Independent Market Operator

Renewable Energy Generation Working Group

Agenda

Meeting No.	10		
Location:	Edison / Tesla Rooms Level 8, Governor Stirling Tower, 197 St Georges Terrace, Perth		
Date:	Thursday 25 February 2010		
Time:	1:30 pm – 4:30 pm		
Item	**Subject**	**Responsible**	**Time**
1.	**Welcome**	**Chair**	2 min
2.	**Meeting Apologies / Attendance**	**Chair**	2 min
3.	**Minutes Of Previous Meeting**	**Chair**	10 min
4.	**Actions Arising**	**Chair**	15 min
5.	**Impact of electric vehicles on the SWIS (presentation)**	**Curtin University**	40 min
6.	**Work Package 1:**		
	a) Response to REGWG comments on Draft Report	**Chair**	10 min
	b) Final Report	**Chair**	10 min
7.	**Work Package 2: Update**	**Chair**	5 min
8.	**Work Package 3: Update**	**Tenet**	5 min
9.	**Work Package 4: Update**	**Tenet**	5 min
10.	**General Business**	**Chair**	20 min

11.	**Next Meetings (proposed dates)**: • Thursday 25 March 2010 • Thursday 21 April 2010	**Chair**	2 min

Independent Market Operator

Renewable Energy Generation Working Group

Minutes

Meeting No.	09
Location:	Edison / Tesla Rooms, Office of Energy Level 8, Governor Stirling Tower, 197 St Georges Terrace, Perth
Date:	Thursday 28 January 2010
Time:	1:30 pm – 4:30 pm

Attendees		
Troy Forward	Independent Market Operator (IMO)	Chair
Jacinda Papps	IMO	Minutes
John Libby	New World Energy	
Steve Gould	Landfill Gas & Power	
David Murphy	Dept. Treasury & Finance	
John Rhodes	Synergy	
Corey Dykstra	Alinta	
Phil Kelloway	Western Power – System Management	
Chris Brown	ERA	
Matthew Rosser	Pacific Hydro	
Kyle Jackson	AUSRA	
Stephen Hurley	Dept. Premier & Cabinet	
Matthew Fairclough	Western Power – System Management	
Brooke Eddington	OOE (SEDO)	
Mathew Martin	OOE	
Rob Rohrlach	Energy Response	
Ian Rose	ROAM Consulting	

Jenny Reisz	ROAM Consulting	
Sam Shiao	ROAM Consulting	
Geoff Glazier	Sinclair Knight Merz	
Michael Carr	Tenet Consulting	
Apologies		
John Vendel	Pacific Hydro	
Shane Cremin	Griffin Energy	
Andrew Everett	Verve Energy	
Tim Bray	Western Power	
Greg Allen	Carnegie Wave Energy	

Item	Subject	Action
1.	**WELCOME** The Chair opened the meeting at 1:35pm and welcomed members and visitors to the Renewable Energy Generation Working Group (REGWG) meeting.	
2.	**MEETING APOLOGIES / ATTENDANCE** The meeting attendance and apologies were noted as listed above.	
3.	**MINUTES OF PREVIOUS MEETING** The minutes of the 8 December 2009 REGWG meeting were circulated to members for review and comment. System Management requested the following amendments: • Page 3: Actions arising: Item 3- replace “report” with “findings presentation”; and • Page 3: Work package 1, bullet three: Add the following to the end of the paragraph “System Management noted that the assumptions were not part of the presentation on the ROAM findings which was circulated to the REGWG. System Management’s final report on the ROAM studies will contain all assumptions used in the studies.” The REGWG agreed with the proposed amendments. As such it was agreed that the draft minutes, as amended, were a true and accurate record of the meeting. *Action: The IMO to finalise the minutes from meeting 08 (8 December 2009) and publish on the IMO website.*	**IMO**

Item	Subject	Action
4.	**ACTIONS ARISING** All actions from the previous meeting were reported as complete.	

5.	**WORK PACKAGE 1: DRAFT REPORT**
	
	The Chair noted that ROAM Consulting was in attendance to present the draft report "Impacts of Government Policy on Intermittent Generation Penetration". The Chair noted that it would be desirable for the REGWG to endorse this report and present the findings to the Market Advisory Committee (MAC).
	
	ROAM Consulting presented on the Draft Report for Work Package 1, noting that its proposed approach had been outlined to the REGWG at the 8 December 2009 meeting. ROAM's presentation is attached as appendix 1.
	
	The presentation outlined:
	
	• The scope of Work package 1; and
	• The broad methodology undertaken as part of this work:
	  o Identification of existing and future policy drivers;
	  o Decide on key drivers and correlations;
	  o Construct scenarios/outlooks;
	  o Assess renewable resource; and
	  o Develop planting schedules.
	
	ROAM noted that as part of the process it had looked at the various interactions between the drivers identified. This was in order to remove unlikely scenarios from the modelling, so it could focus on the most likely scenarios. As a result the following four scenarios have been assessed:
	
	• Strained transmission;
	• Minimal change;
	• Low emissions; and
	• Coal development.
	
	In assessing the renewable energy resource in the South West Interconnected System (SWIS) it was noted that:
	
	• The SWIS has an excellent wind resource, with the limitations around transmission not availability;
	• The SWIS is a prime location for solar energy, if stability constraints can be addressed adequately;
	• There is some geothermal available in the northern sections of the SWIS;	

Item	Subject	Action
	• Biomass technology is likely to be cost effective but there is limited capacity; and • There is potential with wave technology but this is associated with high initial costs. The final step in ROAM's methodology was to develop planting schedules. This involved listing all existing, committed, and proposed projects and listing the likely retirements. These lists were then used to develop a unique planting schedule for each scenario. These planting schedules took into account a number of factors: • Ensuring sufficient capacity/energy each year; • Renewable energy targets; • Geographical distribution; • Impacts of external drivers; and • Awareness of any transmission constraints. It was demonstrated that the electricity sector can reduce greenhouse gas emissions over the longer term for some scenarios, but not in the near term. In saying this, it was noted that the ROAM modelling was not a full dispatch simulation model, therefore the greenhouse gas emissions are estimates only. However, it was noted that these estimates are consistent with Treasury modelling, and that there is no expectation for a huge reduction in emissions from the electricity sector prior to 2030. The Chair thanked ROAM for its presentation and requested comments from the REGWG. The following comments were noted: • The SWIS is a good resource for renewable generation technologies in comparison to other states. It was noted that Queensland has no wind resource available and will likely be behind in meeting its targets; • Western Australia will be able to meet its RET commitments locally, and may be a net exporter of RECs in the earlier years; and • Western Australia, South Australia and Victoria all have high wind resources and it is anticipated that these states will dominate meeting the RET commitments. The Chair noted that it was imperative that the REGWG understand and agree to the assumptions contained in this report using the information available now. This report is then needed to feed into the work for Work Packages 3 and 4. System Management noted that the modelling for this Work Package may need to be reiterated if technical issues/limitations arise from Work Packages 3 and 4.	

Item	Subject	Action
	It was noted that no policies (i.e. Oates Review and the Strategic Energy Initiative) have been identified that may limit the uptake of renewable technologies. It was noted that if anything significant comes out of the Oates Review or the Strategic Energy Initiative then the modelling for this Work Package may need to be revisited. A member queried whether the list of key drivers was correct. ROAM noted that there are lots of drivers, but it wished to distil these into the most significant drivers which have the ability to influence electricity. It was noted that ROAM used its modelling experience to determine the most appropriate drivers and that it considers the list to be robust. The REGWG discussed the capacity outlook, noting that care was needed in listing potential projects and retirements. The Chair noted the importance of making these lists as robust as possible. A member queried how important the list of proposed and possible stations (table 5.1) was to the report's overall integrity. It was agreed that there was value in including this so future reviewers could ascertain how decisions were made. However, it was agreed that table 5.1 could be aggregated (i.e. by location, region, and plant type and size) as opposed to listing specific plant names. A member queried whether this table pre-empts any locational signals, and that there could be the potential to read more into the information than should be. There was a concern that this could divert attention away from the need to increase transmission capacity in constrained areas. Finally, it was noted that Collgar will commission in July, and not 2013 (as the report currently notes). *Action: REGWG members to review the ROAM WP 1 draft report and provide feedback, by 5 February 2010. Among other things, members to address:* • *List of potential projects;* • *List of retirements;* • *Technical specifications of plants;* • *DSM; and* • *Any other drivers missing from the analysis.* *Action: IMO to collate members responses on the ROAM WP 1 draft report and provide to ROAM for review and make potential amendments to the paper.* The REGWG discussed the interaction of this Work Package and the other Work Packages underway. It was noted that ROAM (as the successful tenderer for Work Package 3) will use the scenarios identified. Therefore the importance of getting the	**REGWG Members** **IMO**

Item	Subject	Action
	assumptions correct for this work was again highlighted. A member queried the title of the report and the associated scope of work, noting that CPRS is the only government policy driver identified. It was noted that not all the identified drivers are exogenous (or government driven) and that some, such as availability of technology could be government driven or not. It was noted that the terminology could be changed from “drivers” to variables”. It was also noted that the Work Package title could be potentially misleading, and that as the Work Packages have progressed the content has evolved, therefore it would not have been appropriate to restrict Work Package 1 to just assessing government policy drivers. A member noted that the assumptions outlined in the slides were better than what was outlined in the paper. ROAM agreed to update the paper to be more reflective of what was presented in the presentation. There were a number of smaller modifications suggested for the WP 1 draft report: *Action: ROAM to update the WP 1 draft report:* • *Add a disclaimer regarding the list of potential projects;* • *Update the dates in table 5.3;* • *Add a note regarding what capacity factor the modelling uses for Capacity Credits for Intermittent Generators;* • *Update the text around the assumptions in the draft report to reflect the text in the presentation;* • *Consider aggregating the information in table 5.1 and removing the plant names; and* • *Update in accordance with members submissions.* *Action: ROAM to provide the WP1 presentation to the IMO for circulation.*	**ROAM** **ROAM**
6.	**WORK PACKAGE 3: ASSUMPTIONS AND METHODOLOGY** The Chair noted that ROAM was also in attendance to present the scope, assumptions and methodology for Work Package 3 “Assessment of Frequency Control Services”. The presentation is attached as appendix 2. As part of the presentation ROAM noted the linkages between load following and spinning reserve ancillary services. In particular it was noted that load following is automatic governor actioned and generally for normal fluctuations to correct any SWIS frequency variations. Whereas spinning reserve is the response to the failure of a generation facility or if the alternative is to trigger involuntary load curtailment. In relation to the spinning reserve response times ROAM noted the following: • 6 seconds: frequency usually bottoms out about 6	

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	seconds after losing generation; • 60 second: this is approximately how much stored energy is available in thermal units; and • 6 minutes: this is related to quick start, back up generation. It was noted that the Market Rules outline the standards for ancillary services and the frequency operating standards are defined in the technical rules. It was questioned whether the SWIS needs such a tight frequency range, and that relaxing this could potentially remove a barrier to increasing intermittent generation penetration. It was noted that ROAM has developed a preliminary first principles frequency response model of the SWIS. This model is currently undergoing some calibration and fine tuning. The preliminary analysis had been on 1 minute wind and demand data. It was noted that 4 second wind data is available. ROAM noted that the finer the resolution of date the better the modelling outcomes will be. The REGWG discussed the possibility of separating the load contribution from intermittent generation in the modelling, noting that this will be necessary in order to see the magnitude of each contribution to frequency keeping requirements. *Action: ROAM to remove the confidential information from the WP3 presentation and provide to the IMO for circulation.* *Action: IMO to request data from the Office of Energy (used in the Senergy report) and Investec to feed into the WP3 modelling.* *Action: ROAM to investigate separating the load contribution from the intermittent generation contribution in its modelling for WP3*	**ROAM** **IMO** **ROAM**
7.	**WORK PACKAGE 4: ASSUMPTIONS AND METHODOLOGY** The Chair noted that SKM was in attendance to present the overview for Work Package 4. For additional detail, the presentation is attached as appendix 3. It was noted that this Work Package is dependent on the outputs of Work Packages 1 and 3, and to some extent Work Package 2. SKM noted that it is investigating what needs to be changed in the technical rules to facilitate increasing intermittent generation without compromising security. SKM noted that as part of its assessment it would be reviewing other jurisdictions and undertaking key stakeholder interviews.	

