlooks are provided in Section 5.2).

Development of planting schedules

These scenarios were translated into four possible planting schedules, utilising a compiled list of generators that have been announced for development in the SWIS, or have made applications for connection agreements. A limited number of theoretical stations were also considered, where necessary to meet the rapidly growing demand in the SWIS over the outlook period.

Retirement of plant was also considered; it was considered possible that Kwinana A, Muja C, Muja D and Kwinana C may retire at some point prior to 2030, particularly under the influence of the Carbon Pollution Reduction Scheme (CPRS).

The four planting schedules were developed ensuring annually sufficient energy, capacity and renewable energy, in addition to factors such as geographical distribution, the impacts of other external drivers, and an awareness of transmission constraints.

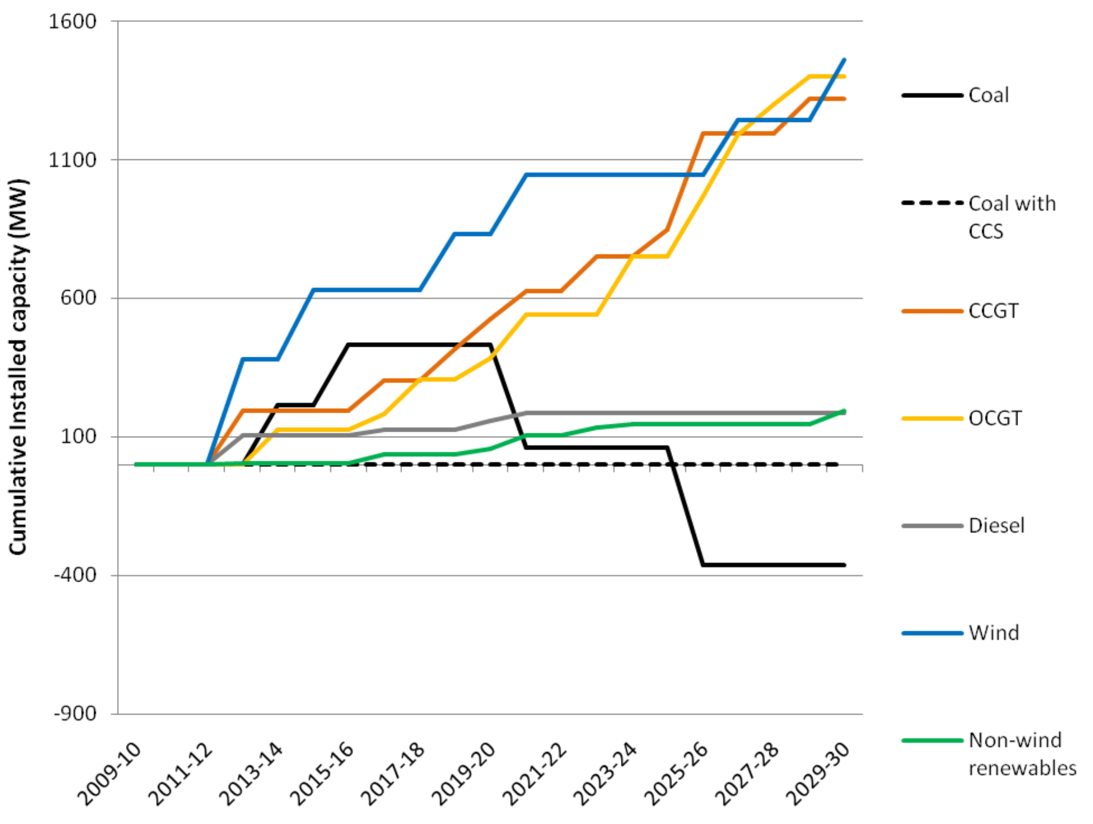
The four resulting planting schedules are described below (and in the body of the report), with full planting schedules for each included in Section 6).

Scenario 1 – Strained network

Under Scenario 1 a moderately strong CPRS (15% reduction below 2000 levels by 2020) causes relatively low investment in coal (see figure below). All installed coal plant is assumed to be "CCS ready", in anticipation of higher emissions prices under the CPRS. The relatively high carbon price drives the retirement of Muja C in 2020-21 and Muja D in 2025-26 (they are replaced by a combination of OCGT and CCGT generation).

In general gas generation is costly due to high gas prices, but remains incentivized by the CPRS (which reduces competition from more emissions intensive alternatives). OCGTs are incentivised by the high quantity of wind installed (which provides energy but very little capacity to the reserve margin).

Scenario 1 – Installed capacity by technology type



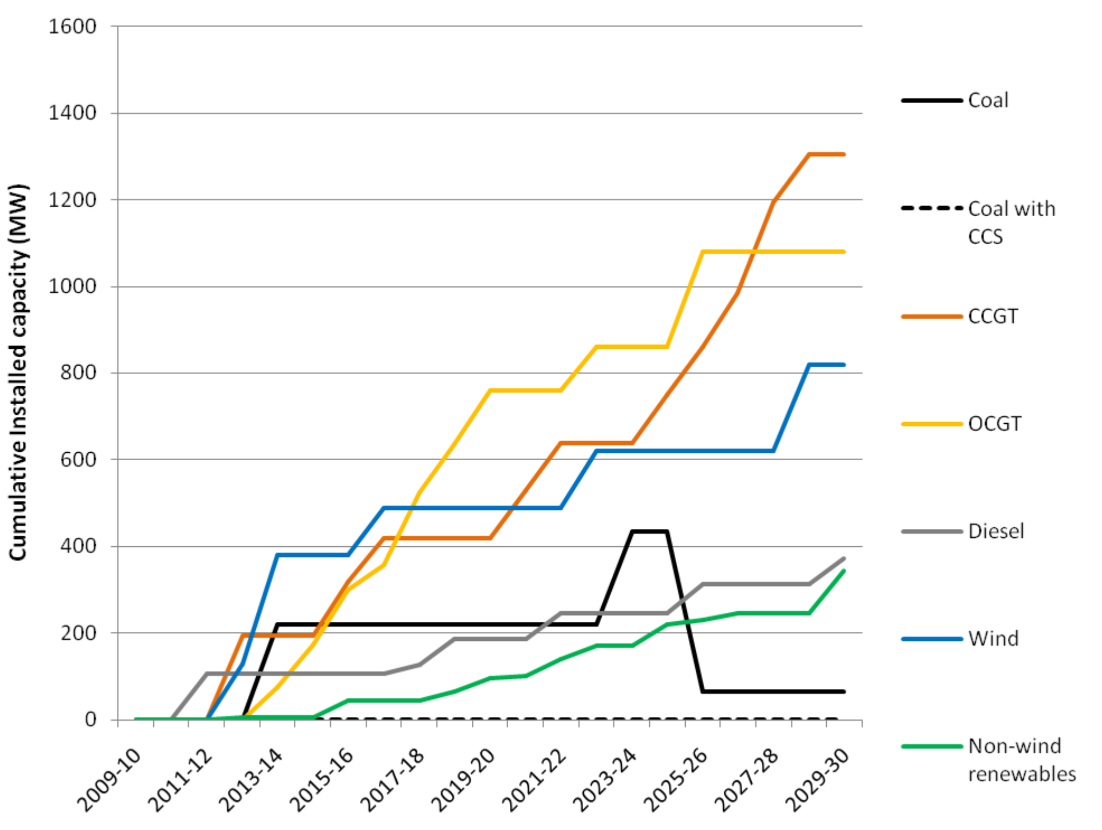
Non-wind renewable technologies develop slowly in this scenario, which drives strong investment in wind energy to meet the RET. Due to the moderately strong CPRS and high gas prices, investment in wind energy exceeds the RET from an early date.

This scenario is designed to explore an outcome where the grid will be maximally strained.

Scenario 2 – Minimal change

Under Scenario 2 the competition between coal and gas is similar to Scenario 1. Despite a much less ambitious CPRS (5% reduction below 2000 levels by 2020), gas prices are lower, allowing a mixture of gas and coal generation to be installed (see figure below).

Scenario 2 – Installed capacity by technology type



The unambitious CPRS in this scenario causes a relatively low level of investment in renewable technologies, with the SWIS only just achieving its share of the RET. Due to lack of incentives the less mature renewable technologies (non-wind) develop slowly and only minor pilot projects in various technologies are installed. Therefore the majority of the RET is met by wind.

Banking of renewable energy certificates is permissible under the RET, incentivising overshoot of the annual targets in the early years of the scheme, and allowing underachievement of targets in the following years.

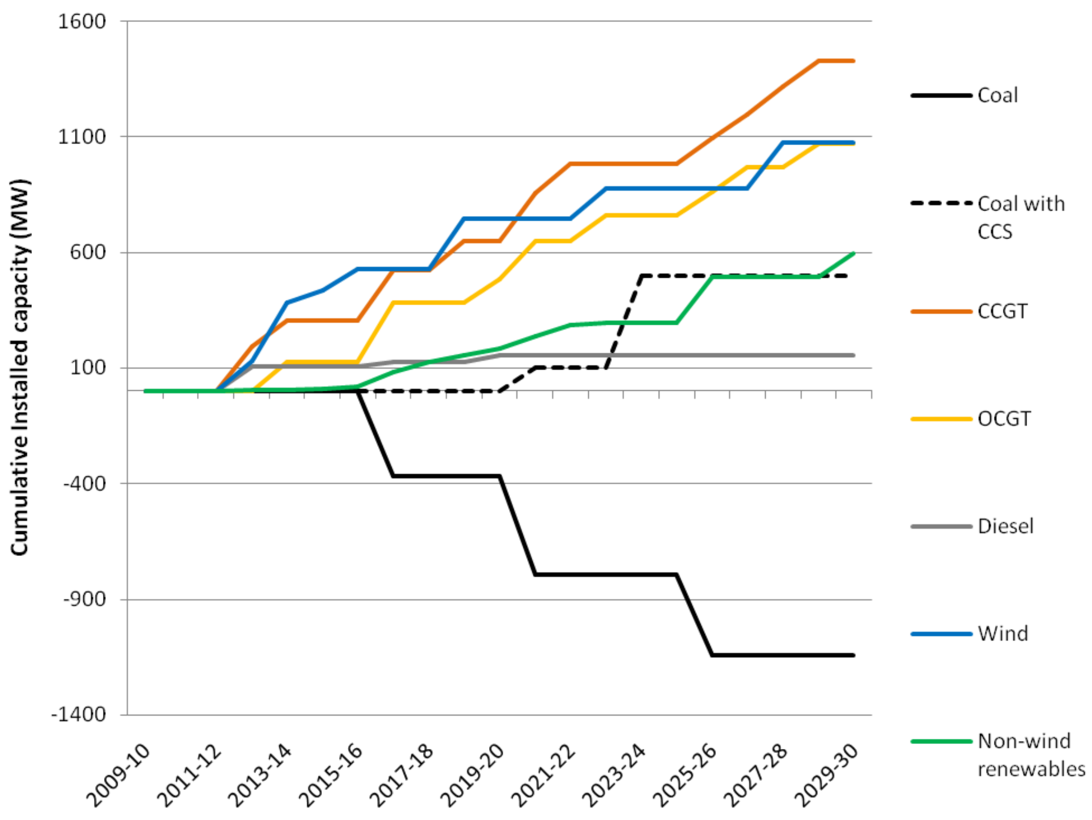
Scenario 3 – Low emissions

In Scenario 3 the very ambitious CPRS (25% reduction below 2000 levels by 2020) excludes the possibility of installing coal plant without CCS technology (see figure below). A pilot 100MW CCS coal plant is installed in 2020, and a larger 400 MW plant several years later in 2023-24.

The very high carbon price drives the retirement of Muja C in 2016-17, when sufficient replacement capacity (in the form of CCGTs) becomes available and undercuts its operation. Muja D similarly retires in 2020-21 when the Electricity Sector Adjustment Scheme ceases to provide incentives for emissions intensive coal-fired plant to remain available to the market.

The high cost of coal technologies drives investment towards gas, further incentivised by the moderate gas prices in this scenario. Investment favours CCGTs in early years of the study due to the lack of other types of inexpensive base-load generation. In the later parts of the study OCGTs are favoured due to the abundance of renewable technologies available providing base-load generation.

Scenario 3 – Installed capacity by technology type



The very high carbon price allows significant investment in renewable technologies, and a wide variety of them are available from an early date. This is the only scenario where non-wind renewable technologies are present in substantial quantities, allowing 600 MW to be installed by 2030. This is accompanied by 1080 MW of wind (in 2030).

The investment in renewable technologies exceeds the RET initially due to the incentives to bank renewable energy certificates. Later, the carbon price is sufficient to incentivise renewable technologies making the RET unnecessary.

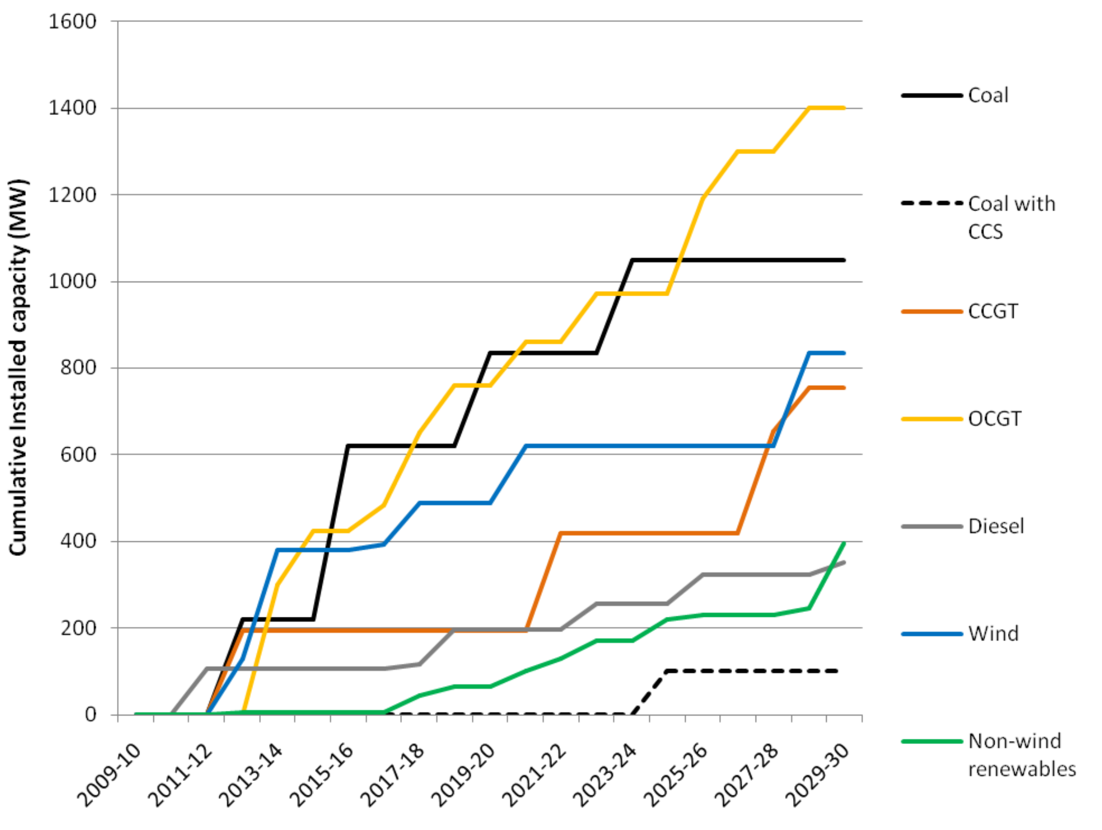
This scenario explores the maximum emissions reductions that are likely to be possible, if all measures are taken and all low carbon technologies receive substantial research and commercialization investment.

Scenario 4 – Coal development

In Scenario 4 an unambitious CPRS (5% reduction from 2000 levels by 2020) combined with high gas prices and high demand growth incentivises the installation of new coal plant, even in the absence of CCS technology. All of this installed coal-fired capacity is assumed to be "CCS ready" in anticipation of higher future emissions prices under the CPRS.

Investment in gas generation is also required to meet the very high demand growth in this scenario. CCGTs are incentivised above further development in coal in the later parts of the study as the carbon prices rises. A small CCS pilot project is available later in the study (2024-25).

Scenario 4 – Installed capacity by technology type



Renewable technologies are installed at a rate only just sufficient to meet the SWIS's proportionate share of the RET, with the majority in wind technology. Banking of renewable energy certificates is incentivised in the early parts of the scheme, allowing underachievement of the target in the following years.

Greenhouse emissions

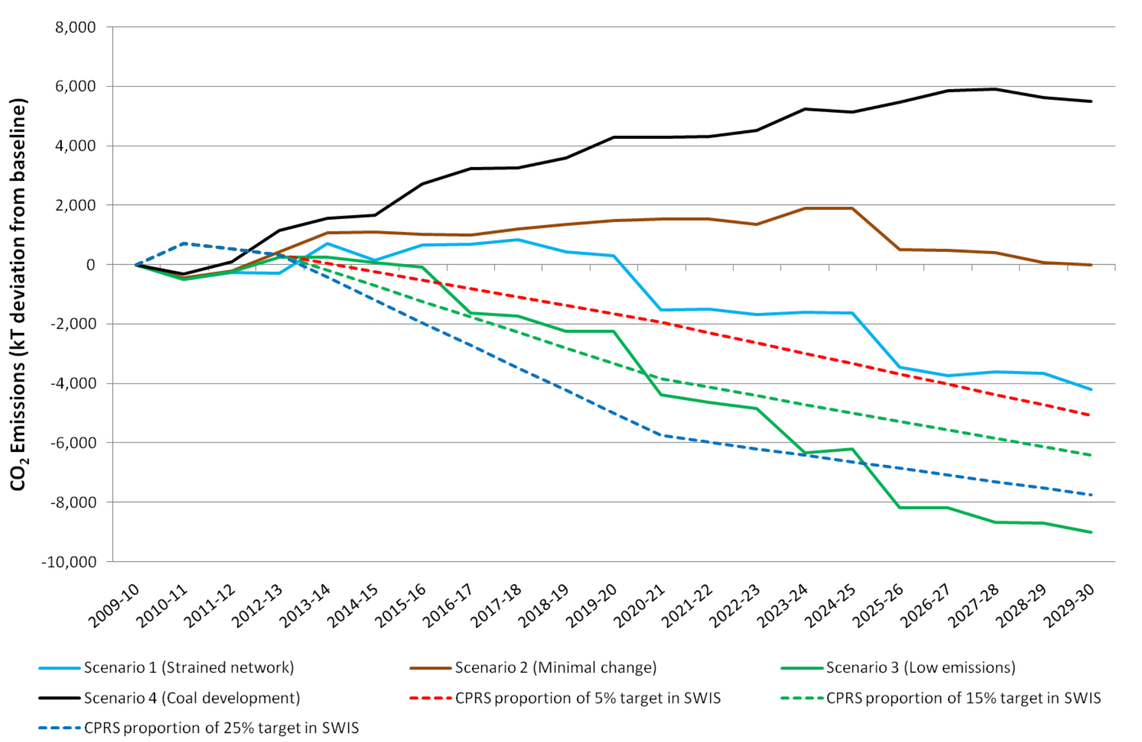
Full dispatch simulation modelling is required to accurately predict the greenhouse emissions resulting from any scenario. However, with some assumptions an estimate of the likely emissions for each scenario can be made. This is illustrated in the figure below.

As would be expected, Scenario 4 (which has strong development in coal) exhibits the highest emissions of the scenarios, with greenhouse emissions continuing to rise strongly despite the CPRS 5% target. In this scenario it is assumed that Australia purchases a large quantity of international credits in order to meet the 5% target (rather than making emissions reductions domestically).

Scenario 3, which explores the measures that might be taken to reduce emissions from the SWIS as far as possible exhibits the lowest emissions. Initially emissions exceed the 5% trajectory, and it could be assumed that Australia would purchase international credits to meet the annual targets in these years (if sufficient borrowing is not available). Past 2020 retirement of the most emissions intensive coal-fired plant can occur (since they are no longer incentivized to remain available by the Electricity Sector Adjustment Scheme), substantially reducing emissions. A wider range of renewable technologies also become available and cost effective under the high carbon prices of this scenario, allowing emissions to fall further.

In between these two, Scenario 1 (which features a large quantity of wind and a strong 15% CPRS) has lower emissions than Scenario 2 (which features a less ambitious 5% CPRS).

Greenhouse emissions estimate (relative to 2009-10 baseline) [1]



All scenarios show an initial rise in emissions, and only Scenarios 1 and 3 show any reduction in emissions over the study timeframe. It should be noted that this is consistent with modelling by the Australian Treasury[2], which shows that the majority of emissions reductions are expected to come from the electricity sector, but that this will only occur after 2035 when CCS technology is assumed to become available. Prior to 2035 the electricity sector is only able to stabilize emissions, but does not manage to achieve substantial reductions.

It is emphasized that these emissions trajectories are estimates only, and full dispatch modelling is required to provide an accurate accounting of emissions.

Conclusion

Four unique scenarios have been provided in this report, exploring possible futures for the SWIS. These are based upon various combinations of the drivers considered to be most significant, which includes the CPRS target, the level of demand growth, the gas price, and the availability of various low emissions technologies.

[1] It should be noted that full dispatch simulation modelling is required to accurately determine the energy outputs of stations in this complex system, and therefore the resulting greenhouse emissions. The numbers illustrated in this figure are only an estimate based on a variety of approximations, designed only to provide a guide for creating the planting schedule outcomes.

[2] Australian Government, Treasury, Australia's Low Pollution Future, The Economics of Climate Change Mitigation, 2008, Chart 6.8, Page 143.

For each of these scenarios, a unique planting schedule outcome has been developed, based upon actual generators that are currently proposed for development in the SWIS or have made applications for connection agreements. Decisions on which plants are most likely for installation in each year of the study were made to be consistent with a wide variety of parameters, including the annual supply-demand balance, maintenance of economically viable capacity factors, requirements of the renewable energy target, and the external drivers relevant to that scenario.

The resulting four planting schedules provide a strong basis for further modelling to explore potential futures for the SWIS.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1) Background

The Renewable Energy Generation Working Group (REG WG) is tasked with the review and investigation of potential issues associated with high levels of penetration of intermittent renewable energy generation projects within the South West Interconnected System (SWIS).