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	As part of this, SKM was seeking guidance on the stakeholders that it should approach. It was agreed that SKM interview Alinta, Carnegie Wave Energy, Griffin Energy, Pacific Hydro, Verve Energy and Renewable Power Ventures. *Action: Tenet to contact stakeholders identified in REGWG meeting to outline the stakeholder interview process for WP4 prior to SKM interviews.* *Action: SKM to provide the WP4 presentation to the IMO for circulation.*	**Tenet** **SKM**
8.	**WORK PACKAGE 2: PROGRESS UPDATE** The Chair provided the REGWG with an update on Work Package 2, noting that the IMO is currently reviewing the work completed by MMA as there were some unexpected results. The Chair noted that the IMO wishes to understand the data, the model and the conceptual issues regarding this analysis. As a result of this the IMO is facilitating a number of meetings for MMA to present the methodology and the results directly with a number of stakeholders. This is prior to providing the draft report to the REGWG. The IMO noted that this process has delayed the presentation of the draft report to the REGWG by approximately 4 weeks.	
9.	**GENERAL BUSINESS** There was no general business.	
10.	**NEXT MEETING** The next meeting is scheduled for 1.30pm – 4.30pm on 25 February 2010.	
CLOSED The Chair declared the meeting closed at 4.00pm.		

REGWG Action Points

Legend:

Shaded	Shaded action points are actions that have been completed since the last REGWG meeting.
Unshaded	Unshaded action points are still being progressed.
# Missing	Action items missing in sequence have been completed from previous meetings and subsequently removed from log.

#	Action	Who	Meeting arising	Due date	Status/Progress
3	IMO to finalise the minutes from meeting 08 (8 December 2009) and publish on the IMO website	IMO	28 Jan 2010	5 Feb 2010	Complete.
4	REGWG members to review the ROAM WP 1 draft report and provide feedback, by 5 February 2010, to market.development@imowa.com.au. Among other things, members to address: • List of potential projects; • List of retirements; • Technical specifications of plants; • DSM; and • Any other drivers.	REGWG members	28 Jan 2010	5 Feb 2010	Complete. ROAM's response to REGWG comments is on today's meeting agenda.
5	IMO to collate members responses on the ROAM WP 1	IMO	28 Jan 2010	10 Feb 2010	Complete.

#	Action	Who	Meeting arising	Due date	Status/Progress
	draft report and provide to ROAM for review and potential amendments to the paper.				
6	ROAM to update the WP 1 draft report: • Add a disclaimer regarding the list of potential projects; • Update the dates in table 5.3; • Add a note regarding what capacity factor the modelling uses for Capacity Credits for Intermittent Generators; • Update the text around the assumptions in the draft report to reflect the text in the presentation; • Consider aggregating the information in table 5.1 and removing the plant names; and • Update in accordance with members submissions.	ROAM	28 Jan 2010	19 Feb 2010	Complete. Updated report on today's agenda.
7	ROAM to provide the WP1 presentation to the IMO for circulation.	ROAM	28 Jan 2010	5 Feb 2010	Complete. Available on the IMO website, under meeting 9 papers: www.imowa.com.au/REGWG
8	ROAM to remove the confidential information from the WP3 presentation and provide to the IMO for circulation.	ROAM	28 Jan 2010	5 Feb 2010	Complete.
9	IMO to request data from the Office of Energy (used in the Senergy report) and Investec to feed into the WP3 modelling.	IMO	28 Jan 2010	10 Feb 2010	Underway.
10	ROAM to investigate separating the load contribution from the intermittent generation contribution in its modelling for WP3	ROAM	28 Jan 2010		Modelling for WP3 underway.
11	Tenet to contact stakeholders identified in REGWG meeting to outline the stakeholder interview process for WP4 prior to SKM interviews.	Tenet	28 Jan 2010		Complete.

#	Action	Who	Meeting arising	Due date	Status/Progress
12	SKM to provide the WP4 presentation to the IMO for circulation.	SKM	28 Jan 2010	5 Feb 2010	Complete. Available on the IMO website, under meeting 9 papers: www.imowa.com.au/REGWG
13	IMO to publish the papers and presentations from the 28 January 2010 meeting on its website.	IMO	28 Jan 2010	8 Feb 2010	Complete. Available on the IMO website, under meeting 9 papers: www.imowa.com.au/REGWG

ROAM Consulting Pty Ltd
A.B.N. 54 091 533 621

Response to comments on report (IMO00015) to

Response to comments on report "Impacts of Government Policy on Intermittent Generation Penetration"

22 February 2010

Response to comments on draft report		
Source	**Comment**	**Response**
Alinta	Provide additional clarity in the report about the objective of the study	ROAM has included the original scope of the work in the introductory section, as stated in the original request for tender documentation. If further clarification about the objective of the study is required this should be provided by the IMO.
	Identify extent to which non Government policy variables are not entirely exogenous	ROAM agrees that many of the variables considered are interdependent, and the non-Government policy variables considered could be significantly impacted by variations in Government policies and regulations (most particularly the CPRS). ROAM has expanded the section commenting on this in the updated report, providing further detail and discussion.
	The differences between the scenarios should reflect only the differences in the key parameters that result from government policies	The stated scope of this work is to 'identify key drivers and constraints that determine scenarios and how changes in those drivers would change the scenario outcomes'. It is not specified that the differences between scenarios should be only the government policies. ROAM believes that the most significant drivers that are currently uncertain (and may therefore drive different futures) are unrelated to government policy, with the exception of uncertainty surrounding the CPRS. Demand growth, gas prices, the availability of CCS and other determining factors around the penetration of renewable technologies are likely to be much more significant in determining the spread of possible futures for the SWIS. Therefore, based on ROAM's interpretation of the scope of this work, we have included these significant drivers as the main basis for differences between scenarios.

	Include a scenario that assumes none of the Government policies incentivising renewable energy are implemented to show the level of future penetration of intermittent generation in the absence of any Government policies	Given our understanding of the purpose of this study ROAM does not believe that this would be a useful scenario to include. The stated scope of this work is to 'determine the likely scenarios for the future generation mix in the SWIS as a result of State and Federal Government policies and regulations'. The legislation for the expanded RET scheme has been passed (in August 2009), so it seems unlikely that a future will occur without it. Similarly for the other government policies included in all scenarios (Solar flagships, CCS Flagships and Geothermal Drilling programs). All of these policies have very important impacts on the generation mix in the SWIS, which have been included in this analysis. ROAM believes that a future scenario without all of these policies is very unlikely, and therefore has not included this scenario in this analysis. The resulting impact of all of these policies has been included in all scenarios, in accordance with ROAM's interpretation of the scope.
Energy Response	The title is rather confusing. It does not differentiate between Federal and State Government policies and moves away from the subject to a more general treatise on renewable energy.	ROAM has used the title from the original request for tender document. As acknowledged at the REGWG meeting this title may have become inaccurate as the scope of the work evolved during tender development. ROAM can provide an updated title if desired to better reflect the content of the report, but sought to avoid confusion by changing the title from that on the tender documentation.
	The Report should deliver more than a conclusion that more modelling is required	In ROAM's understanding Work Package 1 is intended as a basis for further modelling in the following Work Packages (2-4). The comment in the conclusion section simply reflects this, and has been updated to state this more clearly.
	The underlying assumptions behind the scenarios used are unclear (the definitions in the presentation to the meeting were clearer)	ROAM has expanded the explanations of the four scenarios in the report to align more closely with the content of the presentation. Further details of input assumptions have also been included in the Appendices.

	Wind is covered adequately but the other technologies are brushed over	In the section reviewing the renewable and low emissions technologies both solar and geothermal technologies are dealt with in more length than wind technology. Biomass and CCS technologies are outlined more briefly due to the smaller potential for biomass in the SWIS, and the relatively long timeframe over which CCS is considered likely to become available. 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, and has considered their inclusion in the four scenarios on this basis. There are two reasons why 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: 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. It is important to note that none of these scenarios is intended to be considered as 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. This is intentional. Scenario 3 does include higher quantities of the non-wind renewable technologies, to explore the impact of these on the SWIS. Comments to explain this intention more clearly have been included in the report.

	Tables 5.1 and 5.2 are wrong - e.g. Energy Response is certified for 23 MW 2010- 2011 and 73 MW 2011-2012	ROAM has updated these tables and the planting schedules for each scenario to reflect this.
	Energy Response has an interest in modelling the impact DSM has on the stability of the SWIS and would like to see much more DSM added to each model, or at least sensitivity runs to test the impact	ROAM agrees that DSM could play a very significant role in contributing to the stability of the SWIS. ROAM has included all known announced DSM projects in these scenarios, in a similar manner to other (competing) technologies. In addition, a further 400 MW of theoretical capacity has been added to recognise the future potential of this technology. DSM should be considered in much more detail in the later work packages as a possible solution to the issues raised.
	Having reread the report I am still unclear on what contribution the SWIS can make on the federal Government RET	The SWIS has a very large fundamental potential for renewable technologies, but is likely to be limited in actual implementation due to the relatively small size of the system (particularly for the integration of intermittent technologies). Detailed dispatch modelling incorporating transmission limitations would be required to gain insight into the actual amount of renewables that the SWIS can contribute to the RET, and this is outside the scope of Work Package 1. The four scenarios show a range of contributions of the SWIS to the national RET, from a minimal contribution (only just meeting a share proportionate to the load in the SWIS) to a much larger proportionate share of the national target. ROAM believes that this provides a spread of possibilities suitable for further modelling in Work Packages 3 and 4 (intended to investigate these issues further).
LGP	There would be merit in starting with the prevailing IMO forecasts and capacity registrations as the baseline, expanding the IMO's existing gap analysis into the future according to the growth scenarios, and speculating on how the respective gaps might be filled	This is the approach that ROAM has taken.

	I perceive that the low, medium and large growth scenarios could simplify the possibilities just as validly as the proposed four scenarios detailing CRPS and gas prices etc.	ROAM considers the level of load growth to be a very significant driving factor that may or may not be closely linked to the other drivers (CPRS, gas price, etc). In order to capture the full range of different futures the SWIS might expect ROAM believes it is necessary to investigate drivers outside of just the load growth.
	I perceive that this would involve developing a 'merit order' for generation development, which order would be driven by the basic economics of the technologies supplemented by the subsidies offered via government policy, fuel availability and network constraints	This is the approach that ROAM has taken. A list of proposed generation was compiled and placed into a preliminary merit order based upon the maturity of the proposal. For each scenario the merit order was further refined on the basis of assumptions around gas price, carbon price and the other details of that scenario. These input assumptions have been included in an appendix.
	I envisage an assessment of the extent to which each technology (coal, gas, wind etc) is capable of filling the gaps (drilling down into the published developments and network constraints) and perhaps developing a probability of each over time as a function of system installed capacity	This is the approach that ROAM has taken. Numerical probabilities were developed and gave a rough guide as a starting point for developing a scenario. This information was then complemented and refined with other inputs based upon ROAM's experience and market knowledge to develop realistic planting schedules. Any scenario development must take into account a wide range of external parameters and drivers that cannot be adequately captured through a simple numerical analysis alone. Network constraints were considered broadly in this study; later Work Packages are expected to delve into this aspect in more detail.
	I wonder if it would be appropriate to consider the actual generating role of the technologies	This has been done in a preliminary fashion; ROAM assumed typical capacity factors for each technology type and ensured that energy levels were satisfied in each year. Dispatch modelling is anticipated for the completion of Work Package 3, which should provide a closer estimate of the operating parameters of each plant in each scenario.

	I perceive that the comments on gas price are just a placeholder at the moment and at a minimum would ideally include the analysis done for the Energy price Limits	Gas price assumptions used in the development of this work package have been included in an appendix.
	It seems to me that CCS is not viable at the moment and its possible development in the future should not influence the rules for the next 10 years; the report should assume that it isn't available	ROAM agrees that the development of viable CCS over the next 10 years is very unlikely. It has not been included in any scenario within this timeframe. However, CCS technology is a significant focus for government research and development spending, so it must be considered as a possibility over the longer term.
New World Energy	The comments in Section 3.4, 2nd paragraph are a bit misleading when quoting $/MW. The comment "(geothermal) is at least twice as high as wind power, but geothermal plant may produce three times the energy" is misleading as the $/MW figure refers to installed capacity, not generation capacity. Surely the most important figure is the cost per MW-out as it compares apples with apples. Geothermal is forecast to be the cheapest form of renewable energy. This and the fact that it is base load with very high capacity factor should be made clear in the report.	This comment has been removed, and an additional paragraph outlining the value of the dispatchable nature of geothermal added.
	The comment on page 11, second last paragraph, that "HSA is likely to be economical and technically viable by 2020" appears to have constrained the timing of geothermal in the planting schedules (Tables 5.1 to 5.6). HSA geothermal is not reliant on any new technology, with all plant and equipment currently available to buy off the shelf. If the geological conditions are right, we believe that we will be operating a demonstration plant (nominally 5MW capacity) within 4 years (2014) and rapidly progress to commercial production >30-50MW over the following 18 months. Given the low cost of geothermal, its base-load character (with some load-following potential) and its potential availability within 5 years we feel that the earliest introduction of 2018-19 (Table 5.5) is later than it will realistically enter the market.	This comment has been updated to reflect the fact that pilot projects may enter prior to 2020. The earliest date of entry for this technology in Scenario 3 has been brought forward to 2014-15, with further development following in 2015-16 and 2017-18.

Office of Energy	The CPRS -25 scenario presumes moderate gas prices, but it would be expected that if this scenario occurred it would be accompanied by very high international gas demand, since gas substitution would offer relatively cheap emission reduction – there being a significant price buffer before higher gas prices make other alternatives preferable. Consequently it would seem that gas prices should be high in this scenario since the linkage of local to international gas prices appears to be strengthening.	ROAM agrees that high gas prices in the case of a 25% CPRS could be considered the "most likely" scenario, although even in the case of a 25% CPRS there remains uncertainty around the future of the gas market. For this study ROAM has deliberately 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. ROAM proposed that this is a possible scenario that should be explored for its (potentially serious) implications for the SWIS. ROAM has included comments in the report to explain this intention more clearly.
	At several points the report notes that the Electricity Sector Adjustment Scheme would provide an incentive to keep coal plant available to the market - it appears that this may have been the basis of extended operation of existing coal plant. Given that by 2020 Muja C & D will be around 40 years old, these outcomes seem unlikely, particularly for the CPRS-15 and CPRS-25 scenarios. The ESAS is intended to help the transition to a low emissions economy, but it is not designed to incentivise continued operation of high emission plant beyond that needed for supply security. While the proposed ESAS incorporates a (partial) windfall gains test, it also encourages high emissions generators to invest in lower emissions replacement plant while retaining the stream of prospective ESAS payments.	ROAM has adjusted Scenarios 1 - 3 to incorporate retirement of these plant earlier.

	In 2.5 under Ancillary Services Costs, reference is made to previous ROAM work for Western Power. Certainly intermittent generators are likely to be most impacted by the anticipated increases in ancillary services costs and so would be disadvantaged relative to other low carbon sources, but it is not clear that the previous work accounted for the likelihood that the medium-longer term drive for lower carbon would lead to carbon pricing increases that would in effect compensate for the additional intermittent ancillary services costs. In the limiting case, high ancillary services requirements (probably gas based) will in effect reduce the carbon benefit of intermittent generation (especially wind), although this may not be important in the short to medium term when no viable low carbon alternative is expected.	Higher carbon prices flow through into higher wholesale electricity prices, which increase the revenue to renewable generators through sales of 'black' electricity. However, the price of renewable energy certificates (RECs) is likely to simultaneously fall as renewable generators supported by them can earn more of their long run marginal costs through the sales of wholesale electricity. This means that increases in the carbon price do not greatly benefit renewable generators supported through the RET until the point where the wholesale electricity price is so high that the price of RECs falls to zero (this will occur at the point where the wholesale price of electricity is sufficient to support renewable generator long run marginal costs - approximately $120/MWh). ROAM modelling consistently shows that under the conditions considered for the scenarios in this report the wholesale electricity price will not rise this high within the timeframe of this study. Therefore rising carbon prices are unlikely to compensate renewable generators for increasing costs of ancillary services (in the short to medium term). ROAM does agree that high ancillary services requirements associated with wind penetration are likely to reduce the carbon benefit of that renewable generation, especially through the inefficient running of coal-fired generation at minimum load to allow for sufficient load-following plant to be available.
	Also in 2.5, under Capacity Credits, the references to 3% reliance estimates and the comment on anti correlation of wind with demand seem to have little relevance to WA. What isn't clear is what assumptions have been made in relation to intermittent capacity certification here or elsewhere in the report.	Data of this kind is not yet available for WA, since the review of capacity credits for intermittent generation is currently being undertaken. This section simply outlines factors that may be significant for the integration of renewable generation in the SWIS. Later in the report (Section 6.1), where the input assumptions to the modelling are outlined, the assumptions around the capacity contribution of intermittent generators at time of peak have been included (15% for wind, 75% for solar PV).

	At several points the report notes that high gas prices will favour OCGT over CCGT. While this would be true if gas was to be used only for low merit service with little energy usage, it would likely not be the case if the plant was to have a mid-merit role with significant energy usage. In that circumstance the higher efficiency of CCGT would more than compensate for the higher capital cost. On the other hand, if the primary driver for new gas plant was ancillary services provision, this might support more flexible OCGT plant (possibly high efficiency OCGT) over CCGT.	ROAM agrees that OCGTs are not economical to install if they will run at capacity factors greater than 10-20% (dependent upon the assumptions of the scenario). Similarly, it is not economical to install CCGT generators if they will operate at capacity factors below 10-20%. The cut off point between the two depends upon the gas price, carbon price, capital cost of plant and various other costs. In this exercise ROAM has assumed that, all other things being equal, higher gas prices will cause gas generators to bid higher (due to higher short run marginal costs), and therefore be dispatched less. This will incentivise the installation of OCGTs in preference to CCGTs. This depends heavily upon the other generation available in the system, to ensure that sufficient other plant is available such that OCGTs will be dispatched with capacity factors less than 10-20%. Therefore ROAM used typical capacity factors for each generation type to calculate the amount of energy available compared with the forecast energy required by the load, and ensured that an appropriate balance was maintained throughout the scenario period. An extensive discussion on this matter has been added to the report (Section 6.1.1).
	In general, given the high level of uncertainty in any such scenario development, the final scenarios should be seen primarily as an input to the remainder of the present work packages and should be reviewed for relevance and currency before use in other future work streams.	ROAM agrees that there is very high uncertainty in a wide range of variables at the current time. Political factors may shift rapidly, and technological advances may suddenly occur. ROAM therefore also recommends that this work be reviewed prior to use in future work streams (beyond this Work Program).
Pacific Hydro	I suggest ROAM provide a qualifier in the report to cover-off on the use of large scale OCGT's in a carbon constrained high gas scenario There are unlikely to be many OCGTs built in the SWIS owing to the high gas price and low market price cap. CCGTs will be built instead and will operate before, during and after high load periods rather than just for the peak as OCGTs would.	ROAM has added an extensive discussion on the methodology utilised in this Work Package for determining the relatively build rates of OCGTs vs CCGTs (Section 6.1.1).

	The existing stock of wind farms in WA is not very good at smoothing wind transients and therefore the report may be overestimating the load following difficulties. Pacific Hydro may be able to provide actual data for a wind farm at Plymouth Gap, including both wind data and MW data to show that wind gusts may not translate into equivalent rates of change of MW	ROAM agrees that this is a possibility, and will be investigating this matter much further in Work Package 3. In this study ROAM has employed a precautionary approach based on the data currently available. More data is required to justify a larger amount of smoothing of wind transients, so ROAM welcomes any data of this nature for use in Work Package 3. A comment has been added to the report for Work Package 1 to outline this possibility.
Synergy	The draft report does not contain details of all the assumptions used within the assessment and there is minimal description of the modelling techniques used to select one technology/plant over another	Additional discussion has been included in the methodology section, and additional details on input assumptions have been added in a series of appendices.
	Set out key assumption values and how they differ across the scenarios in an appendix, allowing easy reference and comparison. For example, in respect of key scenario drivers, identify the values for carbon, load growth, gas prices, CCS is $/MWh and their relative escalations	Input assumptions have been added in a series of appendices.
	The key cost and indexation of attributes of each technology (and its associated primary fuel) should be disclosed in the appendix so readers can understand why, in a particular scenario, coal or gas or individual renewable technologies appear to dominate in a particular future plant build projection	The methodology section has been expanded with further detail explaining why technology decisions were made in each scenario. Input assumptions have been outlined in a series of appendices.
	Identify any substantial differences in network configurations underpinning each scenario	This analysis has been conducted under the view that network access is a second order cost and will always be provided as generation demands it. Comments to this effect have been added to the report in the appropriate sections.

	State whether the future plant build projections represent an optimised or least cost outcome given the scenario assumptions and whether the technical requirements for the continued secure and safe operation of the network and base load plant were observed. The latter is critical to understanding the implications the plant build projections have on underlying dispatch outcomes which in turn influence the relative costs of the respective technologies/plants and hence their position in the plant build projections	These projections represent neither an optimised nor a least cost outcome. As stated in the report, these scenarios are intended to explore the range of possible futures that might be experienced by the SWIS for the purpose of identification of issues associated with the penetration of renewable technologies. Some of these scenarios may have a low probability of occurring, but are still of high significance due to the serious implications if they should occur. ROAM also recognises that simplistic economic models can often fail to capture very significant drivers. Electricity markets are far from perfect. This methodology allows flexibility to incorporate a wide variety of underlying and often hidden factors that cannot be included in an economic least cost or optimised model. Whilst least cost and optimised economic models can be extremely useful and appropriate for many studies, they were not thought to be the most appropriate method in this case.
	Provide energy as well as capacity graphs so that the energy demand (or demands if they are different across each scenario) can be mapped against supply	Energy calculations were performed on the basis of typical capacity factors to ensure broad consistency. For all scenarios there was a large excess of energy available due to the large quantity of wind which supplies large quantities of energy that are not matched by capacity at the time of peak, as stated in the report. ROAM is reluctant to include these calculations explicitly in the report due to their necessarily approximate nature. For accurate determination of energy supply a full dispatch model would need to be applied, which is outside the scope of Work Package 1. This will be dealt with in much more detail in later Work Packages.
	Provide load factors for each of the different units	Capacity factors have been provided in an appendix.
	Provide a unit retirement schedule for existing or if applicable new plant	Retirements were carefully considered during the planting schedule development process. This full list of plant considered for retirement is included in the appendices.
	Provide more extensive explanations to support the installed capacity charts	The methodology section has been expanded.