The REG WG has been established under the auspices of the Market Advisory Committee (MAC). The working group has been tasked with investigating the range of issues presented by renewable energy generators and to develop and propose solutions to the various issues.

2) Scope

In this package of work, the consultant is asked to:

- identify existing policies or regulations that may promote or impede intermittent generators or dispatchable renewable energy generators locating in the SWIS as a precursor to scenario development;
- determine the likely scenarios for the future generation mix in the SWIS as a result of State and Federal Government policies and regulations; and
- identify the key drivers and constraints that determine these scenarios and how changes in those drivers would change the scenario outcomes (this might be provided or supported by a scenario model).

An analysis of likely outcomes of policies and their impact on the generation mix in the SWIS is required. It is important to determine the priority and timing of recommendations to ensure that the SWIS and the WEM adapt at a pace congruent to the rate at which penetration levels of renewable generation rise.

3) Existing and Potential Policy Drivers

Western Australia has considerable renewable resources, particularly wind, solar, biomass, geothermal and wave resources. The future energy contribution from each resource will be affected by the quality of the resource close to load centres, the maturity and economics of the technologies designed to harness the resource, and the policies and funding supporting the advancement of emerging technologies down the cost curve.

ROAM considers the following Commonwealth policy outcomes to be important in determining the mix of renewable generation in Australia and the SWIS to 2030.

- The expanded Renewable Energy Target (RET)
- The Carbon Pollution Reduction Scheme (CPRS)
- The Solar Flagships Program
- The CCS Flagships Program
- The Geothermal Drilling Program

The SWIS market Rules may also play an important role in encouraging or discouraging the development of renewable technologies in WA.

3.1) *Renewable Energy Target*

The Federal Government's expanded Renewable Energy Target (RET) aims to produce 20% of Australia's energy needs in 2020 from renewable generation. The scheme is Australia wide, and does not place specific requirements on individual states or regions, and Western Australia does not have any state-specific schemes in place.

ROAM expects that of the additional 45,000 GWh of renewable energy generated to meet the RET in 2020, around 14% will be from Western Australian sources. This is in proportion to electricity consumption in WA relative to all of Australia. In previous work for the Department of Climate Change, ROAM modelled the SWIS containing 10% of the total RET renewable technologies, considering the relativity between the SWIS and the remainder of WA . Other specific drivers may increase or decrease this fraction (e.g., load following requirements matching wind).

The scheme also allows small generation units (SGUs) and solar water heaters (SWHs) to produce Renewable Energy Certificates (RECs), which can be sold to subsidise the unit cost. In particular, a "solar multiplier" will be applied to SGUs until 2015, such that additional RECs are produced, further lower costs. This is likely to drive a high installation of SGUs in the near term, lowering demand and reducing the need for large scale renewable technologies to satisfy the RET.

3.2) *Carbon Pollution Reduction Scheme*

The Federal Government has proposed an emissions trading scheme, the Carbon Pollution Reduction Scheme (CPRS), to be implemented from July 2011. The scheme aims for a reduction of 5% to 25% by 2020 (below 2000 levels) and a 60% reduction in emissions by 2050 (below 2000 levels). The 5% target is unconditional, while the 25% target is conditional on achieving a strong global agreement. The legislation was recently blocked in the Senate, raising questions about its future, although government intends to reintroduce the legislation in 2010.

As a strongly affected industry, coal-fired generators with a higher emissions factor than the national average for all fossil fuel-fired generation (0.86tCO_2-e/MWh) will receive a once-and-for-all allocation of permits. The amount of assistance to each will be based on historic output during 2004-05 to 2006-07 and the extent to which the generator exceeds the average emissions factor. This will likely preclude any retirement of coal plant before 2020.

3.3) *Solar Flagships Program*

The Commonwealth Government's Solar Flagship Program (SFP) was announced as part of the Clean Energy Initiative in the May 2009 Budget. The SFP includes funding of $1.6 billion over 6 years to support construction of four large scale solar power stations with a combined capacity of 1000 MW.

The program proposes two selection rounds, with the first round in 2010 selecting one solar PV and one solar thermal plant with a target capacity of 400 MW combined generation. The solar thermal project must be on a single site, but the solar PV project may be located across up to 5 sites, each at least 30 MW in capacity.

For the solar thermal plant, the inclusion of storage will be looked upon favourably, and up to 15% of the plant's total output may be produced from gas or other renewable hybridisation. In both cases, grid connection is preferred so any plant built in WA is likely to be built in the SWIS.

The second selection round will be for 600 MW of plant, in two projects of any technology type. The date of second round offers is to be confirmed, but is likely to be no earlier than 2015.

3.4) GEOTHERMAL DRILLING PROGRAM

The GDP is a competitive merit-based grants program provided as dollar for dollar matched funding and is capped at $7 million per proof-of-concept project. Combined with funding from the newly established Australian Centre for Renewable Energy (ACRE), this is likely to encourage the most promising geothermal projects.

3.5) SWIS RULES

Ancillary Services

The current load following Rules in the SWIS require that sufficient plant (mostly open cycle gas turbines (OCGTs)) be online to meet fluctuations in wind and demand in 99.9% of all periods[3]. Currently, a minimum of 59 MW of load following capacity is required to be online in all periods. If significant new wind (or other intermittent renewable generation) is constructed, the load following plant required will continue to rise. ROAM has previously identified the amount of load following needed for a given amount of new wind under the current rules; approximately 10 MW of load following capacity is required for every 40-50 MW of wind. Maintaining this reserve is likely to force the significant curtailment of wind generation during low demand periods, particularly overnight. High WA gas prices are also likely to limit the installation of new gas plant, or at least increase the total cost of WA generation, and thus reduce the flexibility of dispatch to accommodate increasing amounts of wind.

Previous work by ROAM suggests that approximately 1000 MW may be the practical limit for installed wind capacity under the current load following rules. By this point, either wind is being curtailed significantly overnight or coal and any non-essential gas plant are cycling on a daily basis.

[3] SWIS Market Rules

The 2005 Econnect report[4] suggested that frequency stability would become a significant issue once wind penetration exceeds 20-30% of total energy. By comparison, 1000 MW of wind (where load following plant becomes an issue) would contribute around 15% of projected energy consumption.

The Energy Supply Association of Australia (ESAA) recently advised[5]:

> *"In relation to the funding of ancillary services, it is important that cost allocation is guided by the causer pays principle…This issue may become increasingly relevant as the penetration of intermittent generation increases in response to climate change policies, for example, the cost of back up generation for wind power."*

The report recommended that the WA Government should implement a causer pays model for ancillary services where possible. Depending on the changes, this may impact on intermittent generators who are more likely to cause unexpected operation.

Capacity credits

Intermittent generators are currently assigned capacity credits based on their average capacity factor. The ESAA report recommends that this methodology should be adjusted for intermittent generation "to better reflect its ability to provide capacity at times of peak system demand".

In the NEM, a recent review of South Australian wind found that wind could only be relied upon to provide 3% of its installed capacity, based on a 95% confidence interval (similar reliability to thermal generation during peak periods). In Australia, wind in general is anti-correlated with the temperature driven demand, particularly during summer.

The Renewable Energy Working Group is currently examining this accreditation scheme. Depending on the outcomes and projected future prices, this may impact on the economic viability of (particularly intermittent) renewable technologies in the SWIS.

Network access

The ESAA report suggests that long network access lead times and application queuing policies are cumbersome and may inhibit efficient investment in new generation.

3.6) Transmission Development

Where existing transmission is weak or close to capacity, this may limit generation development options and incentivize particular technologies in particular locations. Transmission development is therefore an important driver for consideration.

[4] Econnect report, *Maximising the Penetration of Intermittent Generation in the SWIS,* 2005

[5] ESAA report, *Western Australian Energy Market Study*, Nov 2009

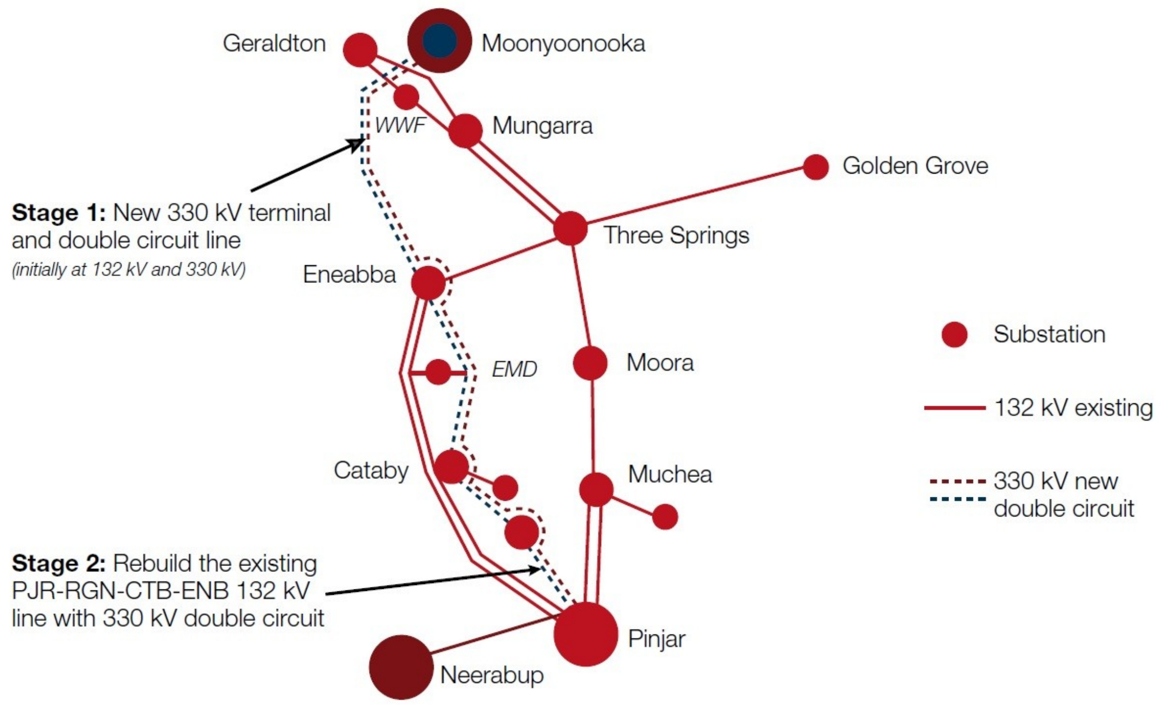
330kV Transmission line Pinjar to Geraldton

Of particular significance in the SWIS over the timeframe of this study is the proposed 330kV double circuit transmission line between Pinjar and Geraldton. The new facility includes:

- A new 330/132 kV terminal station at Moonyoonooka
- A new 330 kV line circuit at Neerabup; and
- A new 132 kV line circuit at Pinjar.

The project is illustrated in Figure 3.1.

Figure 3.1 – Pinjar to Geraldton 300 kV transmission line[6]



The case supporting the proposal for this major augmentation rests to a large extent on supply capacity forecasts in the Mid-West region. The potential to increase capacity is currently limited by the transfer capacity of the transmission network feeding the Mid-West region[7]. This is due to stability concerns (additional sources of reactive power are required to ensure that voltage collapse does not occur) and transmission line surge impedance. The implication is that no new generation capacity can be accepted in the Mid-West region until the transmission network capacity is upgraded or costly reactive power sources are provided.

[6] Western Power Annual Planning Report 2009.

[7] Technical Appraisal of Western Power's Major Augmentation Proposal for a 330kV Transmission Line and Associated Works in the Mid-West region of Western Australia. Prepared for Economic Regulation Authority of Western Australia, Parsons Brinckerhoff Associates, 29 October 2007.

On September 2008 it was determined by the Economic Regulation Authority of Western Australia that the forecast new facilities investment of $300 million for the proposed transmission line meets the new facilities text[8].

Originally this project has been scheduled for completion according to the following stages:

1. Stage 1 - 330 kV line from Neerabup to Eneabba by summer Q4 2010; and
2. Stage 2 - 330 kV line from Eneabba to Moonyoonooka by summer Q4 2011

However, due to the recent global financial crisis it is possible that some prospective loads driving this project could be deferred. This may then delay in the installation of this upgrade[9].

Although the timing of this new line remains uncertain, for this study it has been assumed that this upgrade is installed in a sufficient timeframe to prevent inhibiting generation development in the northern part of the SWIS. For some scenarios with very large development of intermittent generation further augmentation may be required.

In some scenarios in this study the development of over 1000MW of new wind plant in the "North Country" region has been included. Even the proposed dual circuit 330kV lines to Geraldton may struggle to accommodate this level of wind. ROAM has included this extreme level of wind development intentionally to explore and highlight issues surrounding the capability of the transmission grid in meeting the requirements of these possible futures for the SWIS. The intention is for this to be explored further in later work packages.

4) Renewable and Low Emission Resources

ROAM has conducted a review of the available renewable and low emission technology resources in WA. Preliminary results for each technology are presented in this section.

4.1) *Solar*

Western Australia has an excellent solar resource, with transmission accessible sites north and east of Perth receiving in excess of 20 $MJ/m^2/day$. Furthermore, the summer peak solar resource is amongst the best in Australia, particularly north of Perth. This strong correlation with air conditioning and other summer peak loads results in maximal revenue for solar plants.

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[8] Final Determination on the New Facilities Investment Test for a 330kV Transmission Line and Associated Works in the Mid-West Region of Western Australia. Economic Regulation Authority, submitted by Western Power, 3 Sept 2008.

[9] Western Power Annual Planning Report 2009.

Figure 4.1 – WA annual average solar resource with transmission network overlayed

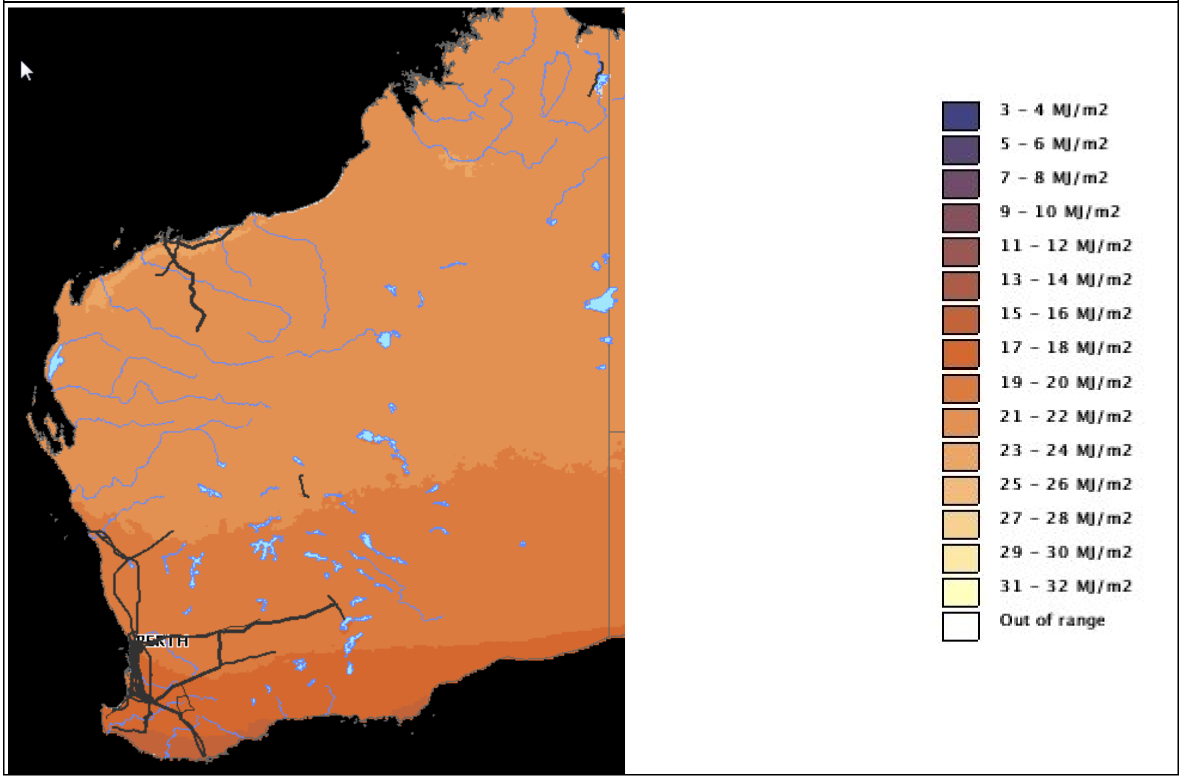
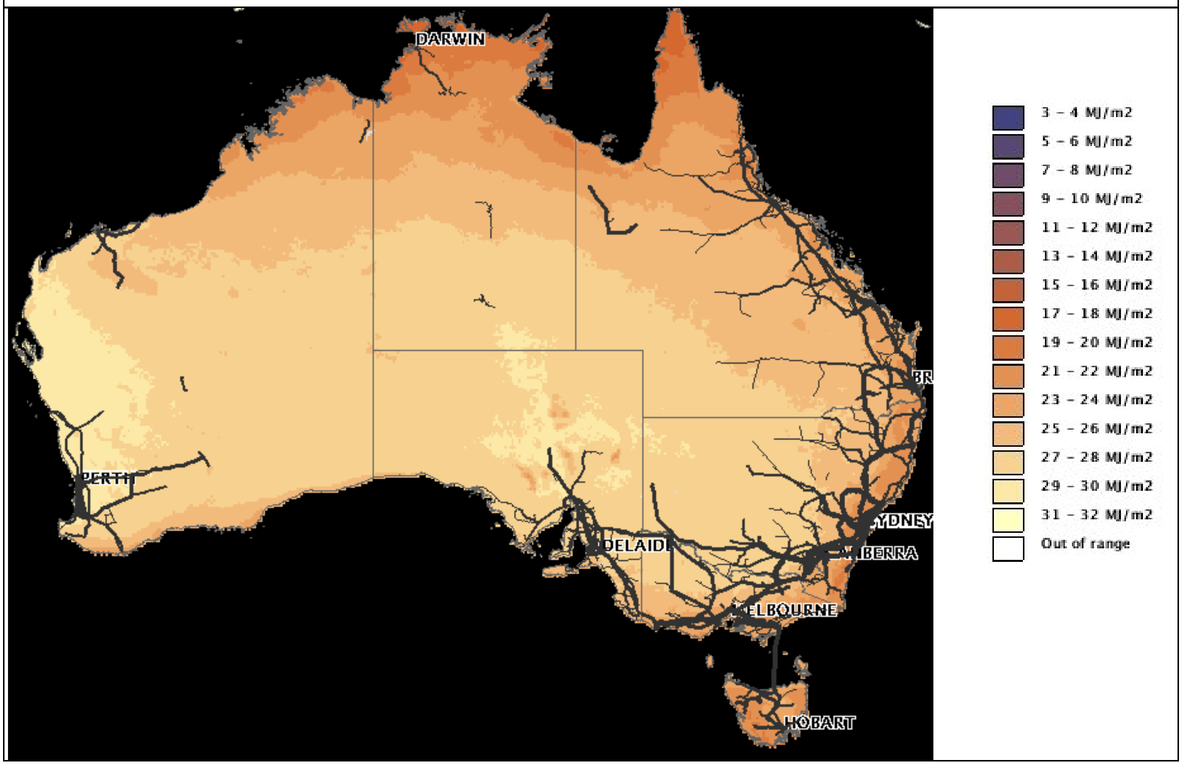


Figure 4.2 – WA January average solar resource with transmission network overlayed



Because the economics of solar plant depends strongly upon the solar resource, Western Australia is likely to be a prime location for solar technologies. Solar plants (which only operate during daytime periods, without storage) are also less likely to be impacted by the overnight low loads.

Engineering firm WorleyParsons has already flagged Mingenew, near Geraldton, as a possible location[10] for a 250 MW plant. WorleyParsons has also announced plans to build plants in the Pilbara, possibly funded by an industry consortium. However, both solar thermal and solar PV power remains expensive and without additional subsidies (such as the Solar Flagships Program), solar power is unlikely to contribute significantly to SWIS generation before 2020. With appropriate cost reductions and a sufficiently high carbon price, however, Western Australia is an ideal location for new solar plant.

Current estimates of Long Run Marginal Costs for solar range from $200 to $350/MWh. However, this is offset to some extent by the higher electricity market prices when solar plant is operating, and may be reduced significantly over time by new entrant solar technologies.

4.2) WIND

Areas of the SWIS have some of Australia's best resources as shown in the figures below. Capacity factors of wind farms in the SWIS regularly approach or even exceed 40%. As the cheapest and most mature renewable generation source[11], wind is expected to make up a large proportion of the RET. However, there are significant integration hurdles for wind in a small grid, such as the SWIS, as discussed above. It is these issues, rather the cost or resource limitations, that may limit the investment in wind power in the SWIS.

Recently installed wind farms have capital costs between $2,500-3,000/kW with long run marginal costs (LRMCs) between $80-$120/MWh. Western Australia wind farm LRMCs are likely to be low given the high capacity factor of existing plant (compared to an average of 30% for most NEM farms). This will likely make WA wind farms attractive over wind farms in the eastern states as well as other renewable technologies in WA.

The SWIS already contains 200 MW of wind farms, and a number of expansions and new wind farms are already under consideration (such as Collgar/Merredin wind farm, with a total capacity of up to 267 MW, and an expansion of the Alinta Walkaway wind farm).

[10] Source: Geoscience Australia *www.ga.gov.au/renewable/proposed/proposed_renewable.xls*

[11] Excluding hydroelectricity. However, opportunities for further hydro development in Australia are limited.