	Scenario 1 shows wind increasing by 400 MW over 2 years from 2018-2020, an investment of some $1 billion, which is a large amount of intermittent energy to be brought into the SWIS, and into the retail energy portfolio (given that merchant wind farms are unlikely to succeed in the SWIS over the medium term), in a very short time period	Based upon the scope of this work ROAM felt it was important to include extreme cases to test the limits of the system and explore possible issues that might arise. All wind developments were based on actual announced projects, or on projects that have made requests for connection agreements. Many of these were not included. The investment referred to in this particular case is the introduction of two discrete 200 MW wind farms. This is a proportionally large quantity for the SWIS, but is an accurate representation of the block sizes that proponents are considering.
	Scenario 2 shows wind increasing by about 300 MW (60%+) over the 8 year period 2022 to 2030 even though the RET peaks at 2020 and stays constant thereafter representing a declining percentage of total energy consumed	Banking of RECs in this scenario allows delayed entry of some renewable generators necessary to reach the 20% target. The remaining wind development occurs in the very late stages of the study time-frame when the carbon price in this scenario is likely to be sufficient to sustain investment in some renewable generation beyond the RET. The quantity entering in this year is a single 200MW wind farm.
	In the absence of optimised dispatch modelling to identify and take into account feedback loops that will undoubtedly occur with the indicated substantial increases in renewable energy, the future plant build programs are likely to represent an estimate rather than a technically feasible and economically sensible response to the different drivers in each scenario.	The outcome of any model is always an estimate, and is always vulnerable to the large uncertainty in input variables. In addition, there are many drivers that are non-economic in nature, which can never be captured by an economic model (there are a wide variety of situations where parties do not act in the way that is the most 'economically sensible'). ROAM has attempted to capture these non-economic influences in this study through knowledge and extensive experience in the sector. ROAM agrees that what is presented in this report is simply an indication of possible futures that might occur. These could be refined based upon the outcomes of later Work Packages, which will be investigating technical feasibility in more detail.

System Management	We would like the results of the Work Package 1 to be reviewed and if necessary modified once the results from Work Packages 3 and 4 are known. Further iterations may be necessary to ensure consistency across all the work packages	ROAM can provide a review of the results of Work Package 1 based upon the outcomes of the later Work Packages. It is possible that some of the scenarios explored in Work Package 1 will have prohibitive barriers regarding system stability, and this is intentional. These scenarios are designed to explore and highlight issues related to the penetration of renewable technologies in the SWIS, and provide insight into areas that may need to be changed or improved. This can only be achieved if the limits of the system are explored.
	Collgar windfarm may be operational before the 2013-14 dates indicated in the scenarios	Collgar windfarm has been brought forward to 2012-13 in Scenario 1 to reflect this possibility.
	Capacity credits for the windfarms of between 10% and 20% seem reasonable to System Management although as noted in the draft report they are under review in Work Package 2	A note was added to the report to refer to this review.
	The report appears to address peak demand growth projections but not load factor change. Energy efficiency and distributed energy are expected which could change the shape of the demand profile. Increases in demand side response at time of peak are also expected and may also change the demand profile. Changes to the demand profile may impact the demand and energy growth rates in SWIS which may accordingly impact the planting schedules required to reach the energy targets.	Energy projections were calculated for every scenario based upon typical capacity factors for each generator type, and compared with projections for the load factor. In all cases the annual energy available exceeded requirements of the load, due to the large quantity of wind generation in all scenarios (which has a reduced contribution to capacity due to intermittency). Increases in demand side response at time of peak were not included, due to the uncertainty surrounding the implementation of enabling technologies. ROAM sought to provide scenarios that would explore potential issues around the penetration of renewable technologies, and therefore deliberately did not include enabling technologies of this kind. ROAM expects that demand side response at the time of peak will be an important solution to many issues surrounding the penetration of intermittent generation, and should be explored further in the following Work Packages. All scenarios were planted to meet the peak demand requirements forecast by the IMO.

Tenet	While we have never envisaged a detailed analysis of network capabilities going forward, I think some more discussion about critical constraint regions (Albany and Geraldton particularly) would enhance the report	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. Additional discussion around this point has been added to the report. (Section 3.6)
	The report would benefit from an Appendix or two summarising the key assumptions in the scenario development. Some examples would be - fuel price assumptions (eg what is meant by high and moderate prices for gas?) ; technology capital cost assumptions; key dates for intro of new technologies (eg CCS); broad assumptions for the SRMC of generation which would be used to compare introduction of " Best New Entrant" plant (eg CCGT is used as the defacto Best New Entrant in forward projections, but there is no real justification for this)	Appendices fitting this description have been added.

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ENERGY MODELLING EXPERTISE

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Report (Imo00015) to

imo
Independent Market Operator

Impacts of Government Policy on Intermittent Generation Penetration

22 February 2010

VERSION HISTORY

Version History				
Revision	**Date Issued**	**Prepared By**	**Approved By**	**Revision Type**
0.5	2009-12-03	Joel Gilmore	Ian Rose	Preliminary
0.8	2010-01-18	Joel Gilmore Jenny Riesz	Ian Rose	Draft results
0.85	2010-01-25	Joel Gilmore Jenny Riesz	Ian Rose	Updated draft results
1	2010-02-19	Joel Gilmore Jenny Riesz	Ian Rose	Revised report incorporating comments from REGWG participants

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.

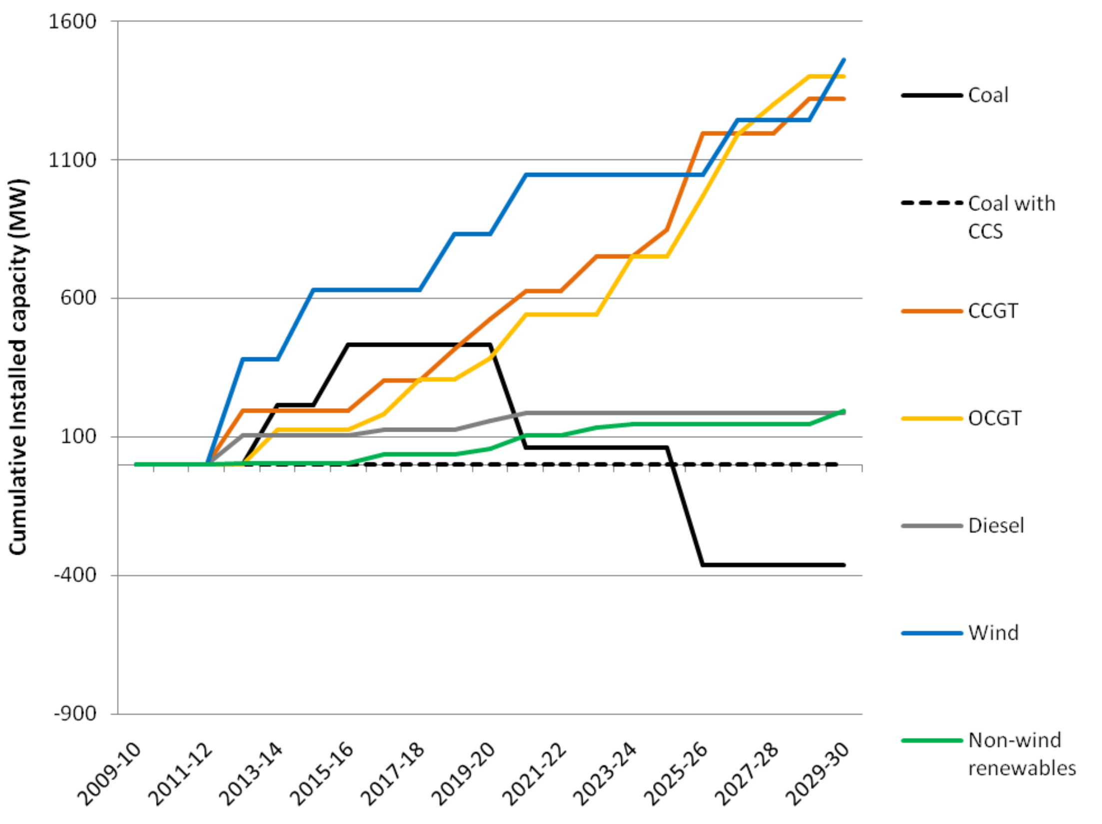
The four resulting planting schedules are described below (and in the body of the report), with full planting schedules for each included in Section 6).

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



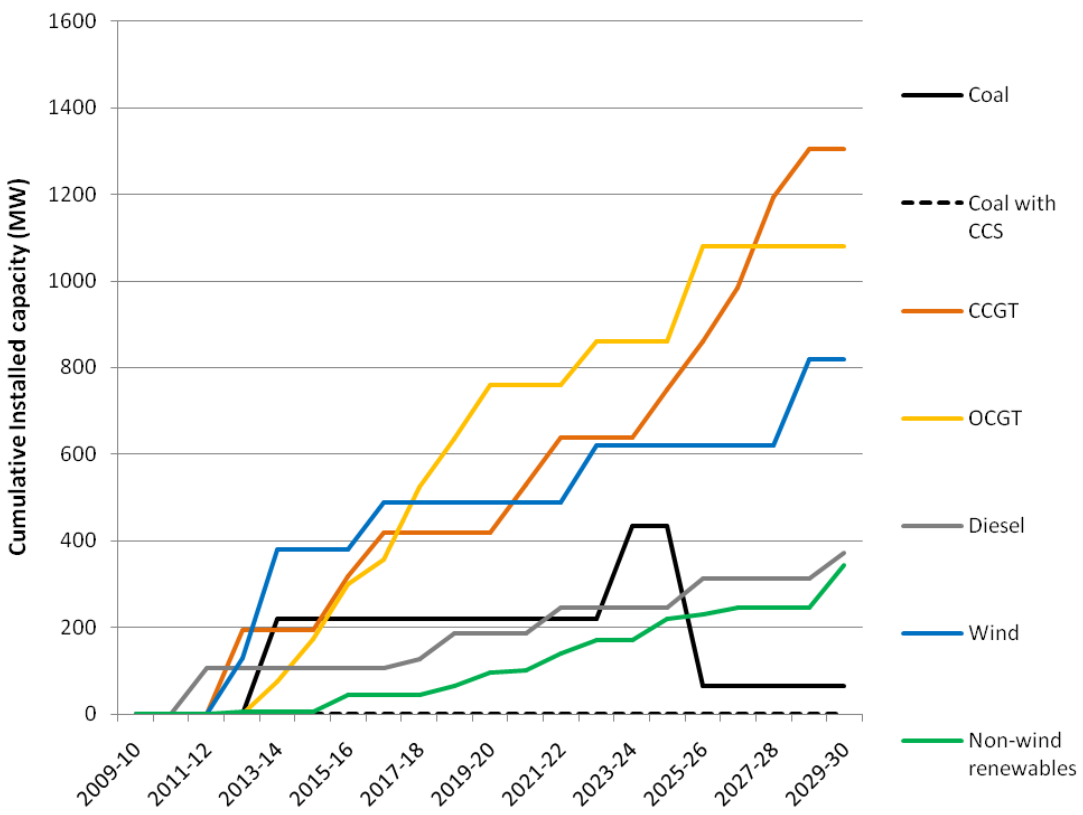
Non-wind renewable technologies develop slowly in this scenario, which drives strong investment in wind energy to meet the RET. Due to the moderately strong CPRS and high gas prices, investment in wind energy exceeds the RET from an early date.

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.