Figure 4.3 – WA annual average wind speeds

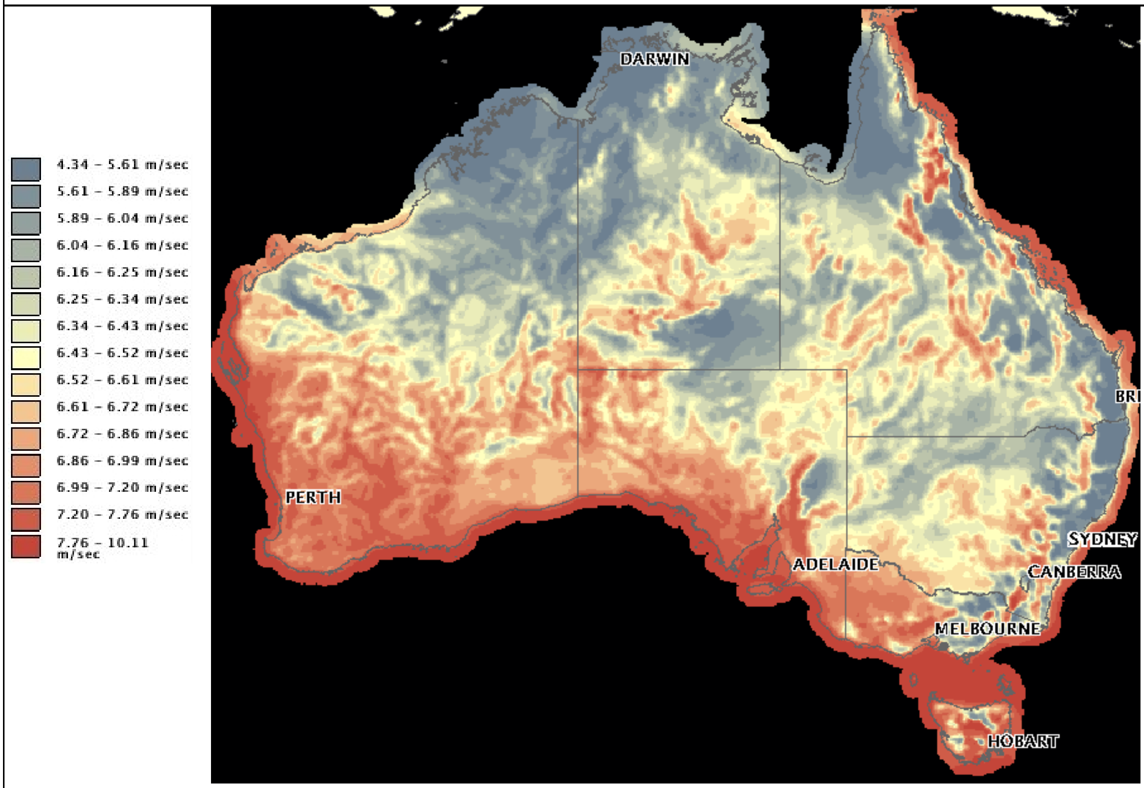
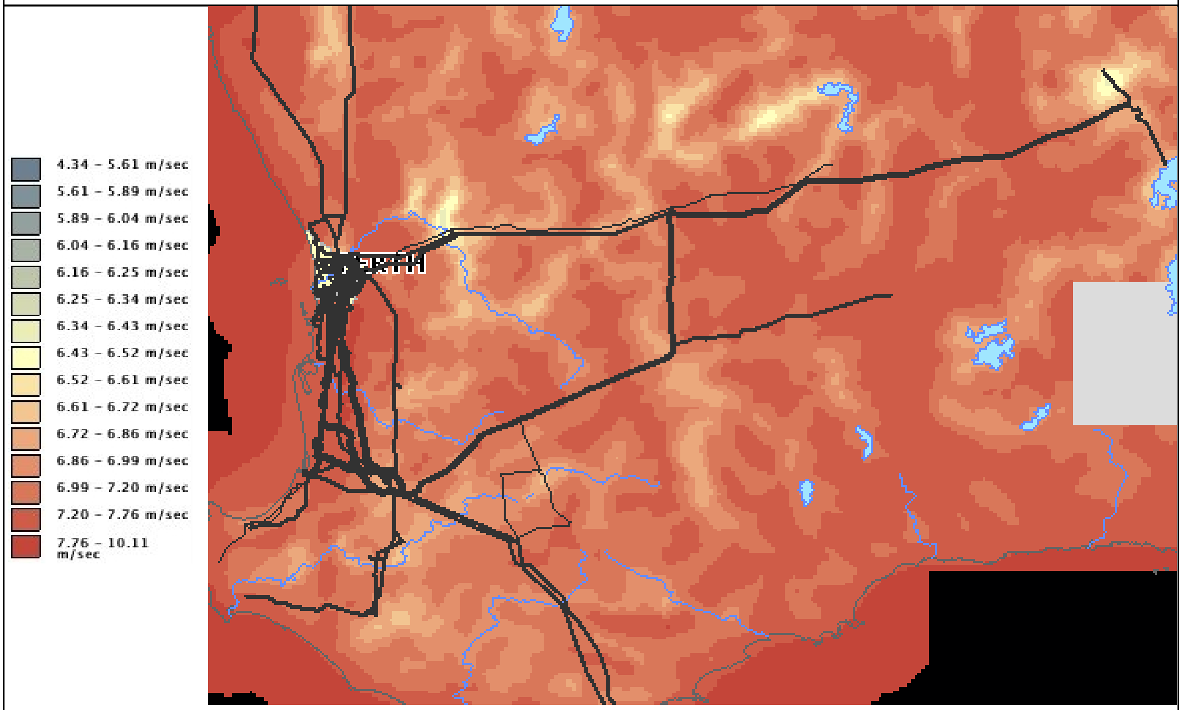


Figure 4.4 – WA annual average wind speeds with transmission overlayed near Perth



4.3) BIOMASS

A number of biomass plants have been proposed for the SWIS, such as the 40 MW Manjimup project backed by the WA Biomass Pty Ltd consortium. Biomass plant costs are comparable with wind, and as a schedulable technology that is also able to provide load following and inertia support to the system, it may prove a valuable option for meeting the RET. However the large area of land required for continuous supply of fuel may limit the total capacity of installed biomass.

4.4) GEOTHERMAL

Geothermal proponents have shown strong interest in the Perth and Carnarvon Basin acreage releases. Suitable sites for both hot sedimentary aquifer (HSA) and enhanced geothermal systems (EGS, or "hot rocks" technology) have been identified. The total capacity of HSA geothermal is likely to be smaller than EGS, but the technology required is simpler and likely to be closer to commercialisation.

Cost estimates for geothermal vary, and the lack of well established pilot plants and the variability between requirements for different sites makes estimates difficult. Current estimates of long run marginal costs are generally between A$90-145/MWh for pilot plants and A$80-$120 for commercial scale plants. Estimates do exist outside these ranges; Panax has estimated costs of as low as A$63/MWh for their HSA Penola project, but did not include return on capital/financing costs and so cannot be directly compared. In contrast, a report by Emerging Energy Research put EGS costs in the United States at around A$150-250/MWh. Again, specific site conditions are likely to cause variability in prices.

Due to the relatively new technologies being implemented, geothermal projects may be more likely to experience cost or schedule overruns and will, in the short term, be dependent on external funding. The Commonwealth Government is providing support in the form of the $50 million Geothermal Drilling Program for proof-of-concept projects, with first round funding given to two South Australian projects. If technological breakthroughs are made in South Australia, geothermal energy may play a significant role in the WA renewable technologies mix beyond 2020.

A further potential advantage in Western Australia is that a number of potential geothermal sites have been identified close to the grid which may reduce transmission costs compared with some South Australian projects.

The main interest in geothermal technology stems from the fact that it provides a dispatchable source of renewable source of energy. Penetration of intermittent technologies to high levels is ultimately challenging, so dispatchable renewable energy has a high value. In addition, geothermal plants are likely to achieve high capacity factors, allowing competitive energy costs despite high capital costs[12].

[12] For a review of multiple estimates, see http://www.panaxgeothermal.com.au/documents/GeothermalEnergy20090615.pdf

4.5) Carbon Capture and Storage

Carbon capture and storage has been proposed as a way to continue using fossil fuels in a low emissions world. A number of possible storage sites suitable for use in the SWIS have been identified, including the Gage sandstone offshore of Perth, the Dongara depleted gas field and the Neocomian sub-crop offshore of Geraldton[13]. The lack of established large scale storage projects makes cost estimates difficult, but estimates range from $60/tonne of CO2 to much higher. This will further close the gap between coal fired generation and higher cost producers, such as gas and renewable.

5) Development of Scenarios

5.1) Drivers

In the previous sections, a number of key factors that would impact on the generation mix in the SWIS have been identified. ROAM has summarized what it considers to be the most significant drivers, and their options below:

- CPRS Target (emissions reductions as compared to 2000 levels)
  - -5% target (by 2020)
  - -15% target (by 2020)
  - -25% target (by 2020)
- Demand projections
  - High
  - Medium
  - Low
- Renewable technologies Mix
  - Primarily intermittent wind, some biomass and solar
  - Mix of technologies – wind, geothermal, solar, biomass and wave
- Gas market developments
  - Large LNG export industry growth significantly increases gas prices towards world parity pricing
  - Only limited LNG export expansions, such that prices experience only moderate growth
- CCS
  - Available
  - Not technically/commercially viable until late

If all drivers were to be considered independent, then 72 possible combinations (3 x 3 x 2 x 2 x 2) would result and need to be considered. However, many of these drivers are correlated and unlikely combinations can be eliminated. For instance, a high CPRS target is likely to result in lower energy demand due to energy efficiency measures and embedded generation.

The specific options and their correlations are explored below.

[13] W.G. Allinson et al *The Cost of Carbon Capture and Storage in the Perth Region* (2006)

CPRS target

Australia's target level of emissions reductions is likely to be chosen independently of other drivers, but will be influenced by both domestic and international climate policy.

Demand projections

Demand growth is driven primarily by economic growth and as such is impacted by both domestic and international economic policy. However, ROAM expects that under high CPRS targets, greater investment will be made in distributed energy and in energy efficiency, driven by the price signal. For instance in the 2009 National Transmission Statement[14], medium demand growth in the NEM is paired with a CPRS -5% target, while a CPRS -15% target is paired with low demand. As such, at the highest and lowest demand projections are unlikely to occur in conjunction with the lowest and highest emissions trajectories, respectively.

Over the longer term a high carbon price may drive energy use in other sectors towards electricity (for example, in the transport sector with movement towards electric vehicles). This may mean that over the longer term a stronger CPRS target drives an increase in demand. This effect has been considered likely to occur outside the timeframe of this study (beyond 2030).

Gas market

The development of the gas export industry is subject to global demand and supply of gas. Gas exports from Australia are presently dominated by the LNG export industry based on the North West Shelf and Timor Sea. The emerging coal seam industry in Queensland is now a significant potential competitor to the North West Shelf, with several new LNG facilities being designed in the Central Queensland area focused on the port of Gladstone.

Hence the expansion of LNG exports from the North West Shelf is subject to considerable uncertainty. For this reason two alternative views of the availability of gas at reasonable prices for the domestic electricity market have been developed, high prices and moderate prices. The prices of gas will correspondingly significantly influence the level of gas usage in the electricity sector.

It could be expected that in the case of a strong international agreement around climate change mitigation very high international gas demand may occur, creating greater incentives for the development of a significant LNG market in the SWIS. Gas substitution offers relatively cheap emission reduction over the short term, there being a significant price buffer before higher gas prices make other alternatives preferable. For this study ROAM has instead utilised a moderate gas price in the 25% CPRS scenario. This is not intended to be a "most likely" future, but is rather intended to explore the combination of external drivers that could achieve the lowest possible emissions from the SWIS. Even in the case of a 25% CPRS target there remains substantial uncertainty around the future of the gas market, so this is a possible scenario that should be explored for its (potentially serious) implications for the SWIS.

[14] NEMMCO *2009 NTS Consultation: Final report*

Renewable Energy mix

Wind power is an established renewable technology that is well advanced along its learning curve. It represents a bankable option for meeting the RET, and is likely to be available in sufficient quantities, albeit limited by the integration hurdles associated with intermittent generation.

The use of emerging renewable technologies such as solar PV, solar thermal, geothermal and wave power depends on both the commercial and technical viability of each technology. Government support for ongoing initiatives such as the Solar Flagships Program and the Geothermal Drilling Program will be a key factor in their development, and in bringing down costs. Based on current developments, HSA geothermal is likely to be economical and technically viable by 2020, barring any unforeseen delays, and pilot plants are likely to enter before this date. However, available capacity is more limited, with project sizes of around 30 MW.

For all emerging technologies, price signals such as the CPRS (providing long term financial security after the expiry of the RET) will also be needed to drive private investment in development and research. As such, these technologies are unlikely to be available under a (CPRS-5%) emissions trajectory.

CCS

The development of CCS will depend on improvements in technology and cost reductions, driven by initiatives such as the Federal Government's Global Carbon Capture and Storage Institute.

A 2005 report for the Society of Petroleum Engineers identified a number of potential storage sites near Perth (the Gage sandstone (offshore), the Dongara depleted gas field, and the Neocomian sub-crop offshore of Geraldton). Costs were estimated at above $60/tone of CO_2 sequestered, which would require relatively high carbon prices to be viable. This cost is in line with other estimates.

The potential for CCS developments in WA has recently improved through the short listing of a WA CCS project in the SWIS as one of four Australia wide for sharing approximately $2billion of funding. However few other details are available.[15]

5.2) SCENARIO DESCRIPTIONS FOR MODELLING

ROAM has combined the above assumptions to develop a range of possible scenarios that are both realistic but also cover a range of the possible future breakdowns of the SWIS. A summary is given in the table below, followed by a description of each scenario.

[15] http://www.dmp.wa.gov.au/7105_9756.aspx

Table 5.1 – Summary of Scenarios						
	Description	**CPRS**	**Demand Growth**	**Gas price**	***CCS***	**Renewable technologies**
1	Strained network	CPRS -15	Low	High	*Not available*	Wind
2	Minimal change	CPRS -5	Medium	Moderate	*Not available*	Wind
3	Low emissions	CPRS -25	Low	Moderate	*Available*	Mix
4	Coal development	CPRS -5	High	High	*Available late*	Wind

Scenario 1 – Strained network

Purpose of scenario - To explore issues that may arise with a very high quantity of wind capacity installed.

In this scenario, moderate emissions cuts (**CPRS -15%**) are agreed upon, and strong energy efficiency measures plus embedded generation results in **low demand growth**.

Connection procedures for renewable generation are streamlined, encouraging a greater capacity of renewable technologies in Western Australia. However, despite the best intentions, the higher carbon prices have not resulted in low emission technologies. Schedulable renewable technologies such as solar and geothermal have not yet proved commercially viable, although smaller pilot projects are constructed, particularly of HSA Geothermal. As such, the RET is met predominantly by **wind** power. However, closer to 2030, some further small wave power projects are constructed.

Strong demand for LNG and a successful WA LNG plant developments results in **high gas prices**, slowing the installation of new gas plant and exacerbating network issues. Despite government support, CCS proves more costly than anticipated and **CCS is not widely installed**, while the high carbon prices limit the installation of conventional coal plant. However, some pilot CCS plants are constructed, both for gas and coal, and any new coal plants are CCS-ready for when the technology becomes available.

In this scenario, the limits of the existing transmission network will be tested and expensive gas plant will be required to provide load following support to the high penetration of wind generation.

Scenario 2 – Minimal Change

Purpose of scenario - To explore a scenario that represents minimal change from business as usual. This is useful as a likely future for comparison to the other more extreme scenarios.

This scenario represents the case where the SWIS is able to continue operating similar to its current fashion.

The world has not committed to strong action on climate change, although discussions are ongoing. The government has agreed to an emissions trading scheme (**CPRS -5%**), but there is insufficient government support and commercial interest in developing these emerging technologies (both renewable technologies and CCS) to make them commercially viable at scale prior to 2030.

The relatively low carbon prices result in a number of coal plant entering in the near term to meet the **medium demand.** Some plant is constructed to be able to be retrofitted with CCS technology, but with no strong incentives **CCS is not expected** to be commercially viable before 2030.

No further support is provided to emerging renewable technologies (such as through rapid connection plans or pre-approval zones) The RET is met predominantly by wind plus some biomass plant, although some small scale HSA geothermal projects are built. **Moderately priced gas** plant provides the necessary support to the intermittent generation, and CCGTs also back up coal in providing base load power.

This scenario will explore a low cost future where well established technologies are further utilized, and minimal disturbance is applied to the network.

Scenario 3 – Low emissions

Purpose of scenario - To explore the combination of external drivers that would allow the SWIS to achieve very significant emissions reductions. This is designed to be a more extreme scenario to ensure adequate coverage of the futures where the SWIS will be required to adapt more strongly and rapidly.

In this scenario, the world is moving quickly to tackle climate change, and Australia commits to making high emission cuts corresponding to a **CPRS -25%** target. Heavy investment in energy efficiency measures and strong community uptake in solar water heaters and rooftop PV results in **low demand**. Global economic growth is also slower, with only moderate demand for LNG, and the LNG export market in Western Australia does not expand rapidly, maintaining **moderate domestic gas prices.**

Heavy investment is made in a **range of renewable technologies** and in **CCS**, resulting in multiple generation technologies that are cost competitive. HSA geothermal projects are operating before 2020, and success in the Cooper Basin spurs on the development of EGS systems in WA during the latter half of 2020-30. Pilot projects for wave power are also built, and several biomass plants are operating.

Procedures for development approval and connection to the SWIS are streamlined such that wind farms are encouraged to site in WA, and WA receives more than its “fair share” of the RET. The low demand, however, reduces the need for new growth, though some older plants are retired and replaced with cleaner options.

In this scenario, a reduction in carbon emissions is a priority, and may see existing plant retired and replaced with cleaner renewable technologies.

Scenario 4 – Coal development

Purpose of scenario - To explore the combination of external drivers that will produce very high greenhouse emissions from the SWIS. This is designed to be another extreme scenario in counterpoint to Scenario 3.

The world fails to reach a global agreement on climate change, although Australia still implements an emissions trading scheme, with a target of **CPRS -5%**. Strong global economic growth coupled with few energy efficiency incentives results in a **high demand.** Strong global demand for LNG has resulted in the rapid growth of the LNG export industry in WA and consequently **high domestic gas prices**.

Research into CCS is ongoing, but technical challenges has meant **CCS is not available** until close to 2030. However, new coal and gas plant are constructed with a view to retrofitting with CCS technology when available. **Wind** makes up the bulk of renewable technologies, with small contributions from other sources, mostly pilot projects. The strong economic growth has improved the funding options for new technologies, and a variety of projects have been explored, but very few have proceeded past the pilot stage.

A strong LNG export industry is established in WA driving **high gas prices**, which results in coal plant comprising the bulk of new generation.

This scenario explores the case where significant quantities of relatively cheap coal plant is built in the SWIS to meet high demand growth with renewable technologies playing a secondary role.

5.2.1) Comment on the probabilities of scenarios

It is important to note that none of these scenarios is intended to be considered a "most likely" future for the SWIS; they are instead intended to explore the range of possible futures that may occur, for the identification of possible issues. Probabilities of each scenario have not been ascribed (since this was not part of the scope), but the probabilities of some scenarios may be quite low.

ROAM has included three scenarios that focus on wind technology to fulfil the requirements of the RET, and only one that includes a large quantity of other renewable technologies. This is for two reasons:

1. Wind is a much more mature technology, and there are a large number of proponents seeking to develop this technology in the SWIS at the current time. Over the near-term wind technology is considered likely to be the most significant contributor to the RET.
2. The stated objective of this work program is to investigate the range of issues presented by renewable energy generators and to develop and propose solutions to

the various issues. Wind technology is considered likely to be the most problematic new technology due to high intermittency.

This report does not intend to imply that the non-wind renewable technologies are any less likely to be a significant contributor to the RET in the longer term. ROAM certainly believes that the non-wind renewable technologies will be an essential part of a low emissions future for the SWIS. ROAM considers all of these technologies to be important emerging technologies that could achieve significant market share if they continue to develop in a promising fashion.

6) Development of Planting Schedules

6.1) *Methodology*

Determination of likely stations

ROAM used a combination of information sources to compile a list of generators that may be installed in the SWIS over the duration of this study. These included:

- Projects that have been publicly announced for development in the SWIS
- Applications for connection agreements (capacities and locations provided by the IMO)
- Theoretical stations that are considered likely for development based upon the key drivers discussed previously, and the required capacity for the SWIS to meet growing demand over the study period.

The resulting list is shown below in Appendix A.

Determination of likely retirements

Retirement of some existing plant is likely within the timeframe of this study, particularly under the more ambitious CPRS scenarios. Retirement of emissions intensive plant is likely to be essential to reach the emissions reduction targets. The list of possible retirements is included in Appendix B.

Development of planting schedules

This list was then used to develop unique planting schedules for each of the previously developed scenarios, ensuring compliance in each year with the following:

- ***Sufficient capacity*** - the supply-demand balance was adequately met in each year, including allowing for the reserve margin
    - Wind generators were considered to contribute 15% of their capacity. The allocation of capacity credits to intermittent generation facilities in the WEM is currently under review.
    - Solar PV generators were considered to contribute 75% of their capacity.
    - All other generator types contribute 100% of their capacity
    - Demand forecasts from the WA IMO were used. These were projected forward to 2030 on the same linear trend as the later parts of the IMO forecast.
- ***Sufficient energy*** – it was assumed that in order to be economically viable each new plant would need to adhere to typical capacity factors. Within this it was ensured that sufficient energy was available to meet the requirements of the SWIS

- ***Sufficient renewable energy*** - the requirements of the renewable energy target scheme were met (this is a national scheme, so it was assumed that a proportion of the renewable development would be met in the SWIS roughly equivalent to the proportion of Australia's load located in the SWIS).
- ***Geographical distribution*** – It was assumed that plants would tend to distribute relatively evenly around the SWIS (rather than concentrated development in one area). This was restricted by the locations of announced plant.
- ***Impacts of external drivers*** – the likely impacts of the previously defined external drivers in each scenario were taken into account in the development of four unique planting schedules.
- ***Awareness of transmission constraints*** – Where transmission constraints are known to exist, or likely to exist under a particular generator combination, the likely impacts of these were taken into account.

The resulting planting outcomes are outlined in the following sections.

6.1.1) OCGTs vs CCGTs

Capacity factor and long run marginal cost

The choice of whether to install a CCGT or OCGT is a complex one involving many factors. Considering first the economics, a developer would determine the capacity factor at which the plant is likely to operate. This will determine whether the long run marginal cost (LRMC) is lower for an OCGT or a CCGT. Based upon present capital and operating costs, it is only economical to install an OCGT if it will operate with a capacity factor less than 5-20%. If the plant will operate at a higher capacity factor the larger capital cost of a CCGT is justified by the higher efficiency.