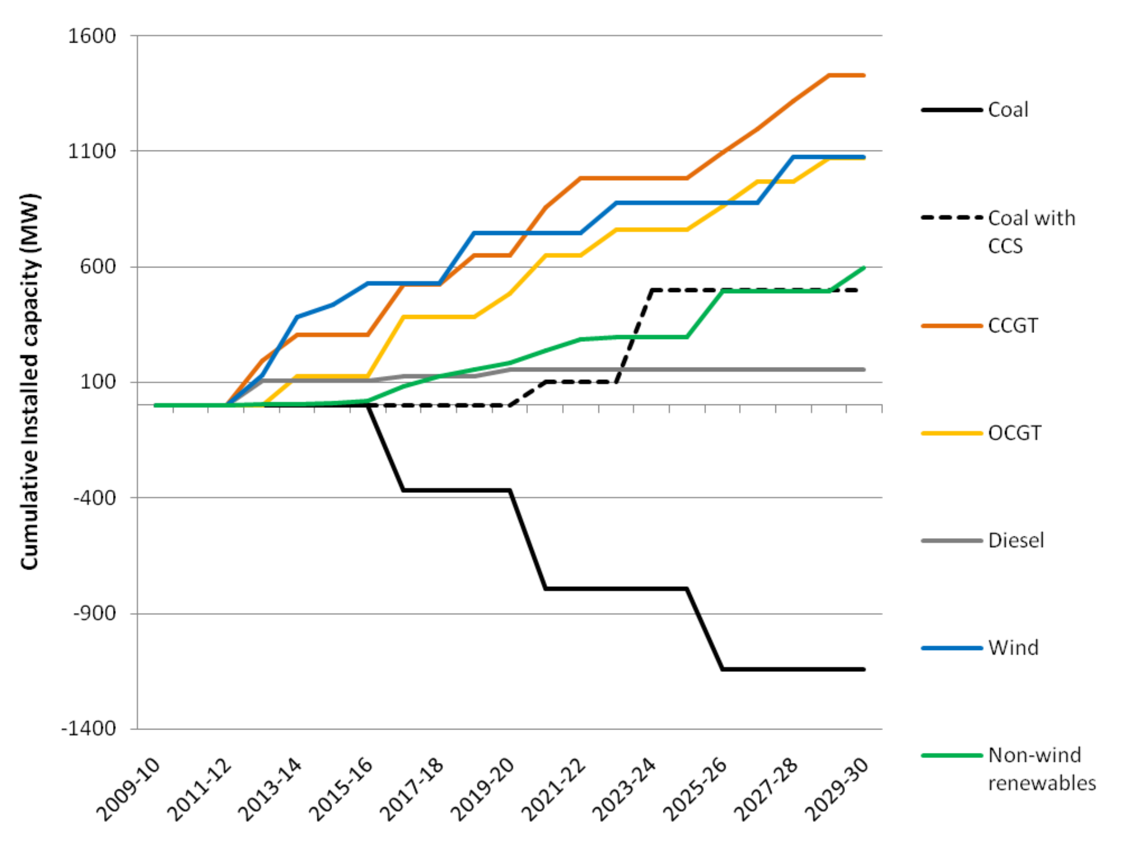
Scenario 3 – Low emissions

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.

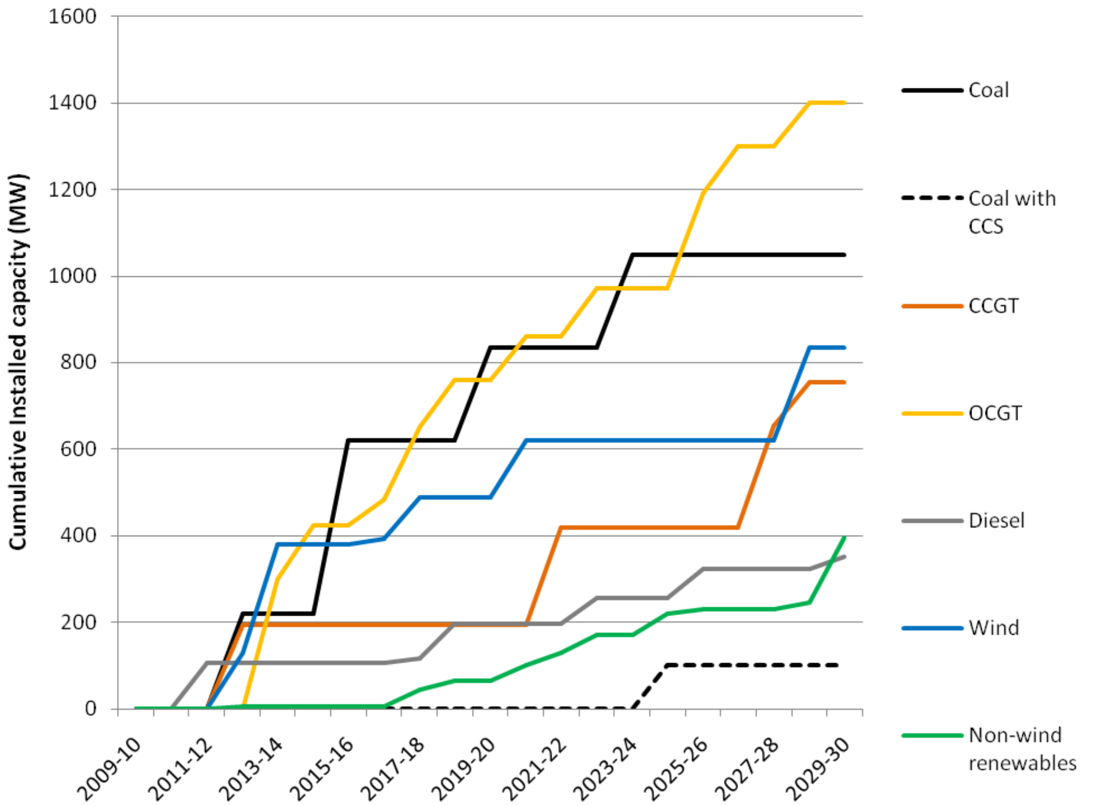
This scenario explores the maximum emissions reductions that are likely to be possible, if all measures are taken and all low carbon technologies receive substantial research and commercialization investment.

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

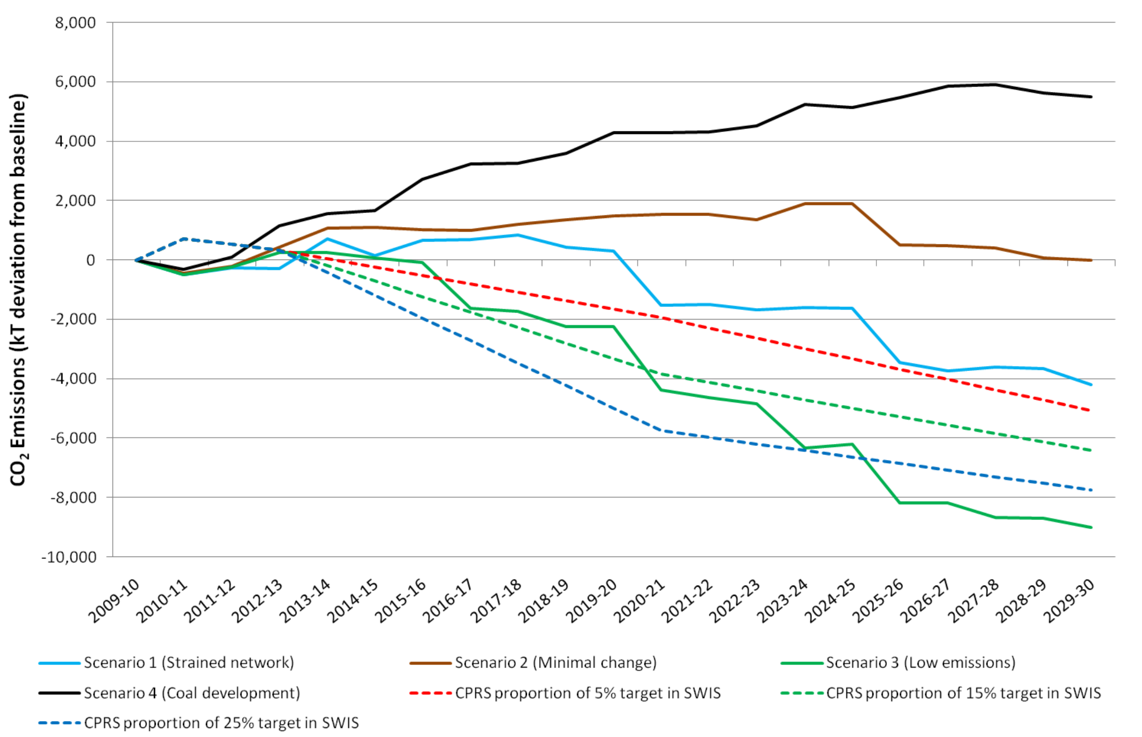
Full dispatch simulation modelling is required to accurately predict the greenhouse emissions resulting from any scenario. However, with some assumptions an estimate of the likely emissions for each scenario can be made. This is illustrated in the figure below.

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.

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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.

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

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

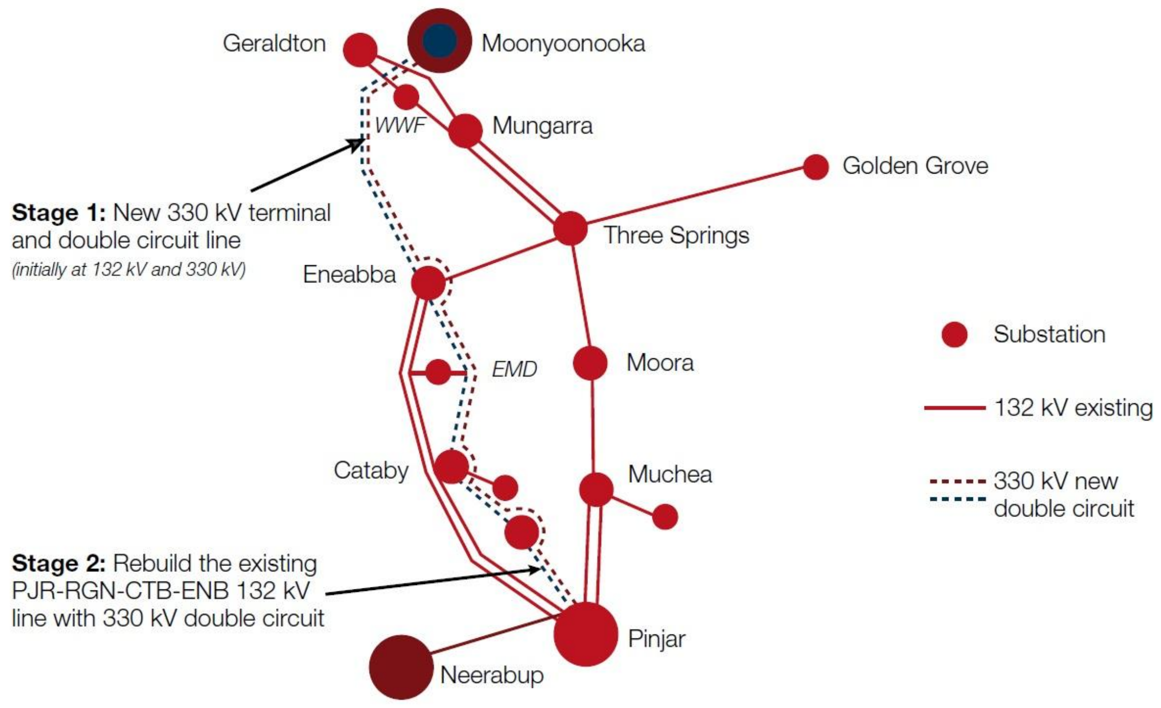
330kV Transmission line Pinjar to Geraldton

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.

The significance of transmission limitations

This analysis has been conducted under the view that network access is a second order cost and will always be provided as generation demands it. This is only true to a point in Western Australia, because deep network assets are not treated as routinely part of the general asset base. This has been the cause of the current protracted debate over the Eneabba and Geraldton 330kV lines (detailed above). Western Power (under the Western Australia Access Code) applies a large and sometimes complex capital contribution component, which often defeats the economics of a project reliant on the construction of deep network assets.