This is illustrated in the charts below. Figure 6.1 shows the long run marginal cost curves for an OCGT and a CCGT with a low carbon price ($20/tCO2-e) and a low gas price ($4-5/GJ). For capacity factors greater than 18% a CCGT has a lower long run marginal cost. For lower capacity factors, the OCGT is the lower cost option. However, if gas and carbon prices are much higher ($60/tCO2-e and $10-13/GJ) as illustrated in Figure 6.2, an OCGT is only the most economical choice if the plant is expected to operate with a capacity factor less than 7%.

Figure 6.1 – LRMC - Low gas price ($4-5 $/GJ), low carbon price ($20/tCO_2-e)

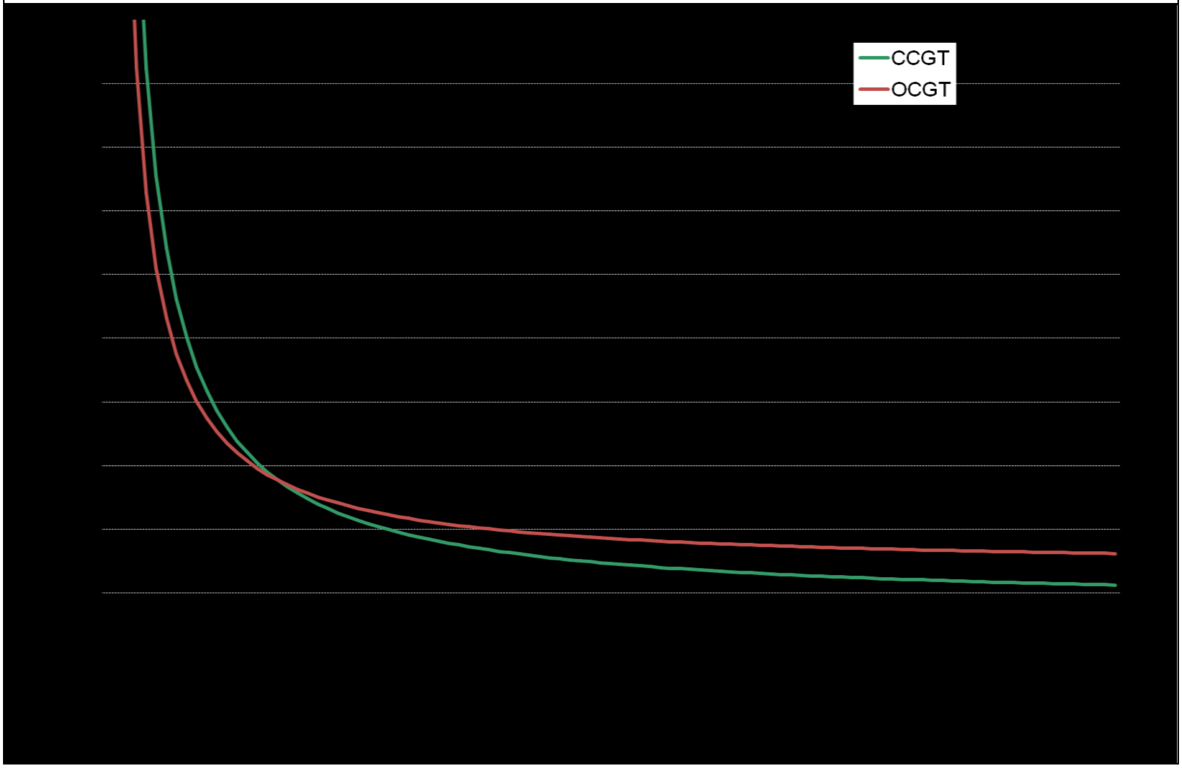
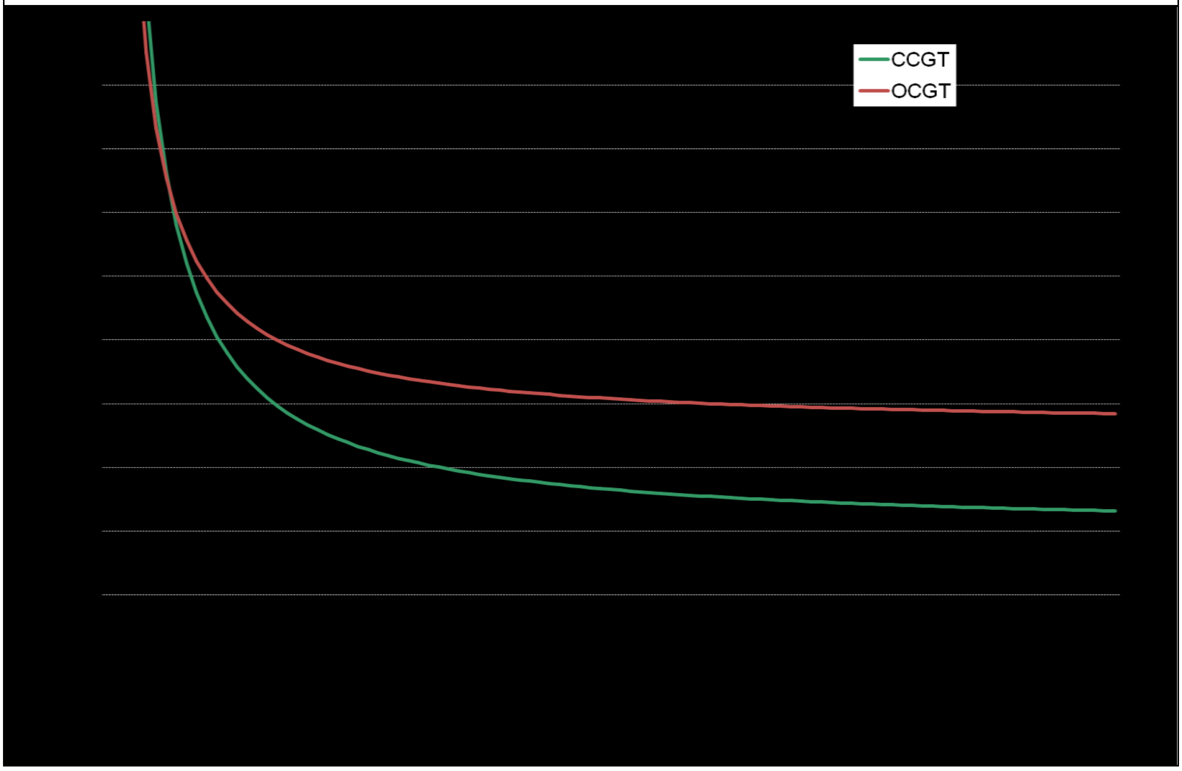


Figure 6.2 – LRMC - High gas price ($10-13/GJ), high carbon price ($60/t$CO_2$-e)



Mixture of existing plant

Predicting the capacity factor at which a plant is likely to operate is complex. It will depend heavily upon the mixture of other plant already in the system. If the system already contains a large quantity of other plant that has low short run marginal costs and wants to operate at high capacity factors (eg. coal-fired plant, other CCGT and wind) then a new entry plant will tend to have a lower capacity factor (being dispatched less frequently than the existing lower short run marginal cost plant). This will incentivise the installation of OCGTs. On the other hand, if the system is currently lacking in low short run marginal cost plant this will tend to incentivize the installation of CCGTs.

Gas price

In addition to determining the range of capacity factors over which a CCGT is more economical than an OCGT, the gas price is a significant factor in determining the likely capacity factor of a new plant. A higher gas price will cause gas plant to bid higher (due to higher short run marginal costs), and therefore be dispatched less, reducing the capacity factor. It will be a balance between the change in capacity factor and the change in the range of capacity factor (and the other drivers) that determines which plant is ultimately the most economical.

Quantity of wind generation

The quantity of wind generation installed is a significant factor in the decision of whether to install a CCGT or an OCGT. Wind generation in this study has been assumed to offer only 15% of capacity at time of peak, but in the SWIS will often actually operate at capacity factors greater than 40%. This means that the installation of a large quantity of wind generation creates an excess of energy in the system that is not matched by capacity. This will tend to decrease the capacity factors of thermal plants and hence incentivise the installation of OCGTs.

Another factor that is important in the decision of whether to install OCGTs or CCGTs is the ability of each plant to provide ancillary services, particularly load following. CCGTs are relatively inflexible[16], whereas OCGTs can easily provide load following. With very large quantities of wind energy installed in the SWIS the requirement for load following will increase dramatically. This may prove to be a serious driver of the installation of OCGTs in the SWIS. The quantity of plant required for load following will be refined in later Work Packages.

All of these competing factors are summarised in Table 6.1.

[16] Lyle Chapman, CS Energy, Swanbank E - Operation and Maintenance Experience with the Alstom G&26B Turbine. 5th Annual Australian Gas Turbines Conference, July 2004.

Table 6.1 – Factors driving OCGTs vs CCGTs		
High gas price	CCGT is more economical for a wider range of capacity factors	Incentivises CCGTs
	Gas plant will bid higher (due to higher short run marginal costs) and therefore be dispatched less, reducing capacity factors	Incentivises OCGTs
Higher carbon price	CCGT is more economical for a wider range of capacity factors	Incentivises CCGTs
	May drive greater investment in intermittent technologies, causing a greater need for load following services	Incentivises OCGTs
Higher quantity of intermittent generation	Greater need for load following services	Incentivises OCGTs
	Intermittent generation provides large quantities of energy that are not matched by capacity at time of peak, generally reducing dispatch of thermal plant	Incentivises OCGTs
Mixture of other plant	Large quantities of low SRMC plant available (coal, wind, CCGT)	Incentivises OCGTs
	Very little low SRMC plant available	Incentivises CCGTs

Since there are so many interrelated factors, detailed dispatch modelling and preferably long range Integrated Resource Planning is required to conclusively determine the competitiveness of OCGTs vs CCGTs in any scenario. This is outside the scope of this Work Package, especially when considering requirements for ancillary services (which will be dealt with in more detail in later Work Packages). However, for this study ROAM has taken a broad first principles approach to incorporate the impacts of each factor, considering previous Integrated Resource Planning studies of the SWIS and other grids. The following guidelines were used:

- Typical capacity factors for each plant installed were used to calculate the balance of energy in each year, and provide a guide for the likely capacity factor of a new plant. If there was generally a large excess of energy OCGT plant was favoured. If there was generally very little excess energy CCGT plant was favoured (in anticipation of higher capacity factors in a dispatch).
- A mixture of OCGT and CCGT plant was installed in all cases, to account for the different roles that each type play in the system (ancillary services, etc).
- Where low SRMC plant (coal-fired plant) was retired it was generally replaced with CCGT plant (expected to operate at a similar capacity factor) in preference to OCGT plant.
- Where large quantities of wind were installed, the additional capacity required was generally filled with OCGTs in preference to CCGTs.
- In scenarios with higher gas prices the amount of excess energy was examined (calculated based upon typical capacity factors for each plant type). If there was a large excess of energy available (as was the case in most scenarios, since all included a large quantity of wind) OCGT plant was given a slight preference in expectation of lower capacity factors under increased short run marginal costs.

Other disruptive technologies

The impacts of other disruptive technologies were not included in this study due to the significant uncertainty in their development. This includes technologies such as large amounts of demand side management, smart meters, energy storage on a large scale, and the possible impacts of electric vehicles. These technologies may have significant impacts on the SWIS, but have very large uncertainty associated with their development and commercialization. They have therefore been considered outside the scope of this study.

A small quantity of demand side management has been included in the planting schedules, since it has been announced for implementation.

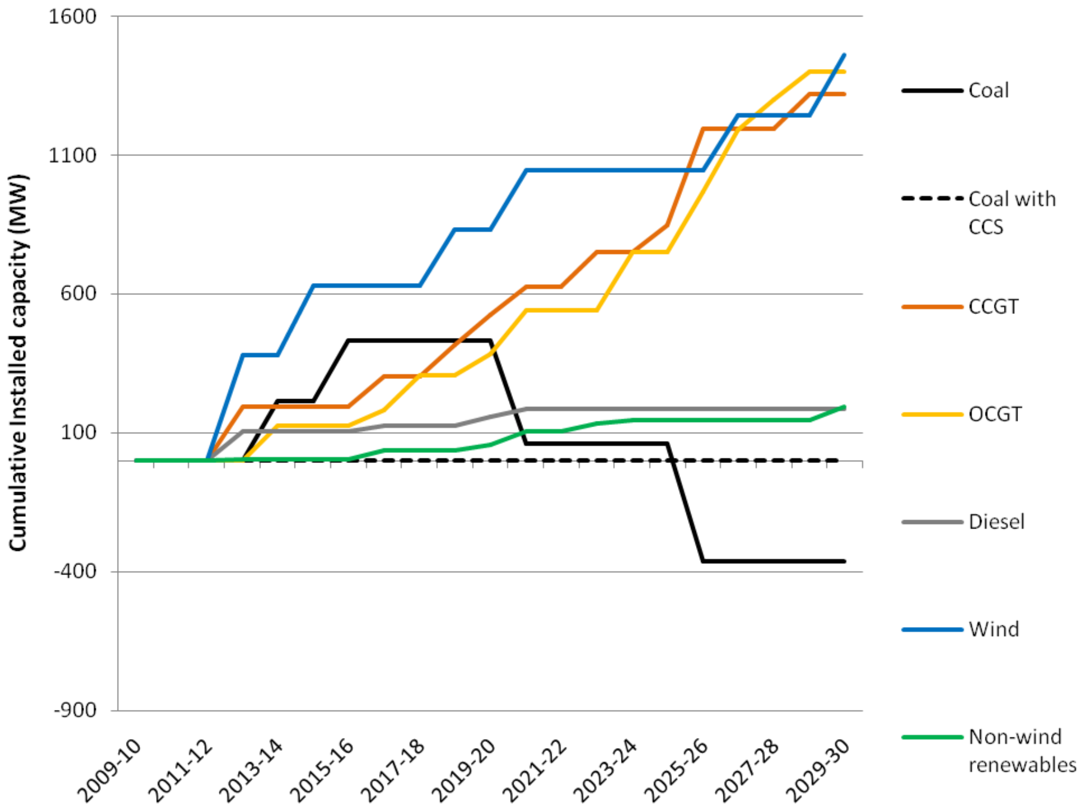
6.2) SCENARIO 1 – STRAINED NETWORK

The full planting schedule for Scenario 1 is listed in Appendix C. The planting outcome for this scenario is explored and illustrated in a variety of figures below.

As illustrated in Figure 6.3, under Scenario 1 a moderately strong CPRS (15% reduction below 2000 levels by 2020) causes relatively low investment in coal, with only 430 MW installed from 2010 to 2030. All installed coal plant is assumed to be “CCS ready”, in anticipation of higher emissions prices under the CPRS. The relatively high carbon price drives the retirement of Muja C in 2020-21 (it is replaced by a combination of OCGT and CCGT generation since a mixture of the two plant types is likely to provide the most similar capacity factor to that at which the coal-fired plant would be expected to operate by this date). Muja D similarly retires soon after in 2025-26, when sufficient replacement capacity becomes available.

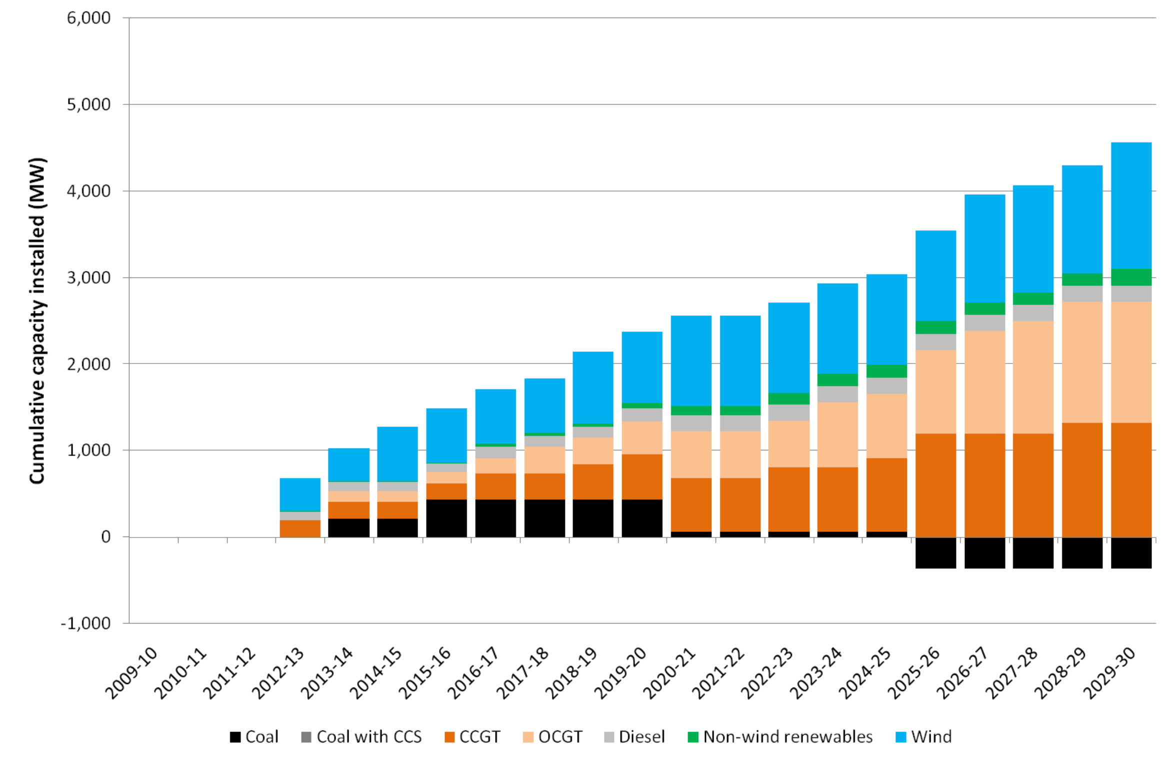
In general gas generation is costly due to high gas prices, but remains incentivized by the CPRS (which reduces competition from more emissions intensive alternatives). OCGTs are incentivized by the high quantity of wind installed (which provides energy but very little capacity to the reserve margin).

Figure 6.3 – Scenario 1 – Installed capacity by technology type



The planting outcome is illustrated in stacked form in Figure 6.4. The total capacity installed under this scenario is high despite the low load growth because a large proportion of the installed capacity is wind generation (which does not contribute its full capacity to the supply-demand balance when calculating reserve margins).

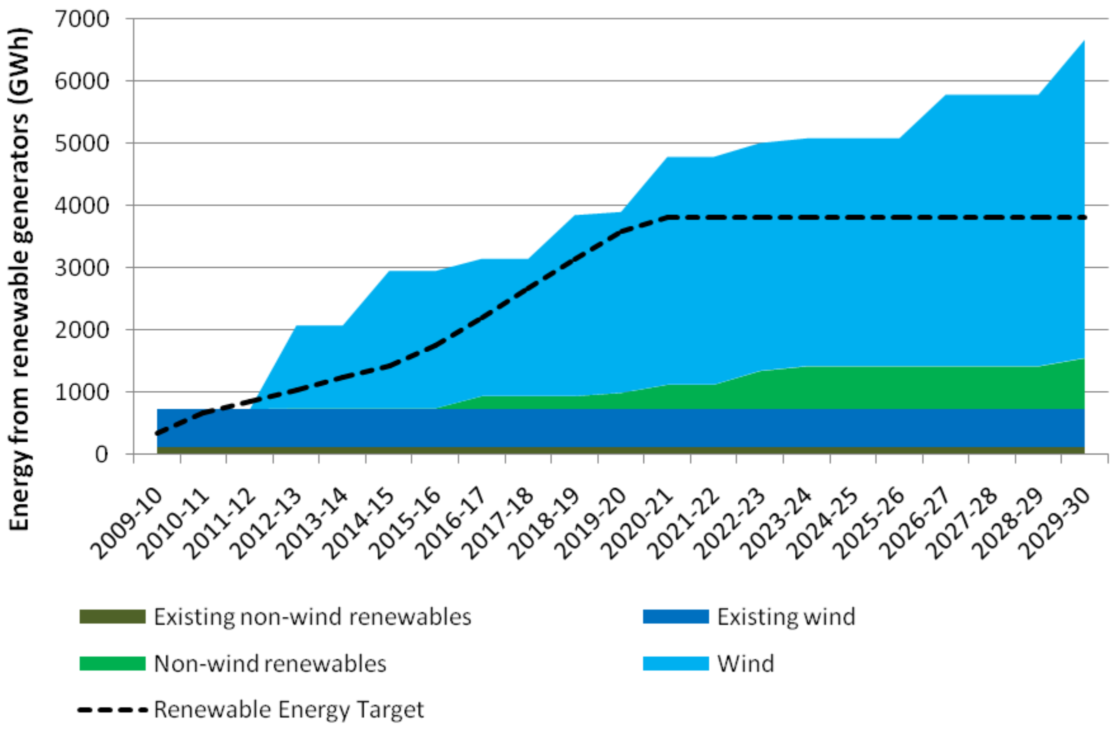
Figure 6.4 – Scenario 1 – Installed capacity by technology type (stacked)



As illustrated in Figure 6.5 non-wind renewable technologies develop slowly under this scenario, which drives strong investment in wind energy to meet the RET. Due to the moderately strong CPRS and high gas prices, investment in wind energy exceeds the RET from an early date. 1045 MW of wind is installed by 2020, and 1460 MW by 2030.

This scenario is designed to explore an outcome where the grid will be maximally strained. It should be noted that a further 850 MW is currently proposed for installation in the SWIS which has not been included in this planting schedule. However, the installation of this quantity of wind generation in the SWIS should be considered a somewhat extreme scenario.

Figure 6.5 – Scenario 1 – Renewable generation to meet the RET[17]



In this chart the line "Renewable Energy Target (10%)" provides an indication of the quantity of renewable energy that would need to be installed in the SWIS to meet a share of the national target proportional to the load in the SWIS. Banking of certificates is permissible under the scheme, which incentivises exceedence of the target in early years.

Figure 6.6 shows the distribution of installed projects by area in the SWIS, divided into intermittent (wind and solar PV) and schedulable generation. Schedulable generation is spread relatively evenly around the SWIS, whereas intermittent generation is concentrated in the North Country, East Country and Muja areas. This is likely to stress the transmission grid (as this scenario is designed to do).