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.

[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.

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.

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

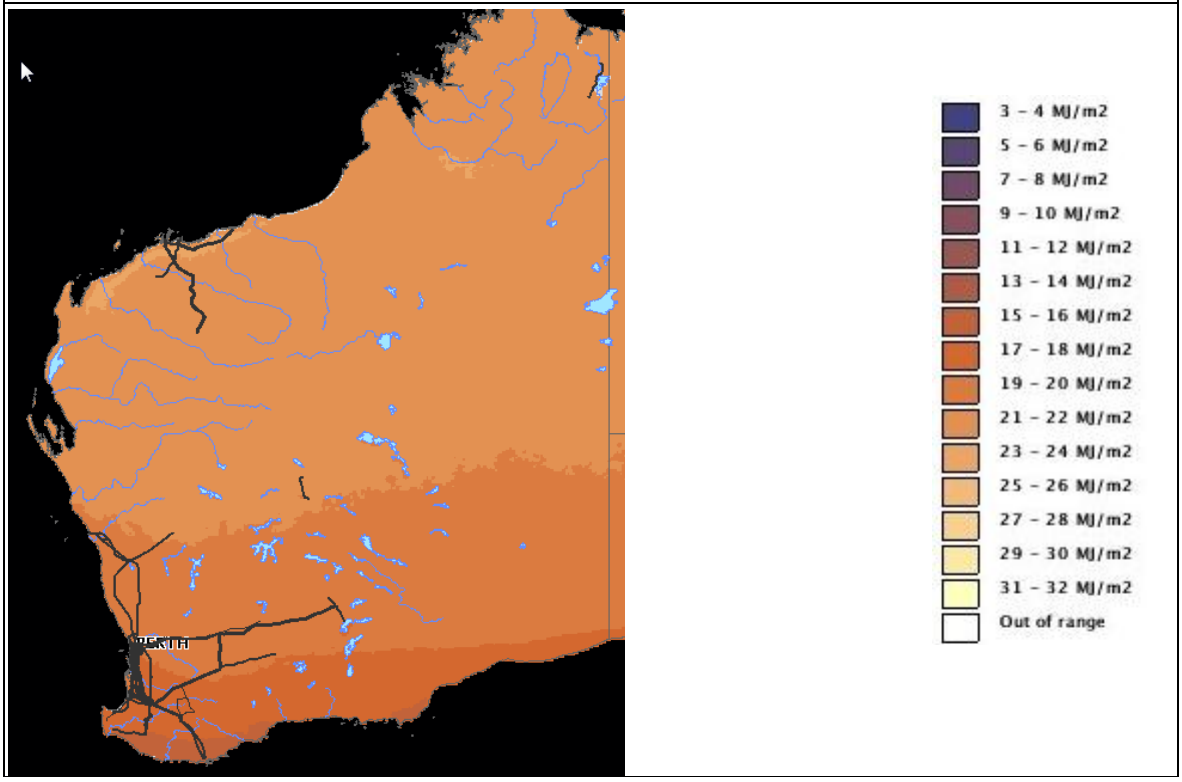
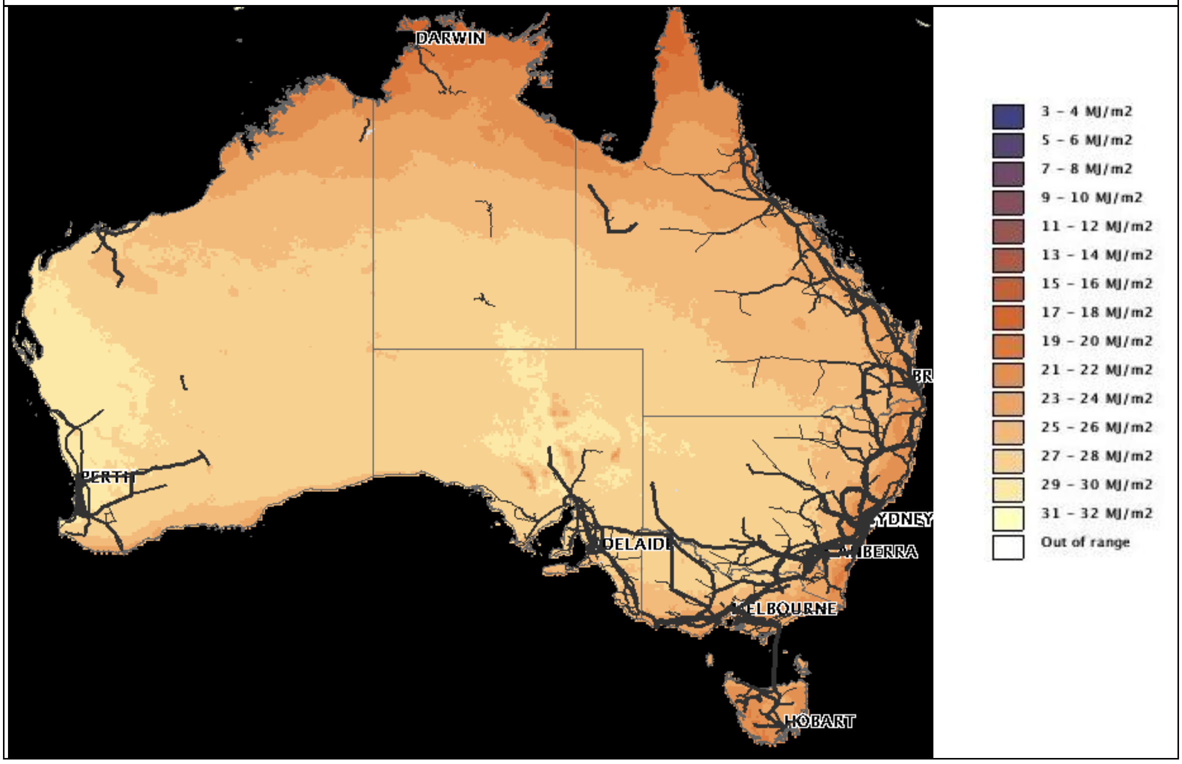


Figure 4.2 – WA January average solar resource with transmission network overlayed



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.

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

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).

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

Figure 4.3 – WA annual average wind speeds

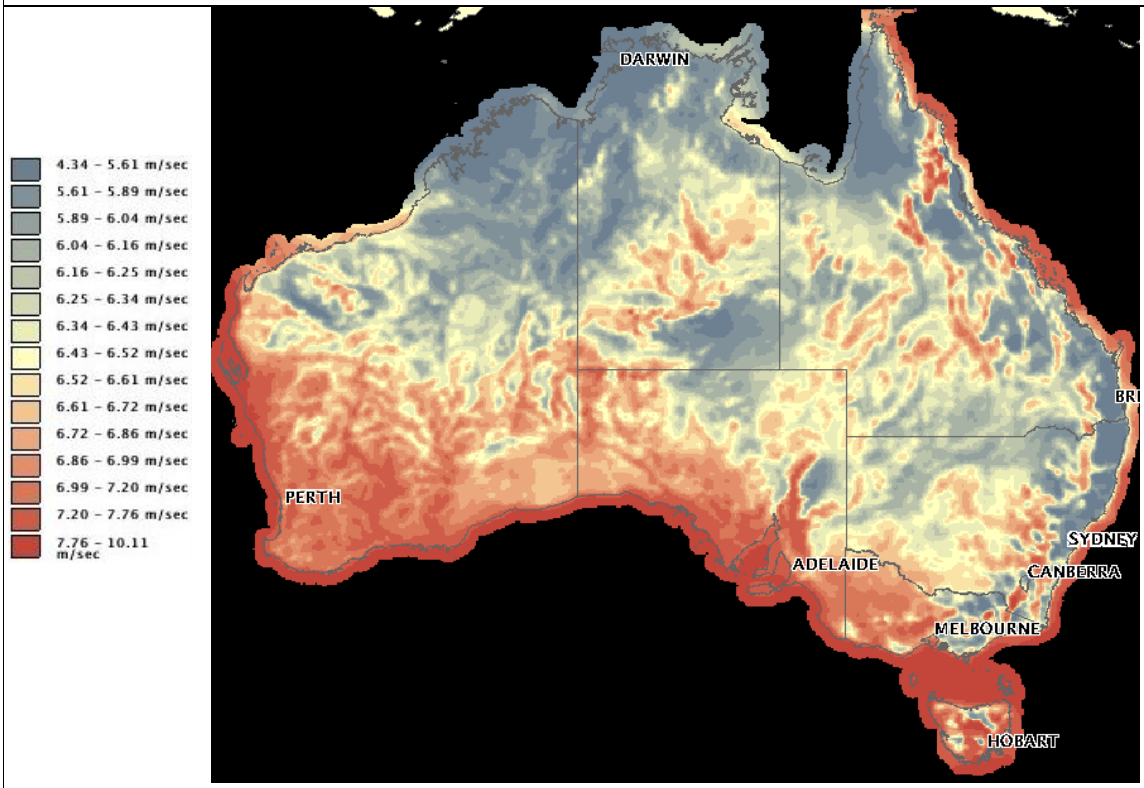
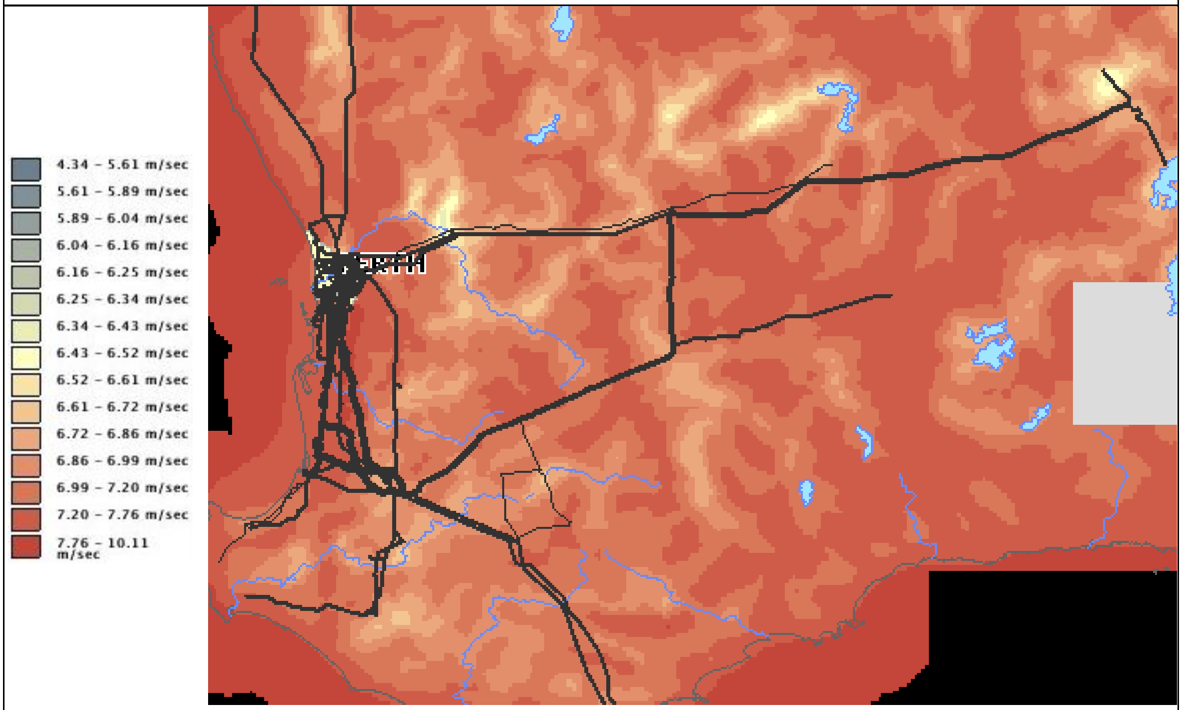


Figure 4.4 – WA annual average wind speeds with transmission overlayed near Perth



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.