[17] It should be noted that full dispatch simulation modelling is required to accurately determine the energy outputs of stations in this complex system. The numbers illustrated in this figure are only an estimate based on a variety of approximations, designed only to provide a guide for creating the planting schedule outcomes.

Figure 6.6 – Scenario 1 – New capacity installed by location by 2030

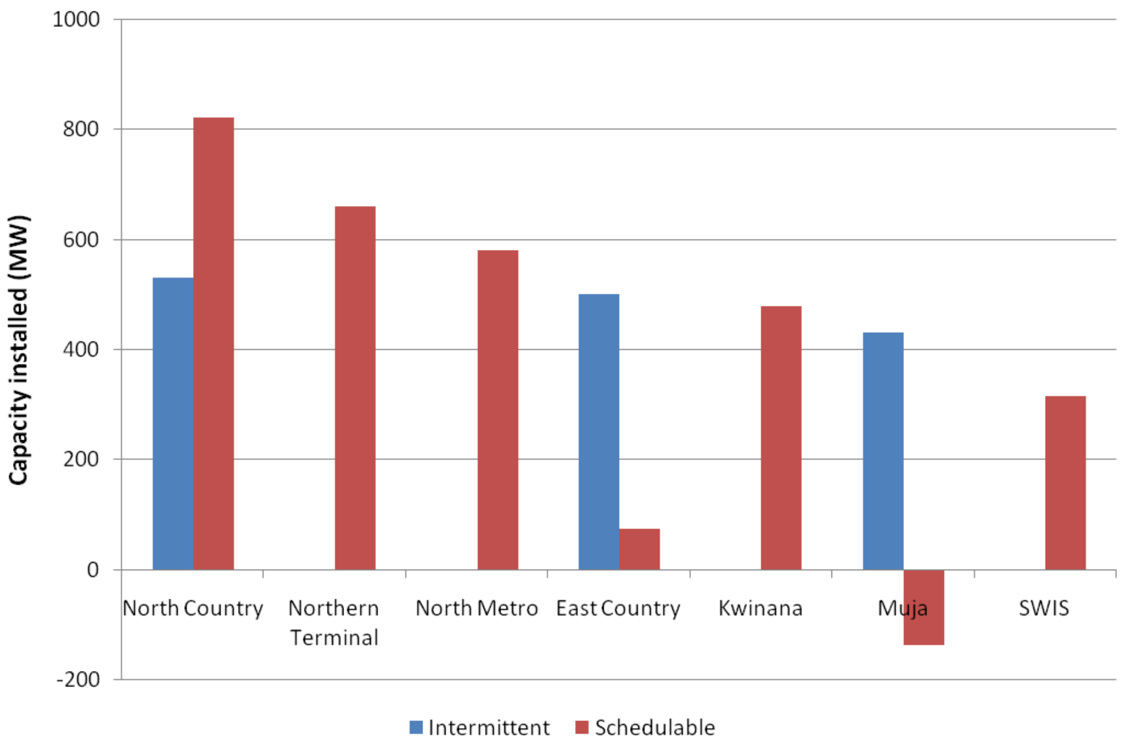
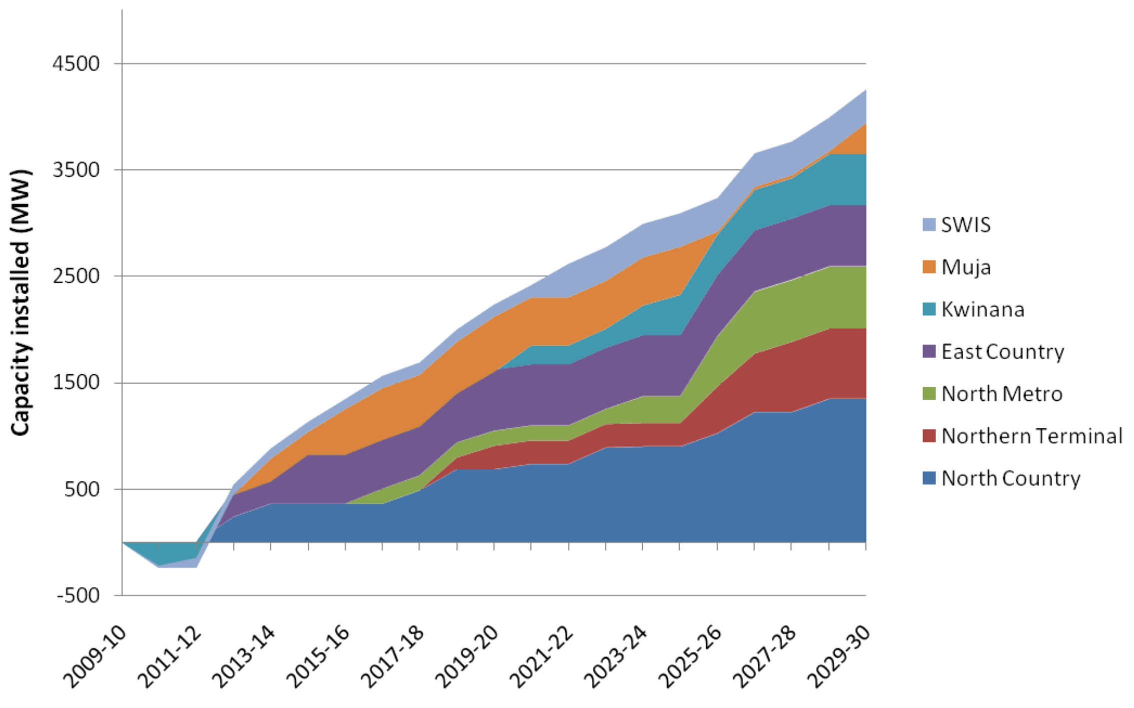


Figure 6.7 illustrates the installation of generation by area over time. The Muja and North Country areas receive a large quantity of new generation, due to the combination of new schedulable and new intermittent generation. There is an initial reduction in the Kwinana area, due to the retirement of the Kwinana A power station in 2010-11.

Figure 6.7 – Scenario 1 – New capacity installed by location (stacked)

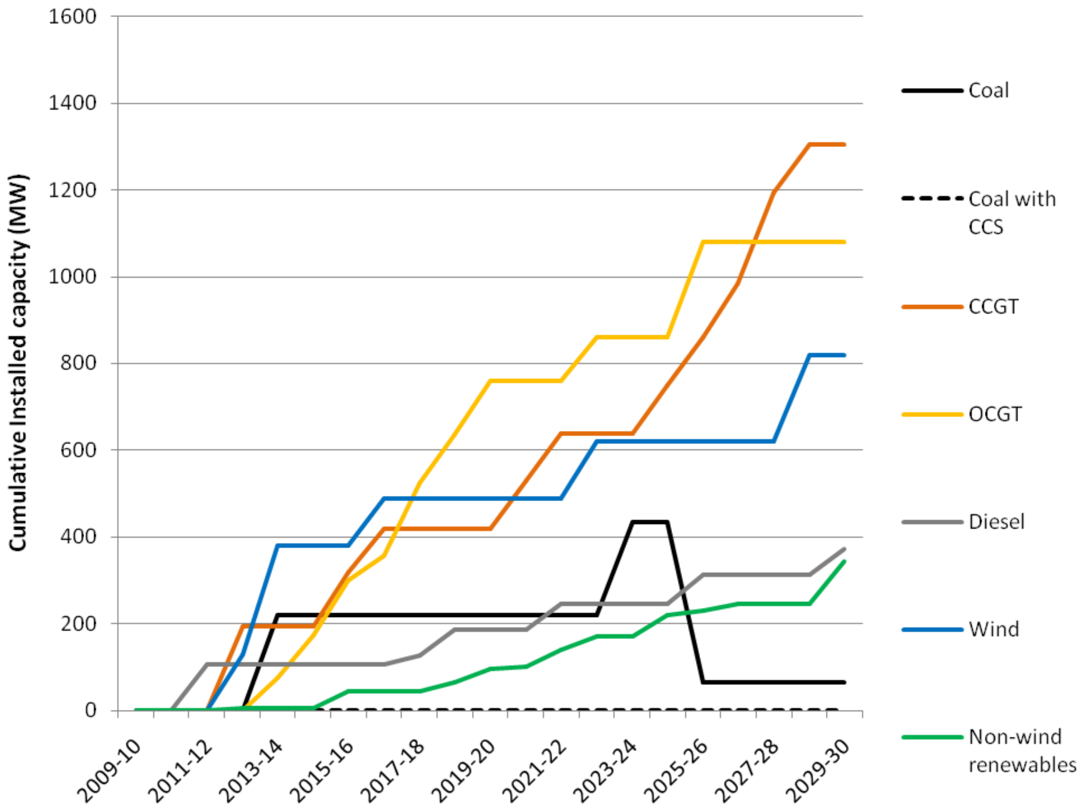


6.3) *SCENARIO 2 – MINIMAL CHANGE*

The planting schedule outcome for Scenario 2 is shown in Appendix C. This outcome is illustrated and explored in the figures below.

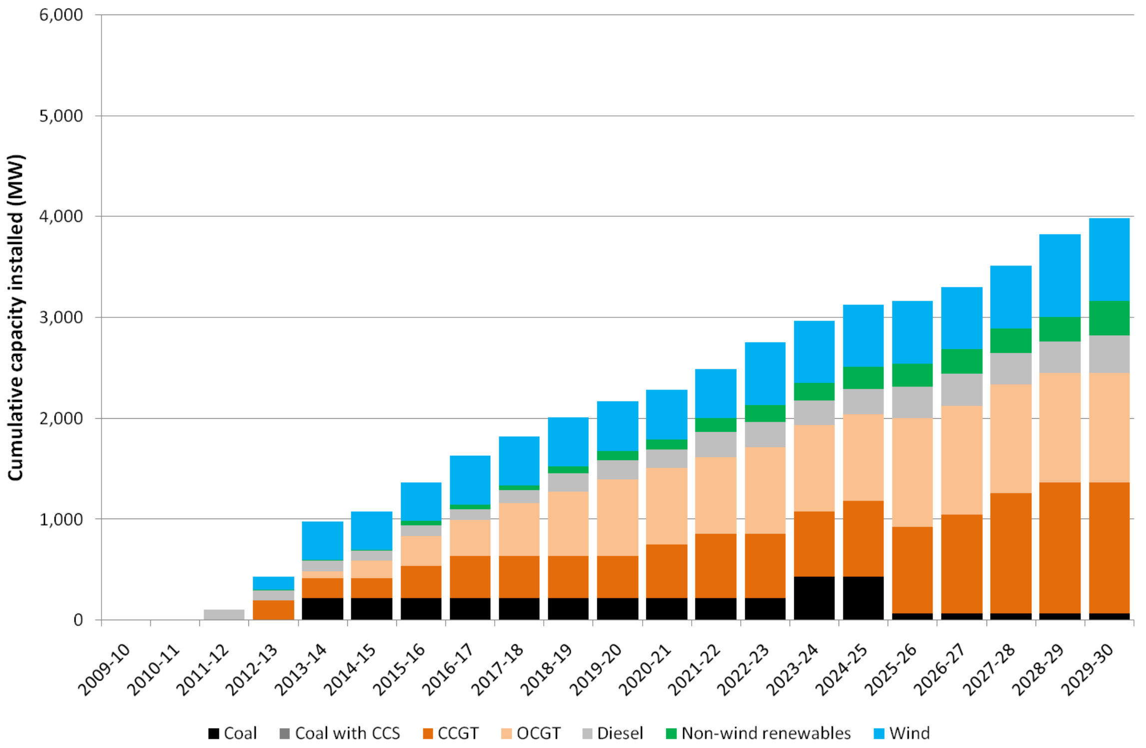
Under Scenario 2 the competition between coal and gas is similar to Scenario 1. Despite a much less ambitious CPRS (5% reduction below 2000 levels by 2020), gas prices are lower, allowing a mixture of gas and coal generation to be installed (Figure 6.8). All installed coal plant is assumed to be "CCS ready", in anticipation of higher emissions prices under the CPRS.

Figure 6.8 – Scenario 2 – Installed capacity by technology type



This is illustrated in stacked form in Figure 6.9.

Figure 6.9 – Scenario 2 – Installed capacity by technology type (stacked)

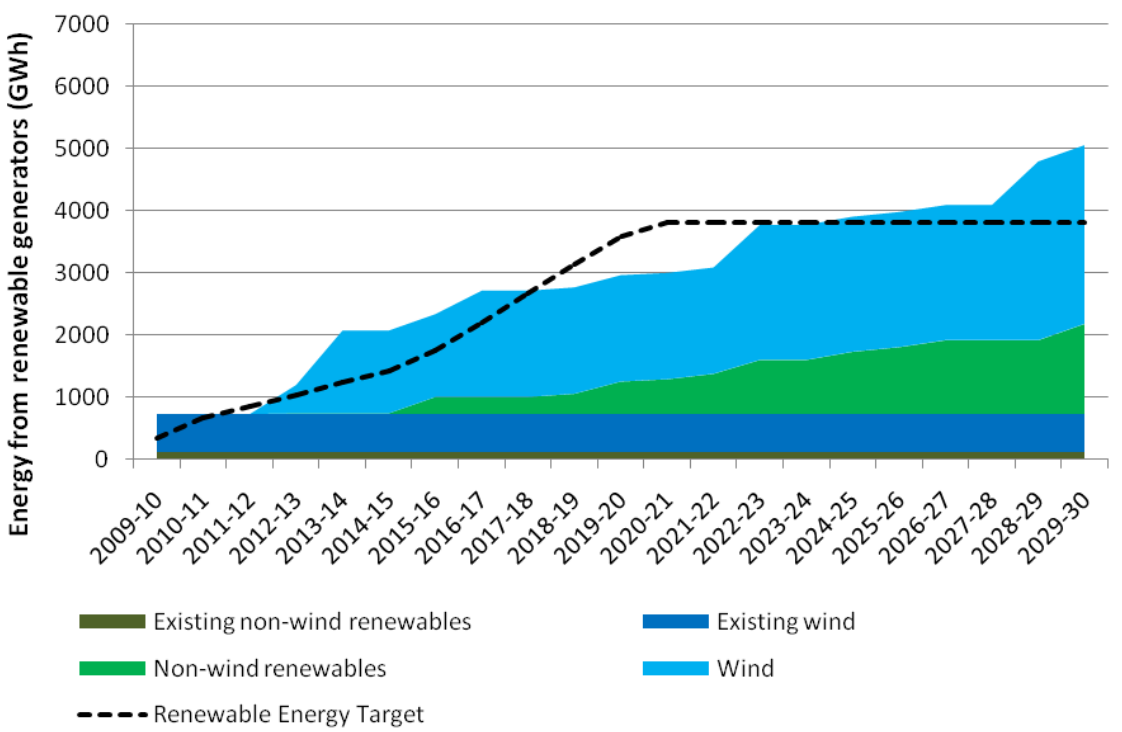


The unambitious CPRS in this scenario causes a relatively low level of investment in renewable technologies, with the SWIS only just achieving its share of the RET (Figure 6.10). Due to lack of incentives the less mature renewable technologies (non-wind) develop slowly and only minor pilot projects in various technologies are installed. Therefore the majority of the RET is met by wind, with 488 MW installed by 2020, and 820 MW by 2030.

Banking of renewable energy certificates is permissible under the RET, incentivising overshoot of the annual targets in the early years of the scheme, and allowing underachievement of targets in the following years.

By the very late part of the study the non-wind renewable technologies become more cost effective, and carbon prices are high enough to incentivise a small amount of additional wind installation beyond the RET (despite the modest 5% target).

Figure 6.10 – Scenario 2 – Renewable generation to meet the RET[18]



In this chart the line "Renewable Energy Target (10%)" provides an indication of the quantity of renewable energy that would need to be installed in the SWIS to meet a share of the national target proportional to the load in the SWIS. Banking of certificates is permissible under the scheme, which incentivises exceedence of the target in early years.

Figure 6.11 illustrates the distribution of projects by area in the SWIS. Development is relatively evenly distributed. This is also illustrated in Figure 6.12 in stacked form.

[18] It should be noted that full dispatch simulation modelling is required to accurately determine the energy outputs of stations in this complex system. The numbers illustrated in this figure are only an estimate based on a variety of approximations, designed only to provide a guide for creating the planting schedule outcomes.

Figure 6.11 – Scenario 2 – New capacity installed by location by 2030

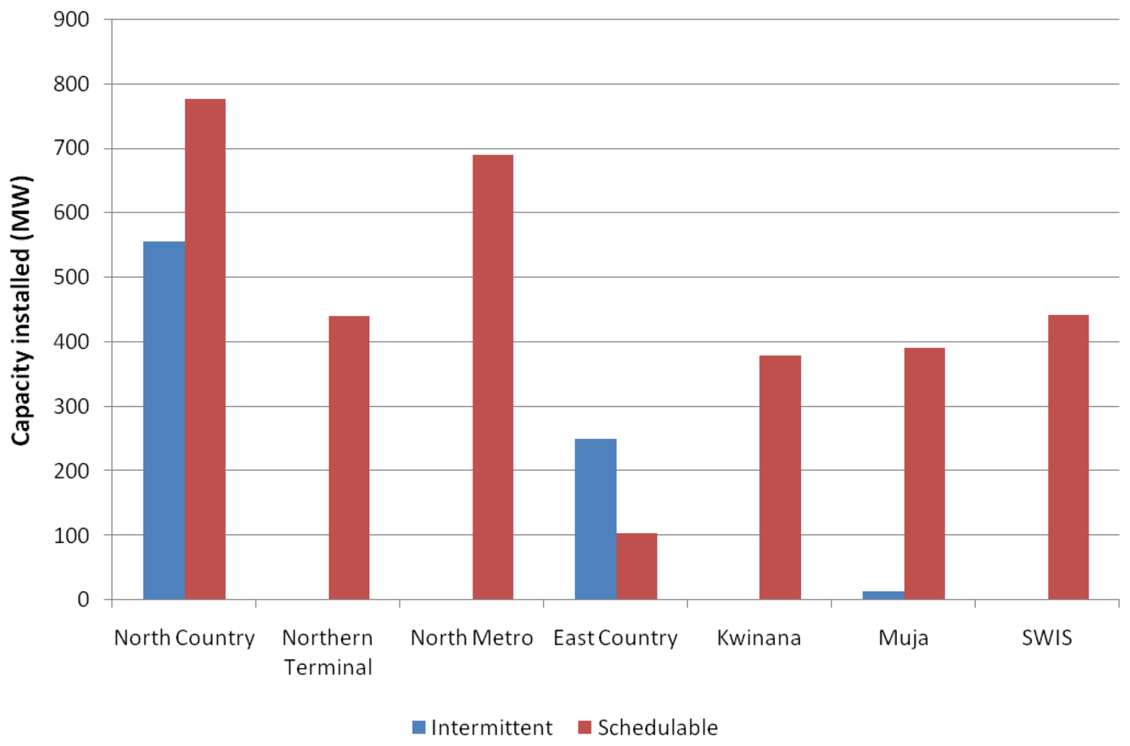
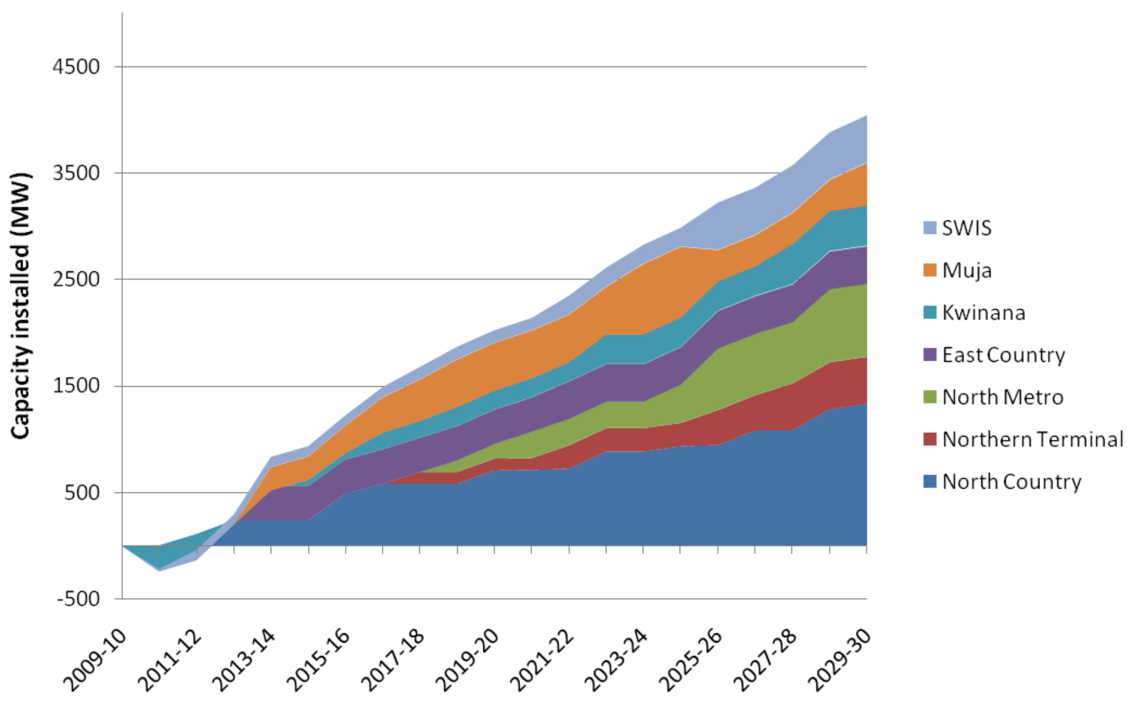


Figure 6.12 – Scenario 2 – New capacity installed by location (stacked)



6.4) *Scenario 3 – Low Emissions*

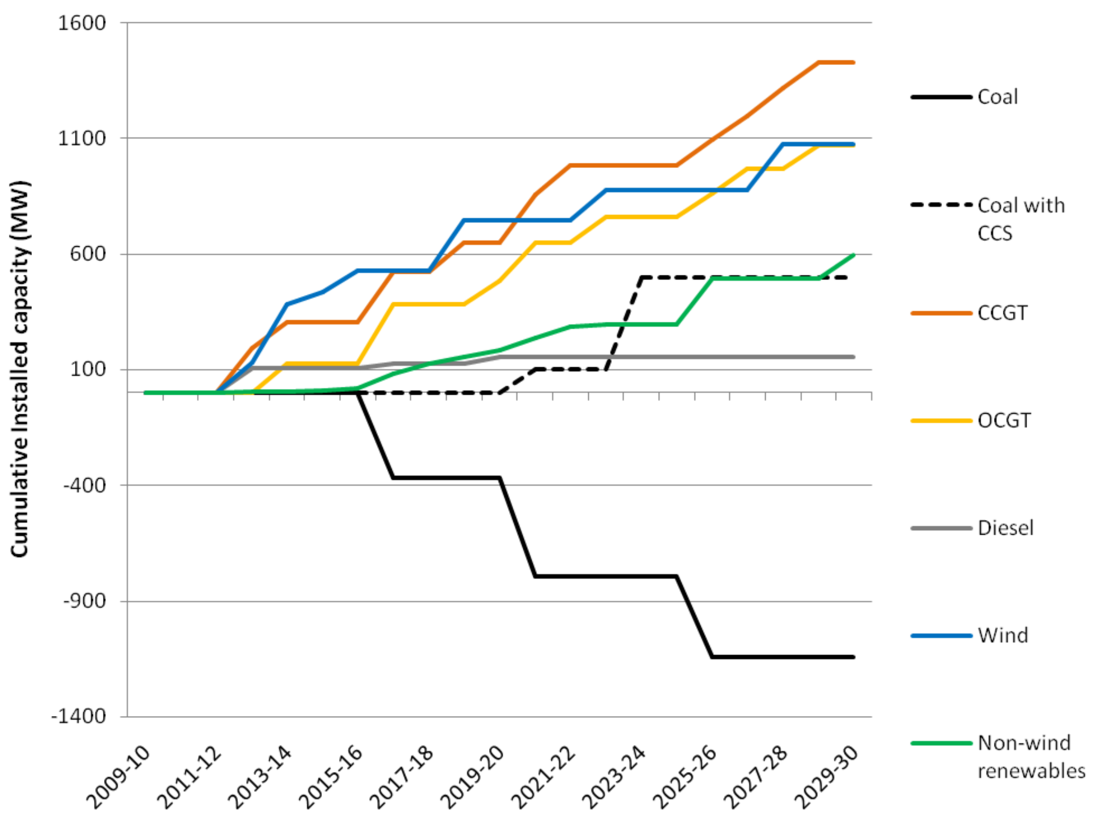
The planting schedule outcome for Scenario 3 is listed in Appendix C and explored further in the figures below.