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

The specific options and their correlations are explored below.

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

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

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.

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/tCO₂-e)

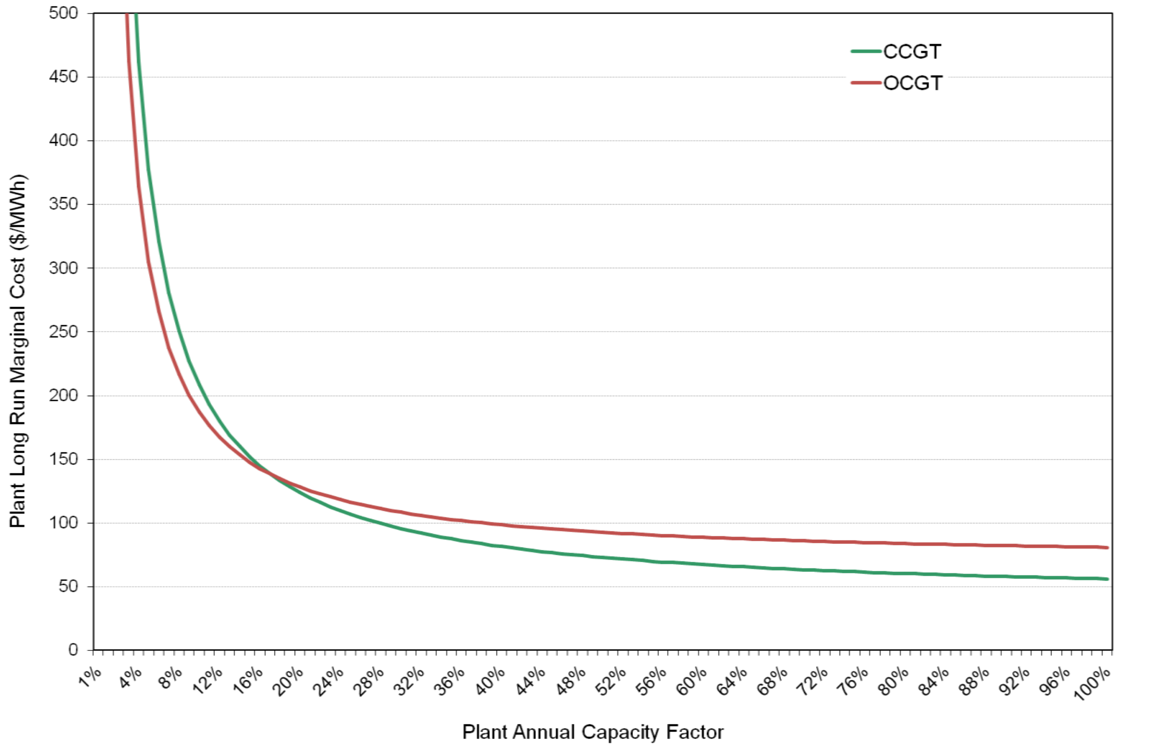
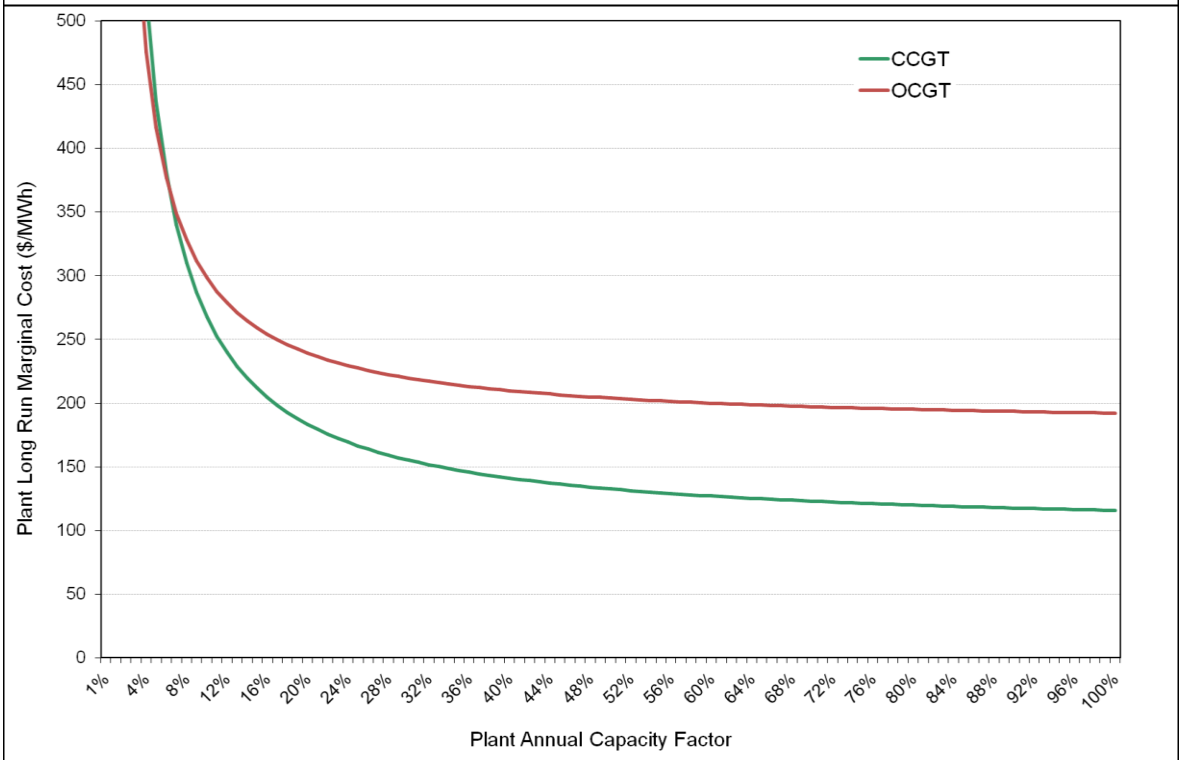


Figure 6.2 – LRMC - High gas price ($10-13/GJ), high carbon price ($60/tCO₂-e)



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.

Table 6.1 – Factors driving OCGTs vs CCGTs

High gas price	CCGT is more economical for a wider range of capacity factors	Incentivises CCGTs

[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.

	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.

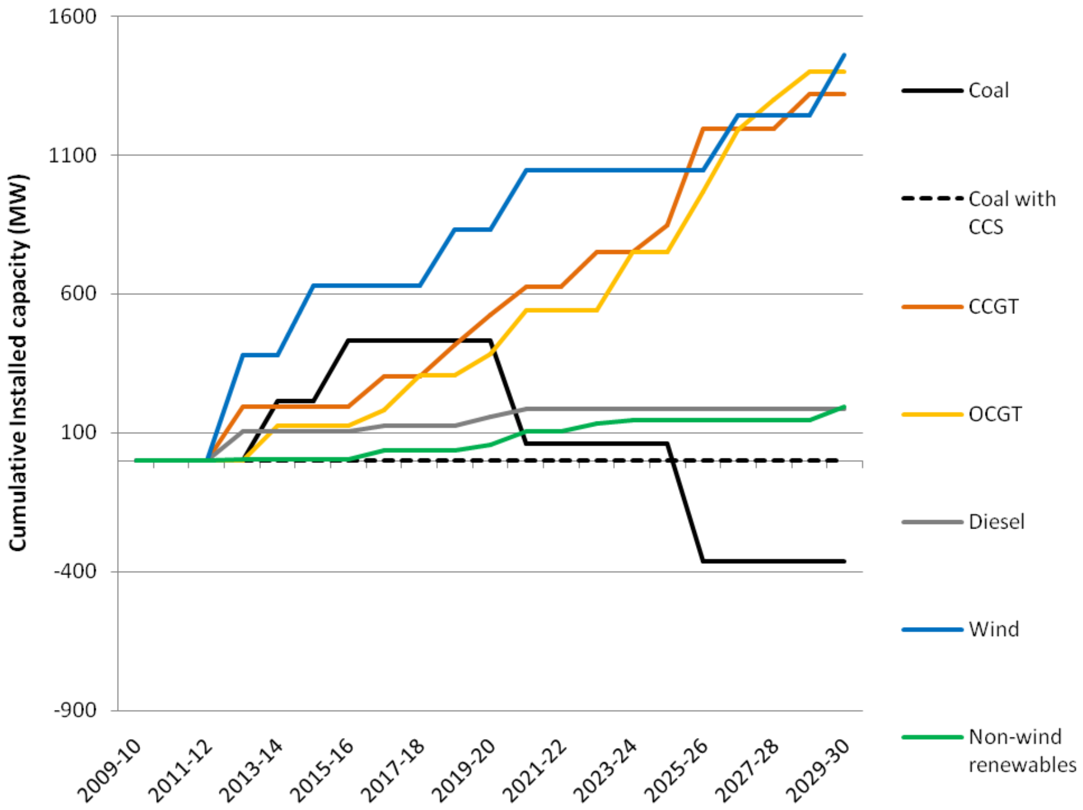
6.2) SCENARIO 1 – STRAINED NETWORK

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.

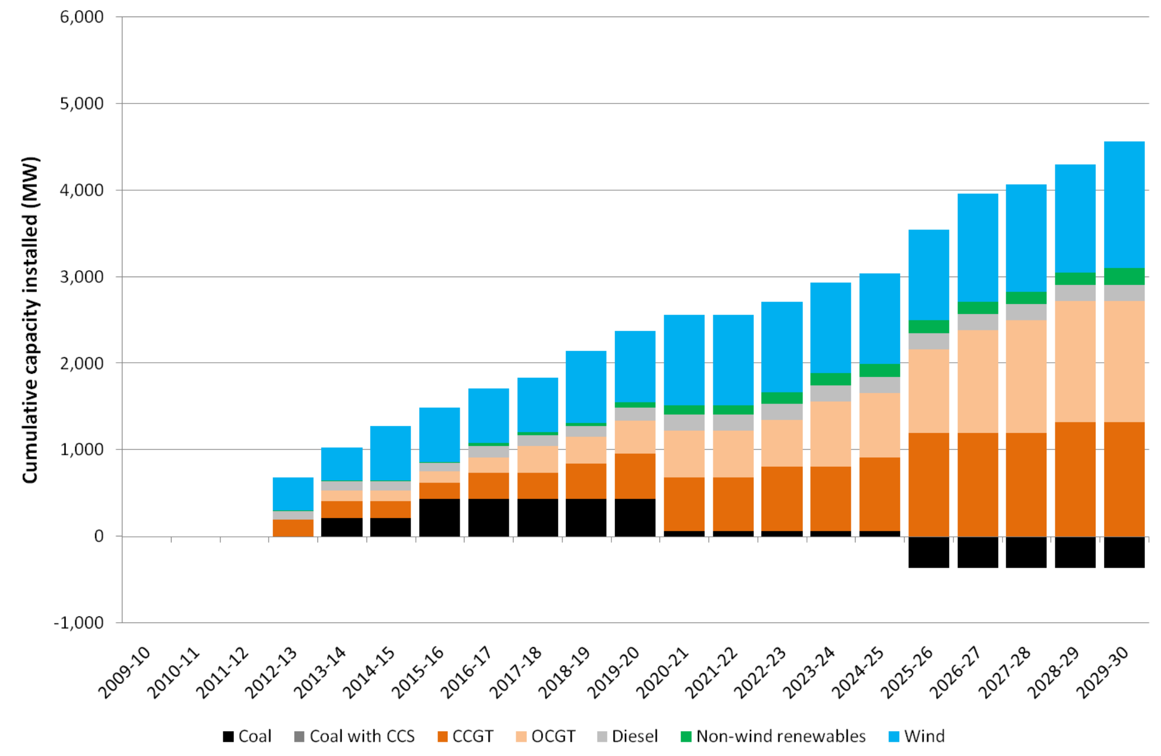
In general gas generation is costly due to high gas prices, but remains incentivized by the CPRS (which reduces competition from more emissions intensive alternatives). OCGTs are incentivized by the high quantity of wind installed (which provides energy but very little capacity to the reserve margin).