In Scenario 3 the very ambitious CPRS (25% reduction below 2000 levels by 2020) excludes the possibility of installing coal plant without CCS technology (Figure 6.13). A pilot 100MW CCS coal plant is installed in 2020, and a larger 400 MW plant several years later in 2023-24.

The very high carbon price drives the retirement of Muja C in 2016-17, when sufficient replacement capacity (in the form of CCGTs) becomes available and undercuts its operation. Muja D similarly retires in 2020-21 when the Electricity Sector Adjustment Scheme ceases to provide incentives for emissions intensive coal-fired plant to remain available to the market.

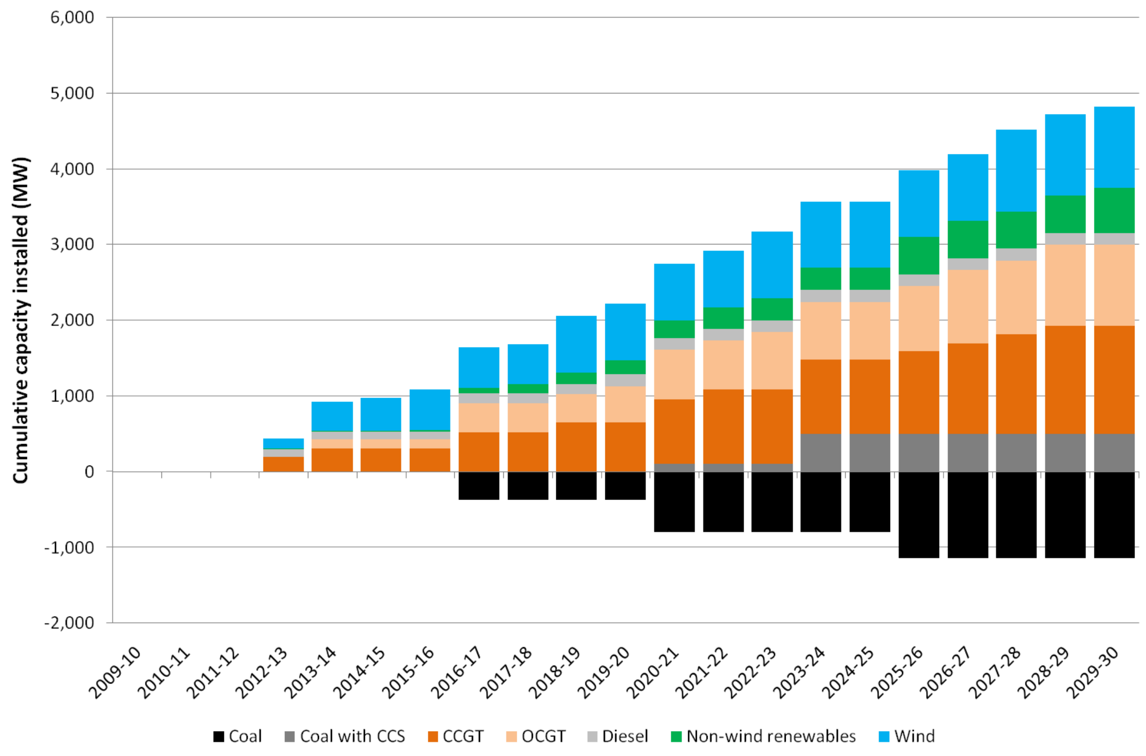
The high cost of coal technologies drives investment towards gas, further incentivised by the moderate gas prices in this scenario. Investment favours CCGTs in early years of the study due to the lack of other types of low short run marginal cost (SRMC) generation. In the later parts of the study OCGTs are favoured due to the abundance of renewable technologies available to provide low SRMC generation.

Figure 6.13 – Scenario 3 – Installed capacity by technology type



The planting outcome is illustrated in stacked form in Figure 6.14.

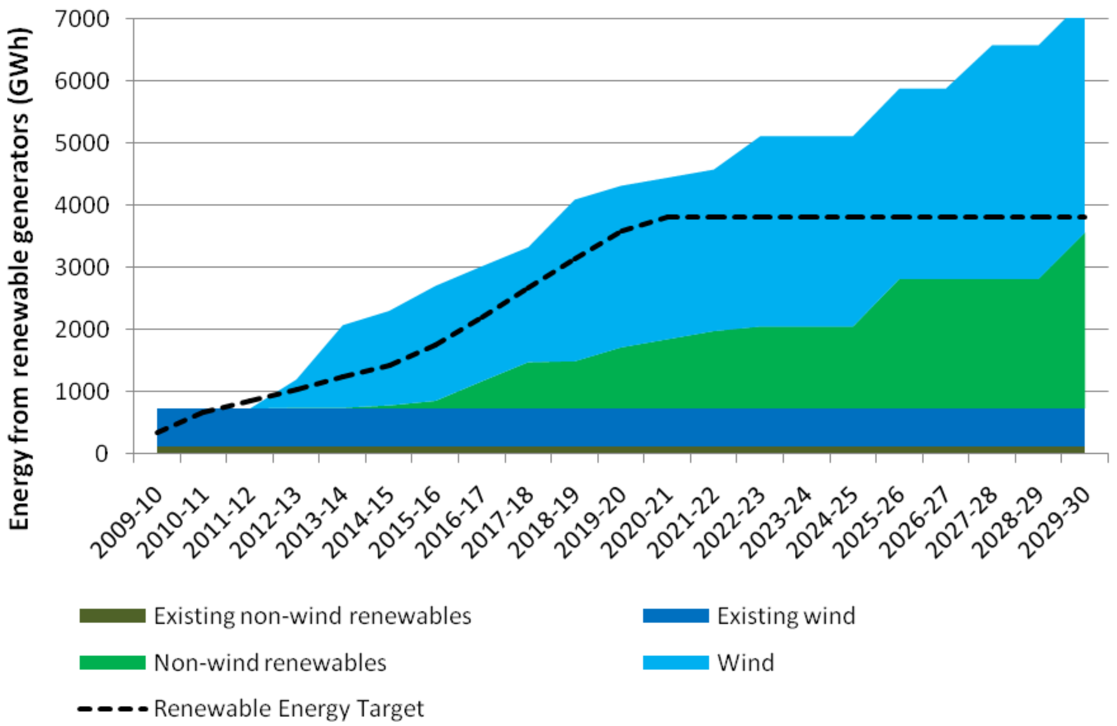
Figure 6.14 – Scenario 3 – Installed capacity by technology type (stacked)



The very high carbon price allows significant investment in renewable technologies, and a wide variety of them are available from an early date (Figure 6.15). This is the only scenario where non-wind renewable technologies are present in reasonable quantities, allowing 600 MW to be installed by 2030. This is accompanied by 1080 MW of wind (in 2030).

The investment in renewable technologies exceeds the RET initially due to the incentives to bank renewable energy certificates. Later, the carbon price is sufficient to incentivise renewable technologies making the RET obsolete.

Figure 6.15 – Scenario 3 – Renewable generation to meet the RET[19]



In this chart the line "Renewable Energy Target (10%)" provides an indication of the quantity of renewable energy that would need to be installed in the SWIS to meet a share of the national target proportional to the load in the SWIS. Banking of certificates is permissible under the scheme, which incentivises exceedence of the target in early years.

This scenario explores the maximum emissions reductions that are likely to be possible, if all measures are taken and all low carbon technologies receive substantial research and commercialization investment.

Figure 6.16 and Figure 6.17 illustrate the distribution of new capacity by area in the SWIS.

[19] It should be noted that full dispatch simulation modelling is required to accurately determine the energy outputs of stations in this complex system. The numbers illustrated in this figure are only an estimate based on a variety of approximations, designed only to provide a guide for creating the planting schedule outcomes.

Figure 6.16 – Scenario 3 – New capacity installed by location by 2030

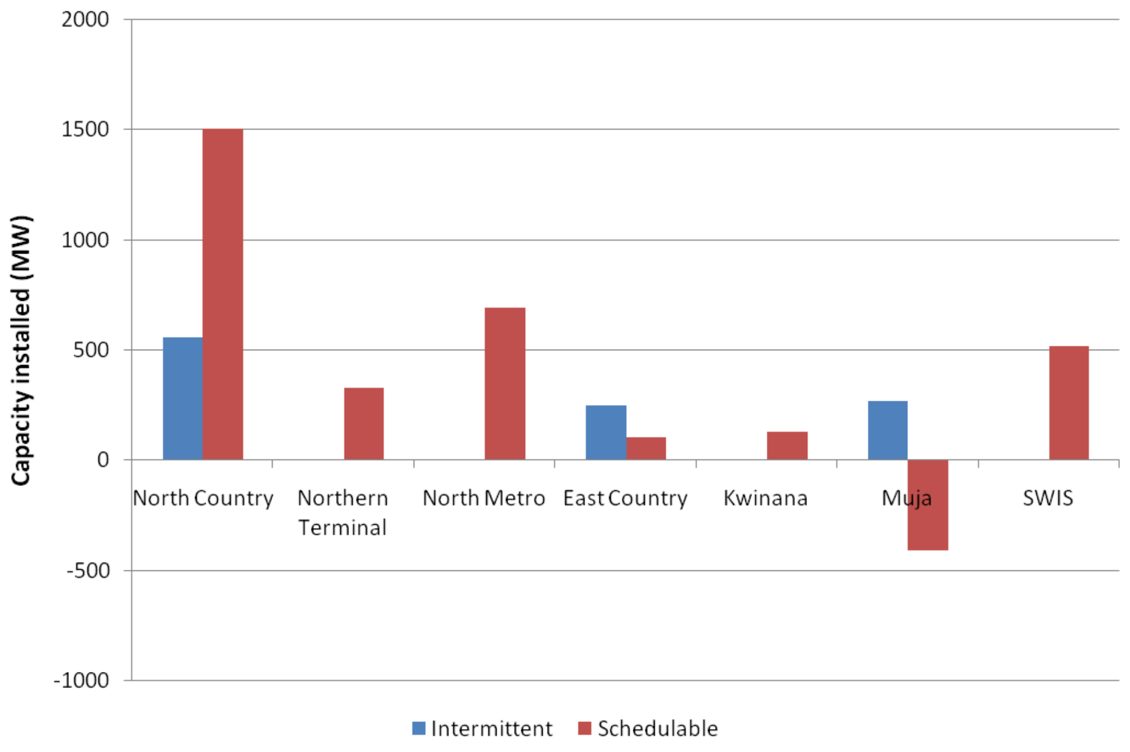
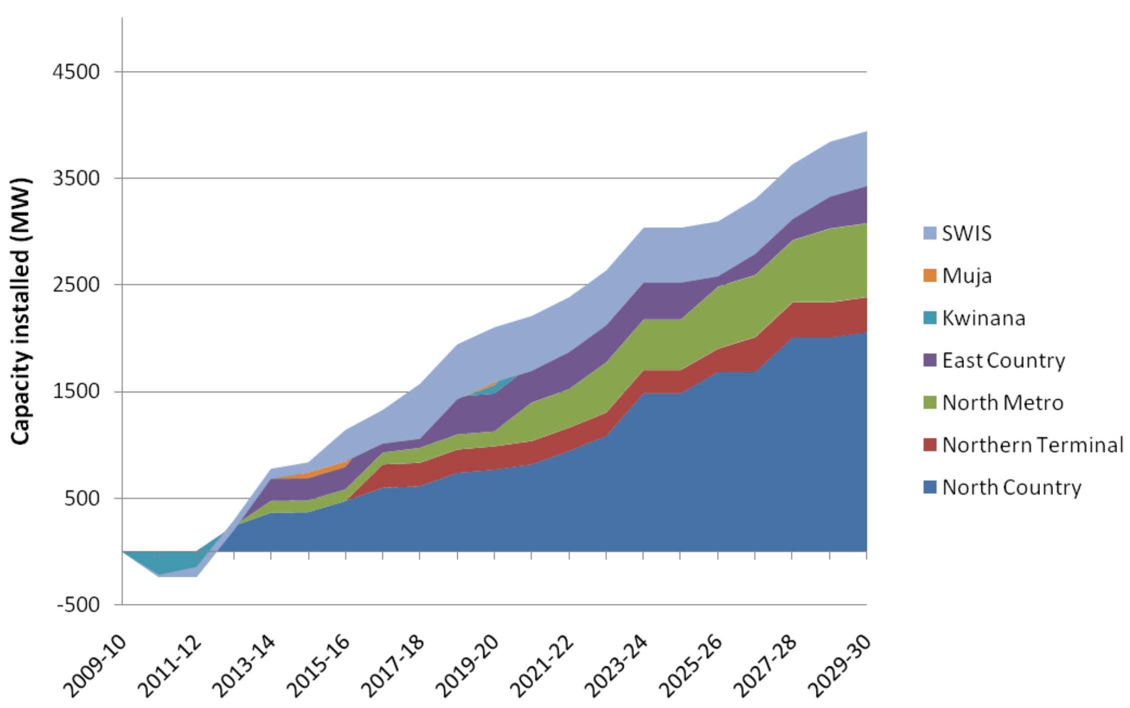


Figure 6.17 – Scenario 3 – New capacity installed by location (stacked)



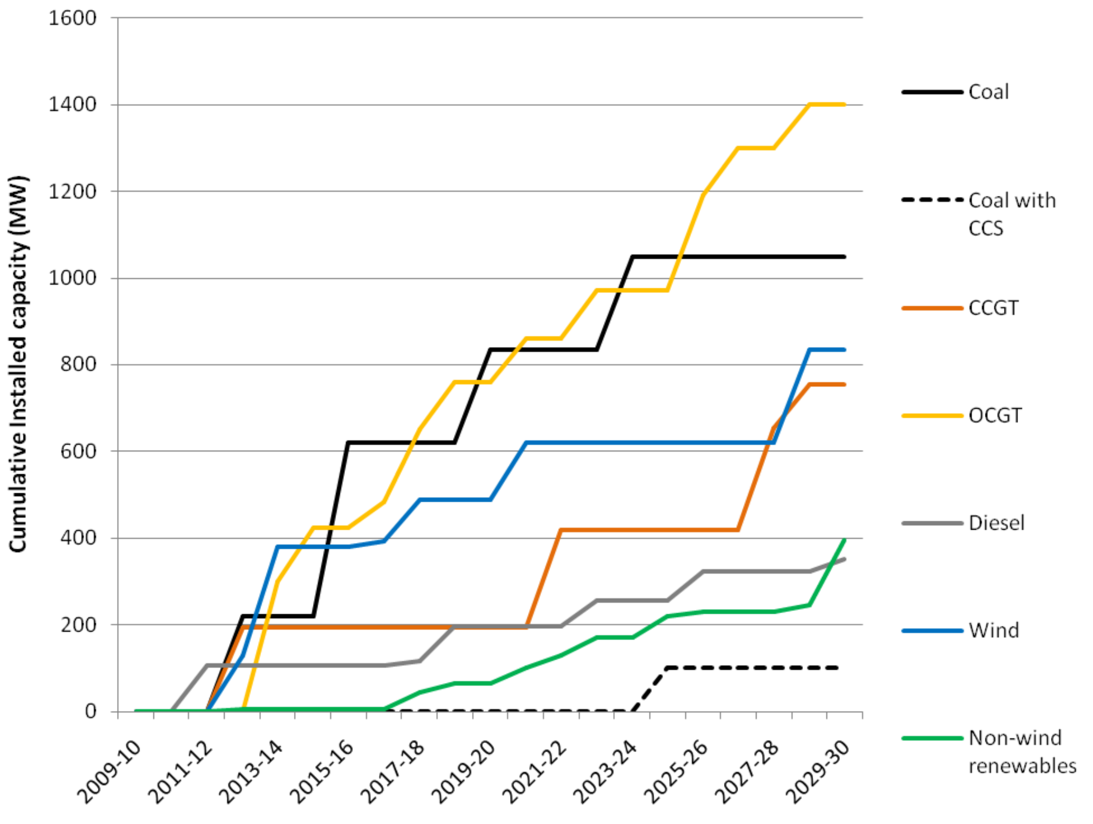
6.5) *SCENARIO 4 – COAL DEVELOPMENT*

The planting schedule outcome for Scenario 4 is shown in Appendix C. This is illustrated and explored further in the figures below.

In Scenario 4 an unambitious CPRS (5% reduction from 2000 levels by 2020) combined with high gas prices and high demand growth incentivises the installation of new coal plant, even in the absence of CCS technology. New coal generation capacity reaches 1050 MW by 2030 (Figure 6.18). All of this installed coal-fired capacity is assumed to be "CCS ready" in anticipation of higher future emissions prices under the CPRS.

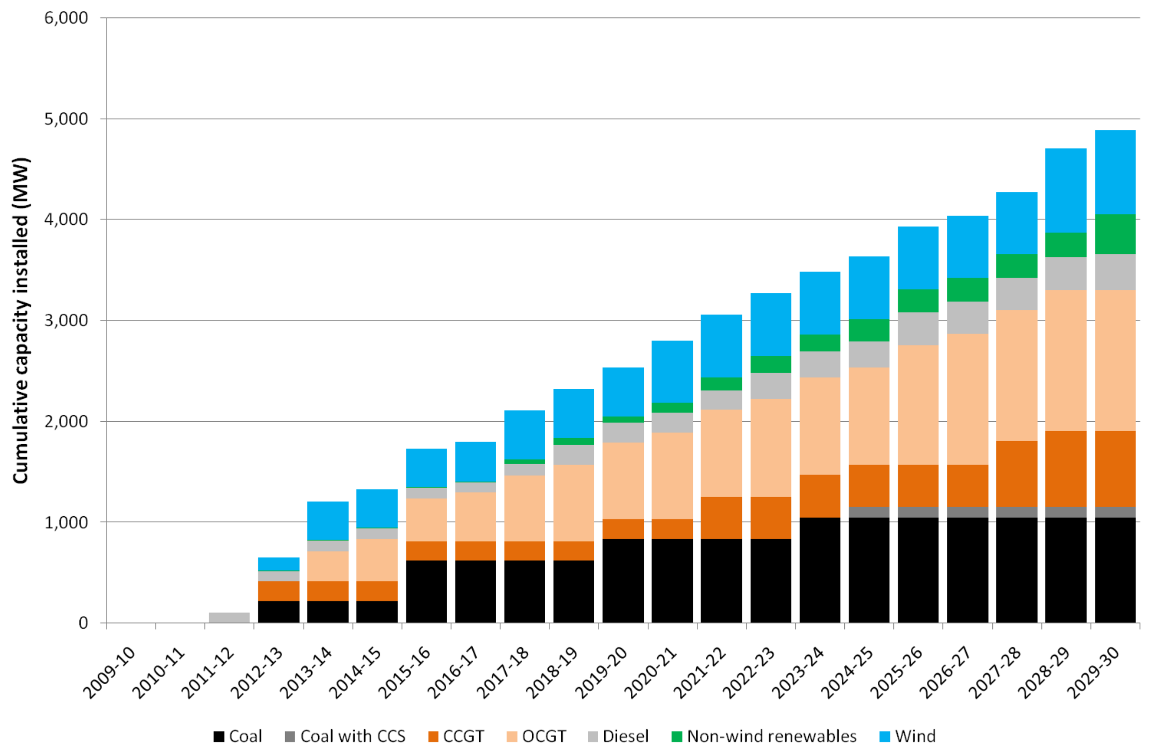
Investment in gas generation is also required to meet the very high demand growth in this scenario. OCGTs are favoured due to the large investment in low short run marginal cost coal-fired generation, but CCGTs are incentivised above further development in coal in the later parts of the study as the carbon prices rises and gas prices gradually approach international parity. A small CCS pilot project is available later in the study (2024-25).

Figure 6.18 – Scenario 4 – Installed capacity by technology type



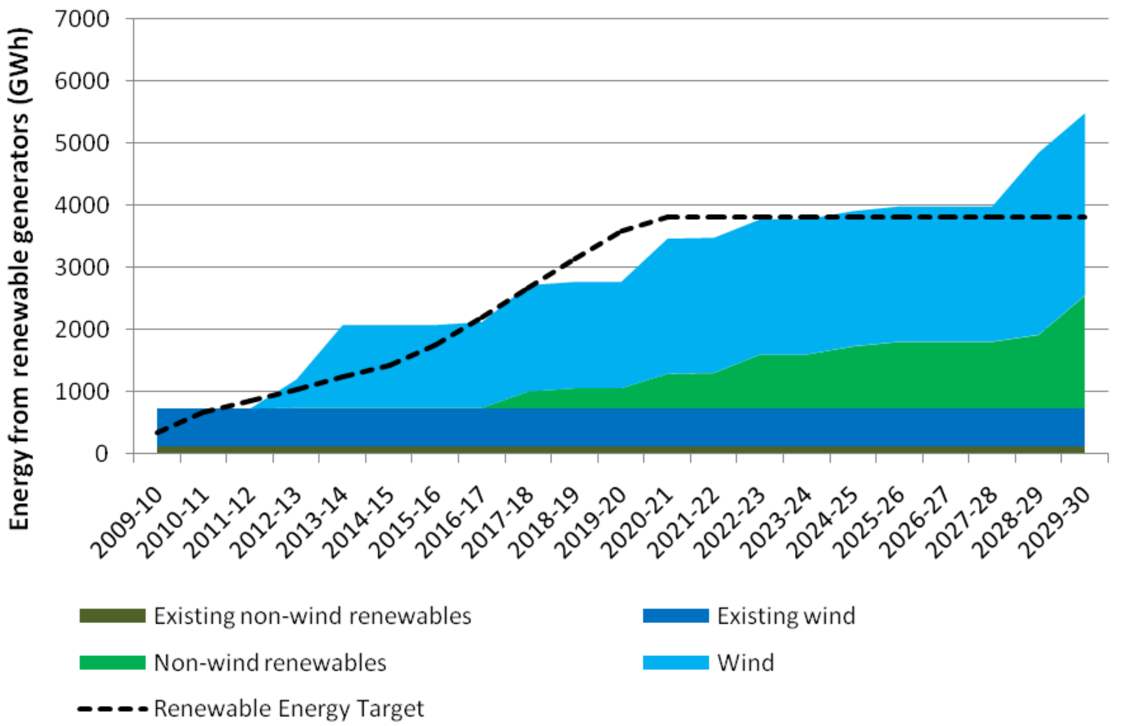
This is illustrated in stacked form in Figure 6.19.

Figure 6.19 – Scenario 4 – Installed capacity by technology type (stacked)



Renewable technologies are installed at a rate only just sufficient to meet the SWIS's proportionate share of the RET, with the majority in wind technology (835 MW by 2030). Banking of renewable energy certificates is incentivised in the early parts of the scheme, allowing underachievement of the target in the following years.

Figure 6.20 – Scenario 4 – Renewable generation to meet the RET[20]



In this chart the line "Renewable Energy Target (10%)" provides an indication of the quantity of renewable energy that would need to be installed in the SWIS to meet a share of the national target proportional to the load in the SWIS. Banking of certificates is permissible under the scheme, which incentivises exceedence of the target in early years.

Figure 6.21 and Figure 6.22 illustrate the geographical distribution of new generation in this scenario.

[20] It should be noted that full dispatch simulation modelling is required to accurately determine the energy outputs of stations in this complex system. The numbers illustrated in this figure are only an estimate based on a variety of approximations, designed only to provide a guide for creating the planting schedule outcomes.

Figure 6.21 – Scenario 4 – New capacity installed by location by 2030

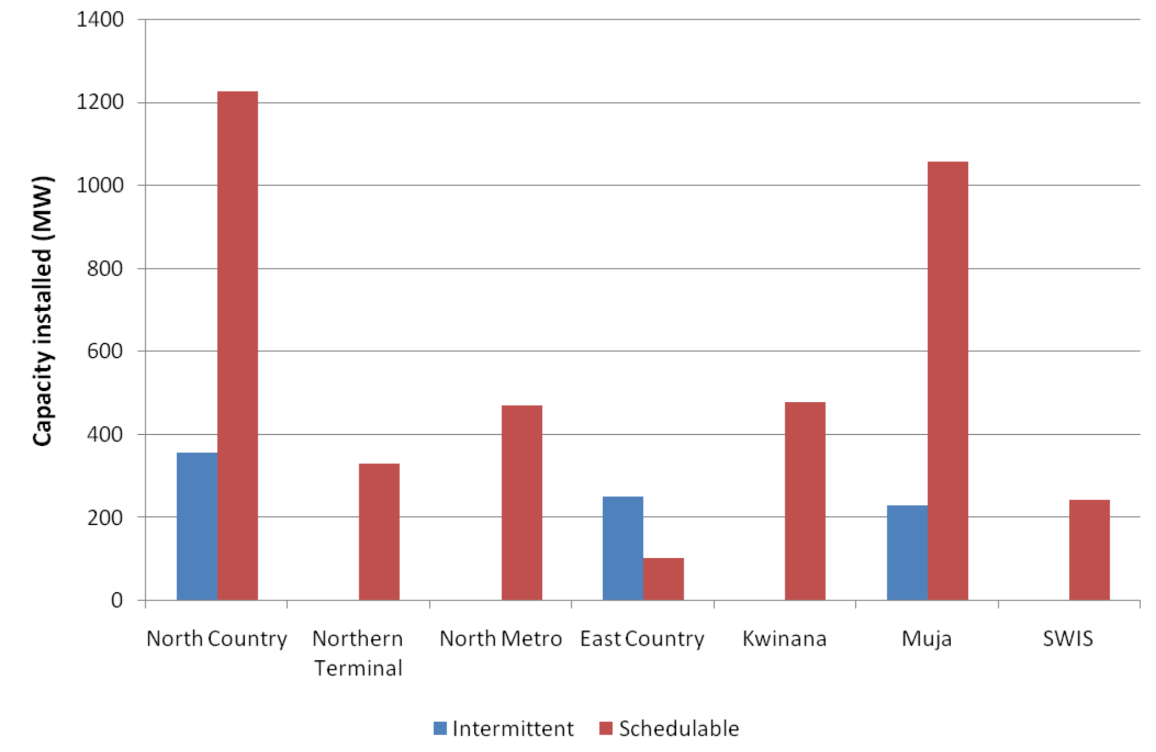
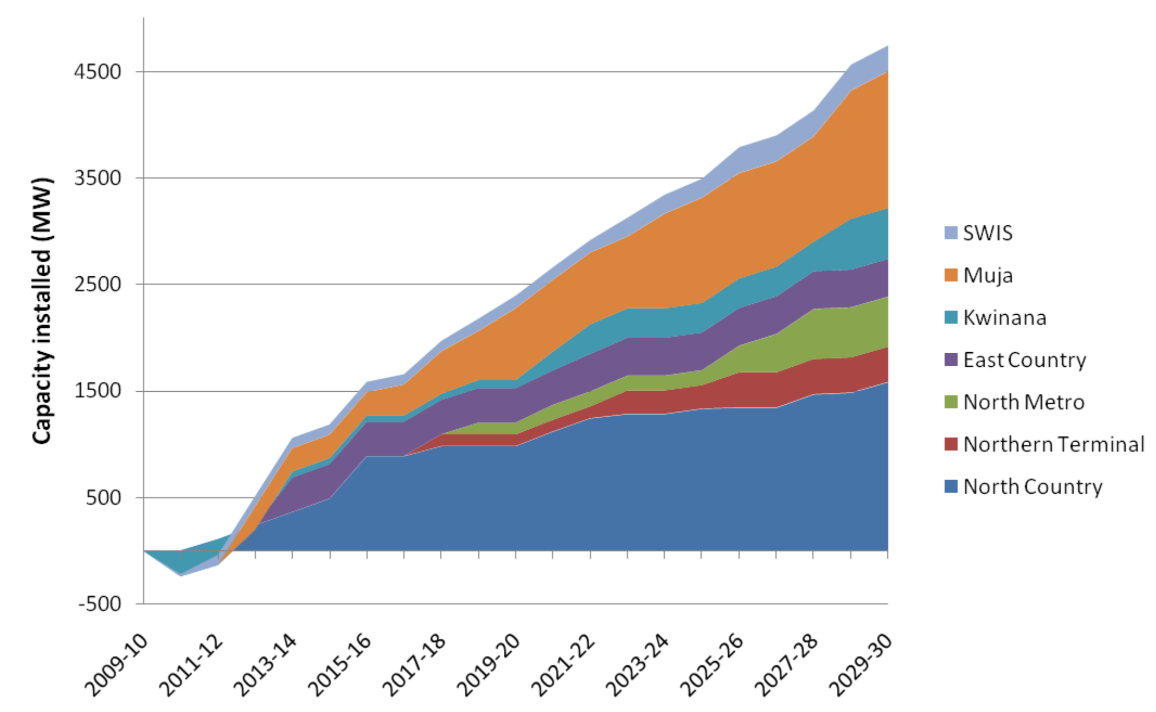


Figure 6.22 – Scenario 4 – New capacity installed by location (stacked)



6.6) GREENHOUSE EMISSIONS

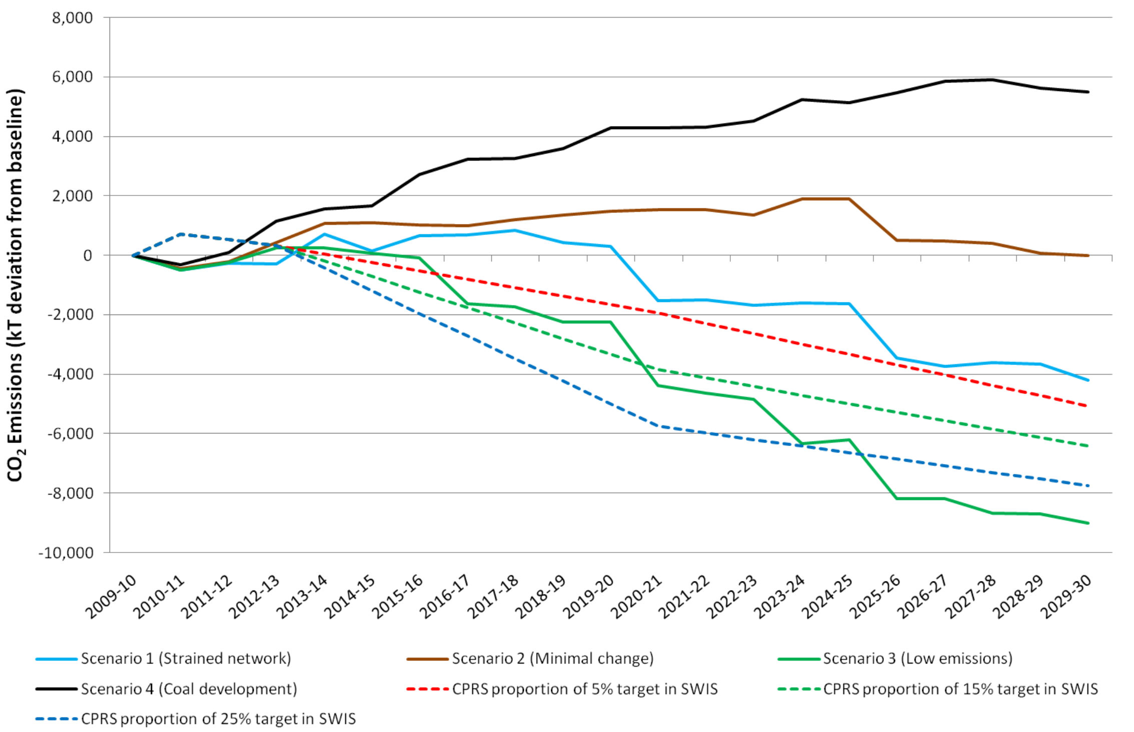
Full dispatch simulation modelling is required to accurately predict the greenhouse emissions resulting from any scenario. However, with some assumptions an estimate of the likely emissions for each scenario can be made. This is illustrated in Figure 6.23.

As would be expected, Scenario 4 (which has strong development in coal) exhibits the highest emissions of the scenarios, with greenhouse emissions continuing to rise strongly despite the CPRS 5% target. In this scenario it is assumed that Australia purchases a large quantity of international credits in order to meet the 5% target (rather than making emissions reductions domestically).

Scenario 3, which explores the measures that might be taken to reduce emissions from the SWIS as far as possible exhibits the lowest emissions. Initially emissions exceed the 5% trajectory, and it could be assumed that Australia would purchase international credits to meet the annual targets in these years (if sufficient borrowing is not available). Past 2020 retirement of the most emissions intensive coal-fired plant can occur (since they are no longer incentivized to remain available by the Electricity Sector Adjustment Scheme), substantially reducing emissions. A wider range of renewable technologies also become available and cost effective under the high carbon prices of this scenario, allowing emissions to fall further.

In between these two, Scenario 1 (which features a large quantity of wind and a strong 15% CPRS) has lower emissions than Scenario 2 (which features a less ambitious 5% CPRS).

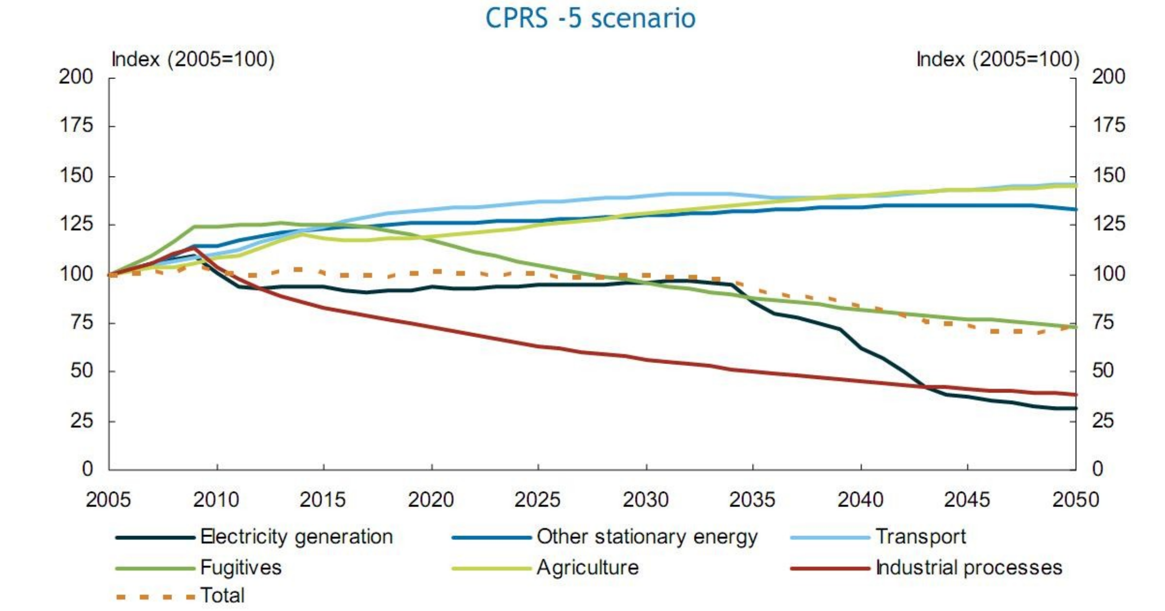
Figure 6.23 - Greenhouse emissions estimate (relative to 2009-10 baseline) [21]



All scenarios show an initial rise in emissions, and only Scenarios 1 and 3 show any reduction in emissions over the study timeframe. It should be noted that this is consistent with modelling by the Australian Treasury (Figure 6.24), which shows that the majority of emissions reductions are expected to come from the electricity sector, but that this will only occur after 2035 when CCS technology is assumed to become available. Prior to 2035 the electricity sector is only able to stabilize emissions, but does not manage to achieve substantial reductions.

[21] It should be noted that full dispatch simulation modelling is required to accurately determine the energy outputs of stations in this complex system, and therefore the resulting greenhouse emissions. The numbers illustrated in this figure are only an estimate based on a variety of approximations, designed only to provide a guide for creating the planting schedule outcomes.

Figure 6.24 – Emission projections by sector from Treasury Modelling [22]



Note: Emissions from forestry are not reported.
Source: Treasury estimates from MMRF.

It is emphasized that these emissions trajectories are estimates only, and full dispatch modelling is required to provide an accurate accounting of emissions.

7) Conclusion

Four unique scenarios have been provided in this report, exploring possible futures for the SWIS. These are based upon various combinations of the drivers considered to be most significant, which includes the CPRS target, the level of demand growth, the gas price, and the availability of various low emissions technologies.

For each of these scenarios, a unique planting schedule outcome has been developed, based upon actual generators that are currently proposed for development in the SWIS or have made applications for connection agreements. Decisions on which plants are most likely for installation in each year of the study were made to be consistent with a wide variety of parameters, including the annual supply-demand balance, maintenance of economically viable capacity factors, requirements of the renewable energy target, and the external drivers relevant to that scenario.

The resulting four planting schedules provide a strong basis for further modelling in the following Work Packages to explore potential futures for the SWIS.

[22] Australian Government, Treasury, Australia's Low Pollution Future, The Economics of Climate Change Mitigation, 2008, Chart 6.8, Page 143.

Appendix A) List of Proposed and Possible Stations

The following list shows the list of generators considered possible for installation in the SWIS over the duration of this study.

Disclaimer: This is not a complete listing of projects possible for development in the SWIS, and only reflects those known by the authors at the time of publication. It is very likely that projects outside of this list will be installed over the study timeframe.

Table A.1 – Possible and proposed stations for development in the SWIS

Capacity (MW)	Plant	Type	Location	Status
23 MW	Energy Response DSM1	DSM	SWIS	Planning approved
73 MW	Energy Response DSM2	DSM	SWIS	Planning approved
200 MW	DSM1	DSM	SWIS	Theoretical
200 MW	DSM2	DSM	SWIS	Theoretical
215 MW	Bluewaters 3	Coal	Muja	Proposed
215 MW	Bluewaters 4	Coal	Muja	Proposed
400 MW	Coolimba Aviva Coal	Coal	North Country	Proposed
220 MW	Muja AB	Coal	Muja	Proposed
100 MW	Kwinana CCGT 1	CCGT	Kwinana	Proposed
100 MW	Kwinana CCGT 2	CCGT	Kwinana	Proposed
194 MW	Kwinana HEGT	CCGT	Kwinana	Proposed
125 MW	North Country CCGT 1	CCGT	North Country	Proposed
125 MW	North Country CCGT 2	CCGT	North Country	Proposed
125 MW	North Country CCGT 3	CCGT	North Country	Theoretical
110 MW	North Metro CCGT 1	CCGT	North Metro	Proposed
110 MW	North Metro CCGT 2	CCGT	North Metro	Proposed
110 MW	North Metro CCGT 3	CCGT	North Metro	Proposed
110 MW	North Metro CCGT 4	CCGT	North Metro	Theoretical
110 MW	Northern Terminal CCGT 1	CCGT	Northern Terminal	Proposed
110 MW	Northern Terminal CCGT 2	CCGT	Northern Terminal	Proposed
110 MW	Northern Terminal CCGT 3	CCGT	Northern Terminal	Theoretical
100 MW	Kwinana OCGT 1	OCGT	Kwinana	Proposed
100 MW	Kwinana OCGT 2	OCGT	Kwinana	Proposed
100 MW	Kwinana OCGT 3	OCGT	Kwinana	Theoretical
58 MW	Muja OCGT 1	OCGT	Muja	Proposed
58 MW	Muja OCGT 2	OCGT	Muja	Proposed
74 MW	Namarkkon	OCGT	East Country	Planning approved
125 MW	North Country OCGT 1	OCGT	North Country	Proposed
125 MW	North Country OCGT 2	OCGT	North Country	Proposed

Table A.1 – Possible and proposed stations for development in the SWIS				
Capacity (MW)	**Plant**	**Type**	**Location**	**Status**
110 MW	North Metro OCGT 1	OCGT	North Metro	Proposed
110 MW	North Metro OCGT 2	OCGT	North Metro	Proposed
110 MW	North Metro OCGT 3	OCGT	North Metro	Proposed
110 MW	Northern Terminal OCGT 1	OCGT	Northern Terminal	Proposed
110 MW	Northern Terminal OCGT 2	OCGT	Northern Terminal	Theoretical
110 MW	Northern Terminal OCGT 3	OCGT	Northern Terminal	Theoretical
106 MW	Joanna Plains Peaking	Diesel	North Country	Proposed
30 MW	Muja Diesel 1	Diesel	Muja	Proposed
30 MW	Muja Diesel 2	Diesel	Muja	Proposed
30 MW	Muja Diesel 3	Diesel	Muja	Proposed
30 MW	Muja Diesel 4	Diesel	Muja	Proposed
20 MW	Tesla Diesel Units 1-2	Diesel	SWIS	Planning approved
60 MW	Tesla Diesel Units 3-8	Diesel	SWIS	Proposed
66 MW	Tesla Diesel Units 9-15	Diesel	SWIS	Proposed
10 MW	Wild Energy	Diesel	Muja	Proposed
94 MW	Alinta Walkaway 2	Wind	North Country	Proposed
130 MW	Badgingarra	Wind	North Country	Planning approved
250 MW	Collgar	Wind	East Country	Proposed
250 MW	East Country Wind 1	Wind	East Country	Proposed
14 MW	Grasmere	Wind	Muja	Proposed
55 MW	Milyeannup	Wind	Muja	Proposed
215 MW	Muja Wind 1	Wind	Muja	Proposed
215 MW	Muja Wind 2	Wind	Muja	Proposed
132 MW	Nilgen	Wind	North Country	Seeking approval
200 MW	North Country Wind 1	Wind	North Country	Proposed
200 MW	North Country Wind 2	Wind	North Country	Proposed
30 MW	Spiritwest Neerabup	Biomass	North Metro	Planning approved
40 MW	WA Biomass	Biomass	Muja	Proposed
30 MW	Kalgoorlie PV	Solar PV	East Country	Proposed
50 MW	Mingenew Solar Thermal 1	Solar Thermal	North Country	Proposed
50 MW	Mingenew Solar Thermal 2	Solar Thermal	North Country	Proposed
100 MW	Mingenew Solar Thermal 3	Solar Thermal	North Country	Proposed
5 MW	Carnegie Wave 1	Wave	Kwinana	Proposed
20 MW	Carnegie Wave 2	Wave	Kwinana	Proposed
50 MW	Carnegie Wave 3	Wave	Muja	Proposed
100 MW	Carnegie Wave 4	Wave	North Country	Proposed
10 MW	EGS Geothermal 1	Geo	North Country	Proposed

Table A.1 – Possible and proposed stations for development in the SWIS				
Capacity (MW)	**Plant**	**Type**	**Location**	**Status**
50 MW	EGS Geothermal 2	Geo	North Country	Proposed
50 MW	EGS Geothermal 3	Geo	North Country	Proposed
50 MW	EGS Geothermal 4	Geo	Muja	Proposed
30 MW	HSA Geothermal 1	Geo	North Country	Proposed
5 MW	Newworld Geothermal 1	Geo	North Country	Proposed
10 MW	Newworld Geothermal 2	Geo	North Country	Proposed
15 MW	Newworld Geothermal 3	Geo	North Country	Proposed
100 MW	CCS Pilot 1	CCS	Muja	Theoretical
400 MW	Coolimba Aviva Coal CCS	CCS	North Country	Theoretical

Appendix B) List of Possible Retirements

The following table lists the plant considered a possibility for retirement in this study.

Table B.1 – Possible stations for retirement				
Capacity (MW)	**Plant**	**Type**	**Location**	**Status**
-240 MW	Kwinana A	Gas	Kwinana	Announced
-370 MW	Muja C	Coal	Muja	Theoretical
-422 MW	Muja D	Coal	Muja	Theoretical
-350 MW	Kwinana C	Coal	Kwinana	Theoretical

Appendix C) Planting Schedules for Each Scenario

The following tables show the planting schedules developed for each scenario.

Table C.1 – Scenario 1 Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2010-11	23MW	Energy Response DSM1	DSM	SWIS
2010-11	-240MW	Kwinana A Retirement	Gas	Kwinana
2011-12	73MW	Energy Response DSM2	DSM	SWIS
2012-13	194MW	Kwinana HEGT	CCGT	Kwinana
2012-13	130MW	Badgingarra	Wind	North Country
2012-13	106MW	Joanna Plains Peaking	Diesel	North Country
2012-13	250MW	Collgar	Wind	East Country
2012-13	5MW	Carnegie Wave 1	Wave	Kwinana

Table C.1 – Scenario 1 Planting Schedule				
Year	Capacity (MW)	Plant	Type	Location
2013-14	215MW	Bluewaters 3	Coal	Muja
2013-14	125MW	North Country OCGT 1	OCGT	North Country
2014-15	250MW	East Country Wind 1	Wind	East Country
2015-16	215MW	Bluewaters 4	Coal	Muja
2016-17	30MW	Spiritwest Neerabup	Biomass	North Metro
2016-17	20MW	Tesla Diesel Units 1-2	Diesel	SWIS
2016-17	58MW	Muja OCGT 1	OCGT	Muja
2016-17	110MW	North Metro CCGT 1	CCGT	North Metro
2017-18	125MW	North Country OCGT 2	OCGT	North Country
2018-19	200MW	North Country Wind 1	Wind	North Country
2018-19	110MW	Northern Terminal CCGT 1	CCGT	Northern Terminal
2019-20	74MW	Namarkkon	OCGT	East Country
2019-20	30MW	Muja Diesel 1	Diesel	Muja
2019-20	110MW	Northern Terminal CCGT 2	CCGT	Northern Terminal
2019-20	20MW	Carnegie Wave 2	Wave	Kwinana
2020-21	50MW	Mingenew Solar Thermal 1	Solar Thermal	North Country
2020-21	215MW	Muja Wind 1	Wind	Muja
2020-21	30MW	Muja Diesel 2	Diesel	Muja
2020-21	100MW	Kwinana CCGT 1	CCGT	Kwinana
2020-21	100MW	Kwinana OCGT 1	OCGT	Kwinana
2020-21	58MW	Muja OCGT 2	OCGT	Muja
2020-21	-370MW	Muja C Retirement	Coal	Muja
2021-22	200MW	DSM1	DSM	SWIS
2022-23	125MW	North Country CCGT 1	CCGT	North Country
2022-23	30MW	HSA Geothermal 1	Geo	North Country
2023-24	100MW	Kwinana OCGT 2	OCGT	Kwinana
2023-24	110MW	North Metro OCGT 1	OCGT	North Metro
2023-24	10MW	EGS Geothermal 1	Geo	North Country
2024-25	100MW	Kwinana CCGT 2	CCGT	Kwinana
2025-26	125MW	North Country CCGT 2	CCGT	North Country
2025-26	110MW	North Metro OCGT 2	OCGT	North Metro
2025-26	110MW	North Metro CCGT 2	CCGT	North Metro
2025-26	110MW	Northern Terminal OCGT 1	OCGT	Northern Terminal
2025-26	110MW	Northern Terminal CCGT 3	CCGT	Northern Terminal
2025-26	-422MW	Muja D Retirement	Coal	Muja
2026-27	200MW	North Country Wind 2	Wind	North Country
2026-27	110MW	North Metro OCGT 3	OCGT	North Metro

Table C.1 – Scenario 1 Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2026-27	110MW	Northern Terminal OCGT 2	OCGT	Northern Terminal
2027-28	110MW	Northern Terminal OCGT 3	OCGT	Northern Terminal
2028-29	125MW	North Country CCGT 3	CCGT	North Country
2028-29	100MW	Kwinana OCGT 3	OCGT	Kwinana
2029-30	215MW	Muja Wind 2	Wind	Muja
2029-30	50MW	Carnegie Wave 3	Wave	Muja

Table C.2 – Scenario 2 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2010-11	23MW	Energy Response DSM1	DSM	SWIS
2010-11	-240MW	Kwinana A Retirement	Gas	Kwinana
2011-12	106MW	Joanna Plains Peaking	Diesel	North Country
2011-12	73MW	Energy Response DSM2	DSM	SWIS
2012-13	194MW	Kwinana HEGT	CCGT	Kwinana
2012-13	130MW	Badgingarra	Wind	North Country
2012-13	5MW	Carnegie Wave 1	Wave	Kwinana
2013-14	220MW	Muja AB	Coal	Muja
2013-14	74MW	Namarkkon	OCGT	East Country
2013-14	250MW	Collgar	Wind	East Country
2014-15	100MW	Kwinana OCGT 1	OCGT	Kwinana
2015-16	40MW	WA Biomass	Biomass	Muja
2015-16	125MW	North Country CCGT 1	CCGT	North Country
2015-16	125MW	North Country OCGT 1	OCGT	North Country
2016-17	14MW	Grasmere	Wind	Muja
2016-17	94MW	Alinta Walkaway 2	Wind	North Country
2016-17	100MW	Kwinana CCGT 1	CCGT	Kwinana
2016-17	58MW	Muja OCGT 1	OCGT	Muja
2017-18	20MW	Tesla Diesel Units 1-2	Diesel	SWIS
2017-18	58MW	Muja OCGT 2	OCGT	Muja
2017-18	110MW	Northern Terminal OCGT 1	OCGT	Northern Terminal
2018-19	30MW	Muja Diesel 1	Diesel	Muja
2018-19	30MW	Muja Diesel 2	Diesel	Muja
2018-19	110MW	North Metro OCGT 1	OCGT	North Metro
2018-19	20MW	Carnegie Wave 2	Wave	Kwinana
2019-20	30MW	Spiritwest Neerabup	Biomass	North Metro

Table C.2 – Scenario 2 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2019-20	125MW	North Country OCGT 2	OCGT	North Country
2020-21	5MW	Newworld Geothermal 1	Geo	North Country
2020-21	110MW	North Metro CCGT 1	CCGT	North Metro
2021-22	60MW	Tesla Diesel Units 3-8	Diesel	SWIS
2021-22	30MW	Kalgoorlie PV	Solar PV	East Country
2021-22	10MW	Newworld Geothermal 2	Geo	North Country
2021-22	110MW	Northern Terminal CCGT 1	CCGT	Northern Terminal
2022-23	132MW	Nilgen	Wind	North Country
2022-23	100MW	Kwinana OCGT 2	OCGT	Kwinana
2022-23	30MW	HSA Geothermal 1	Geo	North Country
2023-24	215MW	Bluewaters 3	Coal	Muja
2024-25	50MW	Mingenew Solar Thermal 1	Solar Thermal	North Country
2024-25	110MW	North Metro CCGT 2	CCGT	North Metro
2025-26	66MW	Tesla Diesel Units 9-15	Diesel	SWIS
2025-26	200MW	DSM1	DSM	SWIS
2025-26	110MW	North Metro OCGT 2	OCGT	North Metro
2025-26	110MW	North Metro OCGT 3	OCGT	North Metro
2025-26	10MW	EGS Geothermal 1	Geo	North Country
2025-26	110MW	Northern Terminal CCGT 3	CCGT	Northern Terminal
2025-26	-370MW	Muja C Retirement	Coal	Muja
2026-27	15MW	Newworld Geothermal 3	Geo	North Country
2026-27	125MW	North Country CCGT 2	CCGT	North Country
2027-28	100MW	Kwinana CCGT 2	CCGT	Kwinana
2027-28	110MW	Northern Terminal CCGT 2	CCGT	Northern Terminal
2028-29	200MW	North Country Wind 1	Wind	North Country
2028-29	110MW	North Metro CCGT 3	CCGT	North Metro
2029-30	50MW	Mingenew Solar Thermal 2	Solar Thermal	North Country
2029-30	30MW	Muja Diesel 3	Diesel	Muja
2029-30	30MW	Muja Diesel 4	Diesel	Muja
2029-30	50MW	Carnegie Wave 3	Wave	Muja

Table C.3 – Scenario 3 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2010-11	23MW	Energy Response DSM1	DSM	SWIS
2010-11	-240MW	Kwinana A Retirement	Gas	Kwinana

Table C.3 – Scenario 3 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2011-12	73MW	Energy Response DSM2	DSM	SWIS
2012-13	194MW	Kwinana HEGT	CCGT	Kwinana
2012-13	130MW	Badgingarra	Wind	North Country
2012-13	106MW	Joanna Plains Peaking	Diesel	North Country
2012-13	5MW	Carnegie Wave 1	Wave	Kwinana
2013-14	250MW	Collgar	Wind	East Country
2013-14	125MW	North Country OCGT 1	OCGT	North Country
2013-14	110MW	North Metro CCGT 1	CCGT	North Metro
2014-15	55MW	Milyeannup	Wind	Muja
2014-15	5MW	Newworld Geothermal 1	Geo	North Country
2015-16	94MW	Alinta Walkaway 2	Wind	North Country
2015-16	200MW	DSM1	DSM	SWIS
2015-16	10MW	Newworld Geothermal 2	Geo	North Country
2016-17	74MW	Namarkkon	OCGT	East Country
2016-17	20MW	Tesla Diesel Units 1-2	Diesel	SWIS
2016-17	40MW	WA Biomass	Biomass	Muja
2016-17	58MW	Muja OCGT 1	OCGT	Muja
2016-17	125MW	North Country OCGT 2	OCGT	North Country
2016-17	110MW	Northern Terminal CCGT 1	CCGT	Northern Terminal
2016-17	110MW	Northern Terminal CCGT 2	CCGT	Northern Terminal
2016-17	20MW	Carnegie Wave 2	Wave	Kwinana
2016-17	-370MW	Muja C Retirement	Coal	Muja
2017-18	30MW	Spiritwest Neerabup	Biomass	North Metro
2017-18	200MW	DSM2	DSM	SWIS
2017-18	15MW	Newworld Geothermal 3	Geo	North Country
2018-19	30MW	Kalgoorlie PV	Solar PV	East Country
2018-19	215MW	Muja Wind 1	Wind	Muja
2018-19	125MW	North Country CCGT 1	CCGT	North Country
2019-20	30MW	Muja Diesel 1	Diesel	Muja
2019-20	100MW	Kwinana OCGT 1	OCGT	Kwinana
2019-20	30MW	HSA Geothermal 1	Geo	North Country
2020-21	50MW	Mingenew Solar Thermal 1	Solar Thermal	North Country
2020-21	100MW	Kwinana CCGT 1	CCGT	Kwinana
2020-21	58MW	Muja OCGT 2	OCGT	Muja
2020-21	110MW	North Metro OCGT 2	OCGT	North Metro
2020-21	110MW	North Metro CCGT 2	CCGT	North Metro
2020-21	100MW	CCS Pilot 1	CCS	Muja

Table C.3 – Scenario 3 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2020-21	-422MW	Muja D Retirement	Coal	Muja
2021-22	125MW	North Country CCGT 2	CCGT	North Country
2021-22	50MW	Carnegie Wave 3	Wave	Muja
2022-23	132MW	Nilgen	Wind	North Country
2022-23	110MW	North Metro OCGT 1	OCGT	North Metro
2022-23	10MW	EGS Geothermal 1	Geo	North Country
2023-24	400MW	Coolimba Aviva Coal CCS	CCS	North Country
2025-26	50MW	Mingenew Solar Thermal 2	Solar Thermal	North Country
2025-26	100MW	Kwinana OCGT 2	OCGT	Kwinana
2025-26	110MW	North Metro CCGT 3	CCGT	North Metro
2025-26	100MW	Carnegie Wave 4	Wave	North Country
2025-26	50MW	EGS Geothermal 2	Geo	North Country
2025-26	-350MW	Kwinana C Retirement	Coal	Kwinana
2026-27	100MW	Kwinana CCGT 2	CCGT	Kwinana
2026-27	110MW	Northern Terminal OCGT 1	OCGT	Northern Terminal
2027-28	200MW	North Country Wind 1	Wind	North Country
2027-28	125MW	North Country CCGT 3	CCGT	North Country
2028-29	110MW	North Metro CCGT 4	CCGT	North Metro
2028-29	100MW	Kwinana OCGT 3	OCGT	Kwinana
2029-30	50MW	EGS Geothermal 3	Geo	North Country
2029-30	50MW	EGS Geothermal 4	Geo	Muja

Table C.4 – Scenario 4 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2010-11	23MW	Energy Response DSM1	DSM	SWIS
2010-11	-240MW	Kwinana A Retirement	Gas	Kwinana
2011-12	106MW	Joanna Plains Peaking	Diesel	North Country
2011-12	73MW	Energy Response DSM2	DSM	SWIS
2012-13	220MW	Muja AB	Coal	Muja
2012-13	194MW	Kwinana HEGT	CCGT	Kwinana
2012-13	130MW	Badgingarra	Wind	North Country
2012-13	5MW	Carnegie Wave 1	Wave	Kwinana
2013-14	74MW	Namarkkon	OCGT	East Country
2013-14	250MW	Collgar	Wind	East Country
2013-14	100MW	Kwinana OCGT 1	OCGT	Kwinana

Table C.4 – Scenario 4 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2013-14	125MW	North Country OCGT 1	OCGT	North Country
2014-15	125MW	North Country OCGT 2	OCGT	North Country
2015-16	400MW	Coolimba Aviva Coal	Coal	North Country
2016-17	14MW	Grasmere	Wind	Muja
2016-17	58MW	Muja OCGT 1	OCGT	Muja
2017-18	10MW	Wild Energy	Diesel	Muja
2017-18	40MW	WA Biomass	Biomass	Muja
2017-18	94MW	Alinta Walkaway 2	Wind	North Country
2017-18	58MW	Muja OCGT 2	OCGT	Muja
2017-18	110MW	Northern Terminal OCGT 1	OCGT	Northern Terminal
2018-19	20MW	Tesla Diesel Units 1-2	Diesel	SWIS
2018-19	30MW	Muja Diesel 1	Diesel	Muja
2018-19	30MW	Muja Diesel 2	Diesel	Muja
2018-19	110MW	North Metro OCGT 1	OCGT	North Metro
2018-19	20MW	Carnegie Wave 2	Wave	Kwinana
2019-20	215MW	Bluewaters 3	Coal	Muja
2020-21	30MW	Spiritwest Neerabup	Biomass	North Metro
2020-21	132MW	Nilgen	Wind	North Country
2020-21	5MW	Newworld Geothermal 1	Geo	North Country
2020-21	100MW	Kwinana OCGT 2	OCGT	Kwinana
2021-22	30MW	Kalgoorlie PV	Solar PV	East Country
2021-22	100MW	Kwinana CCGT 1	CCGT	Kwinana
2021-22	125MW	North Country CCGT 1	CCGT	North Country
2022-23	60MW	Tesla Diesel Units 3-8	Diesel	SWIS
2022-23	10MW	Newworld Geothermal 2	Geo	North Country
2022-23	30MW	HSA Geothermal 1	Geo	North Country
2022-23	110MW	Northern Terminal OCGT 3	OCGT	Northern Terminal
2023-24	215MW	Bluewaters 4	Coal	Muja
2024-25	50MW	Mingenew Solar Thermal 1	Solar Thermal	North Country
2024-25	100MW	CCS Pilot 1	CCS	Muja
2025-26	66MW	Tesla Diesel Units 9-15	Diesel	SWIS
2025-26	110MW	North Metro OCGT 2	OCGT	North Metro
2025-26	10MW	EGS Geothermal 1	Geo	North Country
2025-26	110MW	Northern Terminal OCGT 2	OCGT	Northern Terminal
2026-27	110MW	North Metro OCGT 3	OCGT	North Metro
2027-28	125MW	North Country CCGT 2	CCGT	North Country
2027-28	110MW	North Metro CCGT 2	CCGT	North Metro

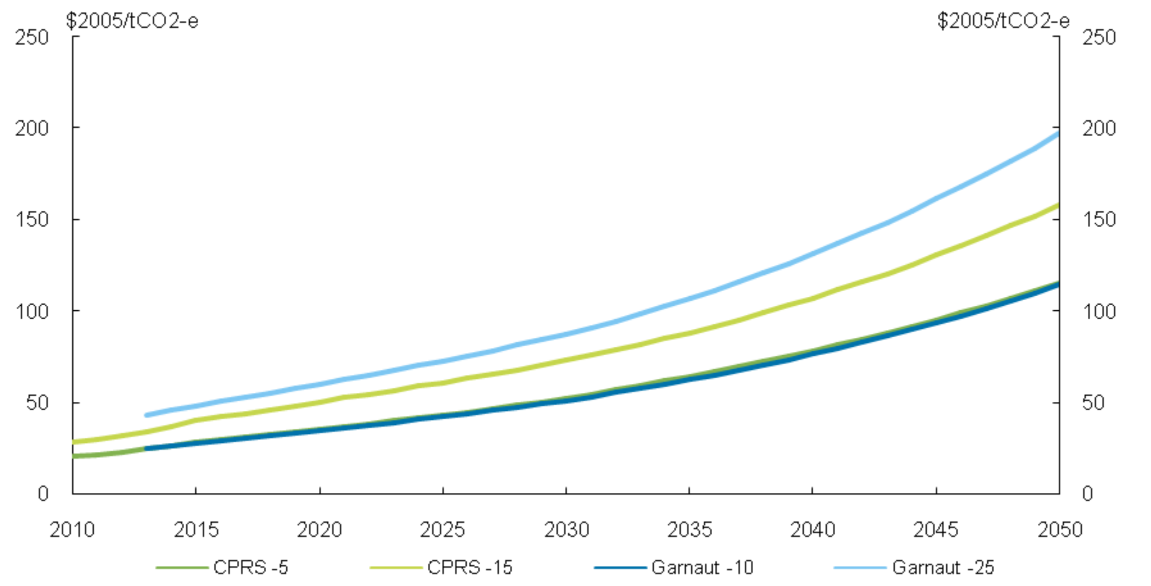
Table C.4 – Scenario 4 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2028-29	215MW	Muja Wind 1	Wind	Muja
2028-29	15MW	Newworld Geothermal 3	Geo	North Country
2028-29	100MW	Kwinana CCGT 2	CCGT	Kwinana
2028-29	100MW	Kwinana OCGT 3	OCGT	Kwinana
2029-30	50MW	Mingenew Solar Thermal 2	Solar Thermal	North Country
2029-30	30MW	Muja Diesel 3	Diesel	Muja
2029-30	50MW	Carnegie Wave 3	Wave	Muja
2029-30	50MW	EGS Geothermal 2	Geo	North Country

Appendix D) OTHER INPUT ASSUMPTIONS

D.1) EMISSIONS TRADING

Carbon price trajectories under the Carbon Pollution Reduction Scheme in the various scenarios were considered to be those modelled by the Australian Government Treasury (Australia's Low Pollution Future, The Economics of Climate Change Mitigation, Commonwealth of Australia, 2008). These are illustrated in the figure below.

Figure D.1 – Australian emissions price (Treasury modelling, Australia's low pollution future)



D.2) DEMAND GROWTH

Demand growth at low, medium and high levels was considered to be equivalent to the latest IMO forecasts at those levels.

D.3) GAS MARKET DEVELOPMENT

Gas prices utilised in the development of these scenarios were assumed to be in the ranges shown in the table below.

Table D.5 – Gas price assumptions (Real 2009-10 dollars)

	Price to CCGTs	Price to OCGTs
Moderate gas price (scenarios 2 and 3)	4-9 $/GJ	5-11 $/GJ
High gas price (scenarios 1 and 4)	8-11 $/GJ	10-14 $/GJ

D.4) TECHNOLOGY ASSUMPTIONS

Table D.6 – Technology assumptions

Plant type	Capital cost ($/kW)	Earliest possible entry date	Short run marginal cost	Typical capacity factor
Coal	$3,000 - $5,000	Any	Low to high (depending upon carbon price)	80%
CCGT	$1,400 - 1,700	Any	Moderate to high (depending upon gas price)	70%
OCGT	$900 - 1100	Any	High	5%
DSM	N/A	Any	High	10%
CCS	$4,000 - 7,000	2020 to 2030	Moderate	90%
Wind	$2,500 - 3,000	Any	Negligible	40%
Biomass	$5,000 - 6,000	Any	Moderate	60%
Solar Thermal	$1,000 - 9,000	2010 to 2015	Negligible	30%
Solar PV	$2,000 - 6,000	2010 to 2015	Negligible	20%
Wave	$2,000 - 8,000	2012 to 2025	Negligible	80%
HSA Geothermal	$5,000 - 8,000	2015 to 2020	Negligible	85%
EGS Geothermal	$5,000 - 11,000	2015 to 2020	Negligible	85%