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).

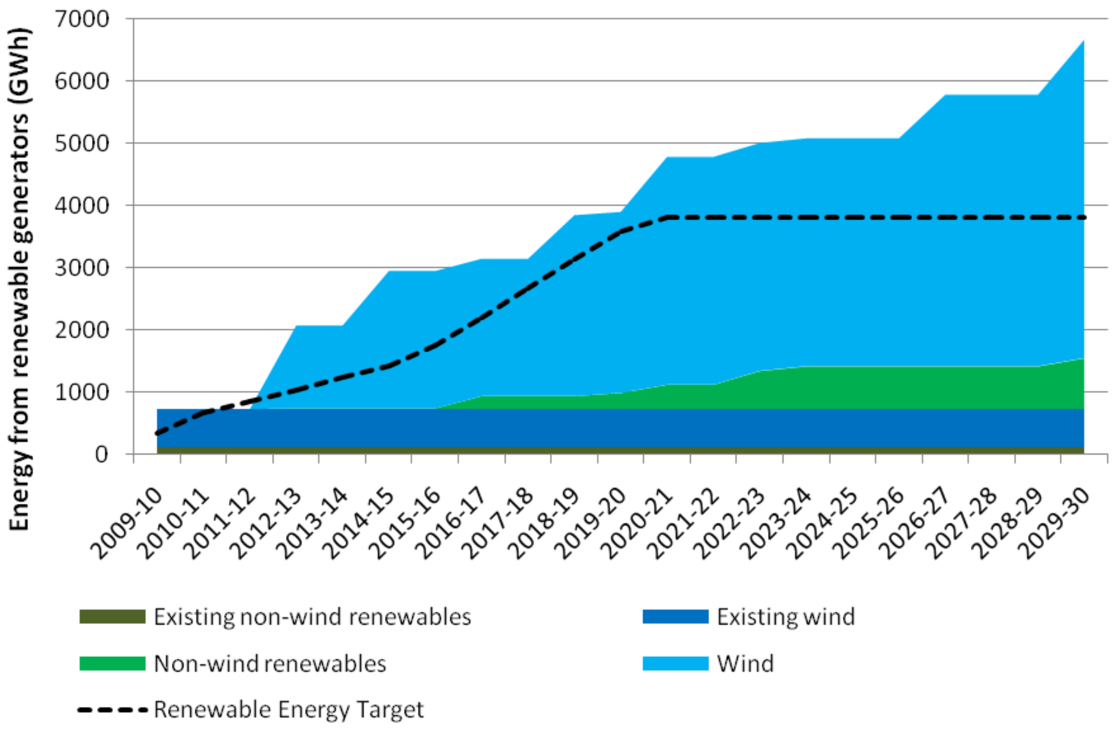
Figure 6.4 – Scenario 1 – Installed capacity by technology type (stacked)



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

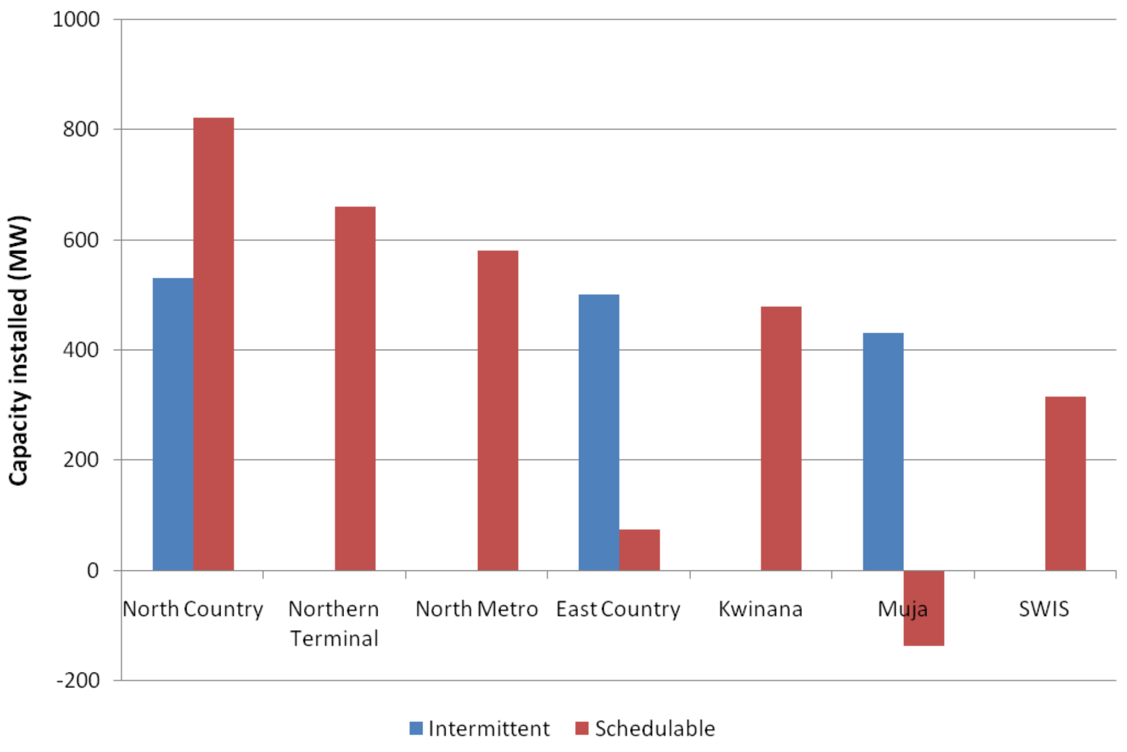
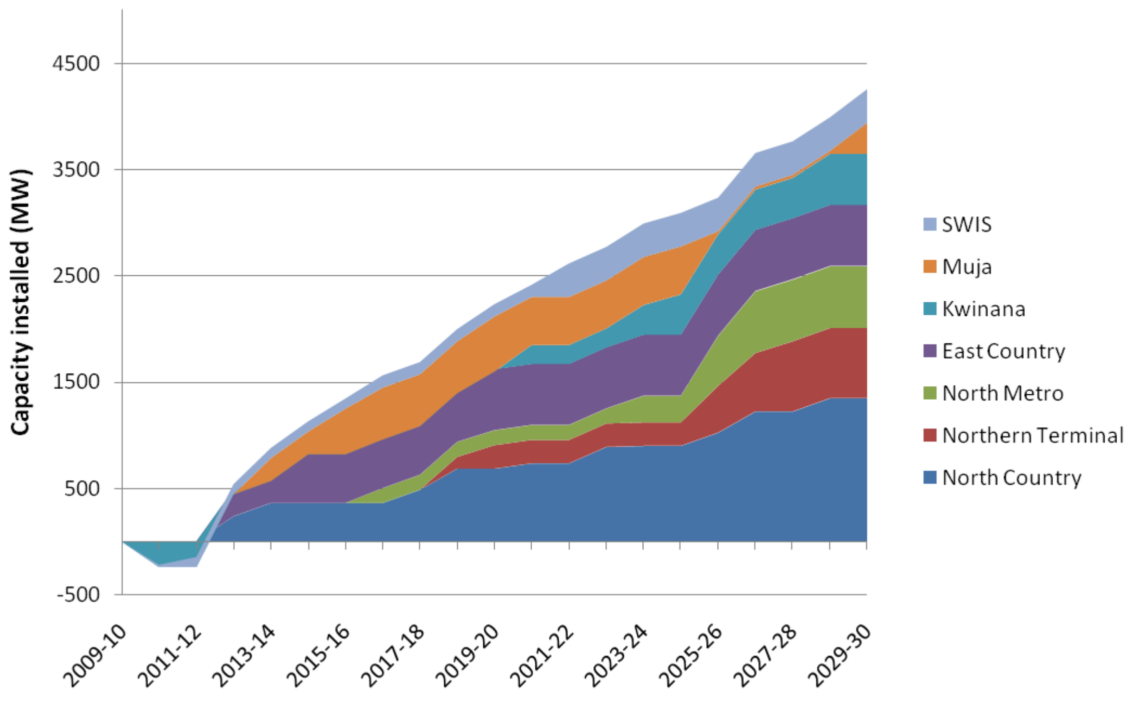


Figure 6.7 illustrates the installation of generation by area over time. The Muja and North Country areas receive a large quantity of new generation, due to the combination of new schedulable and new intermittent generation. There is an initial reduction in the Kwinana area, due to the retirement of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

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

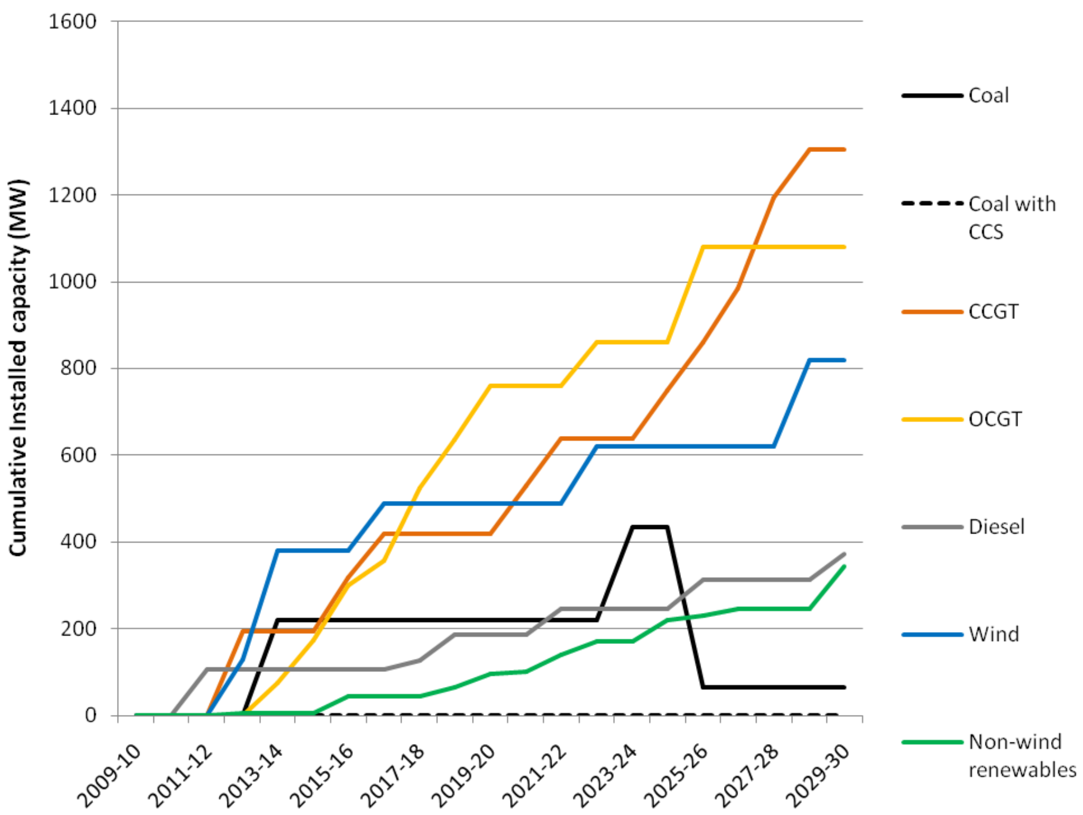


6.3) *Scenario 2 – Minimal Change*

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

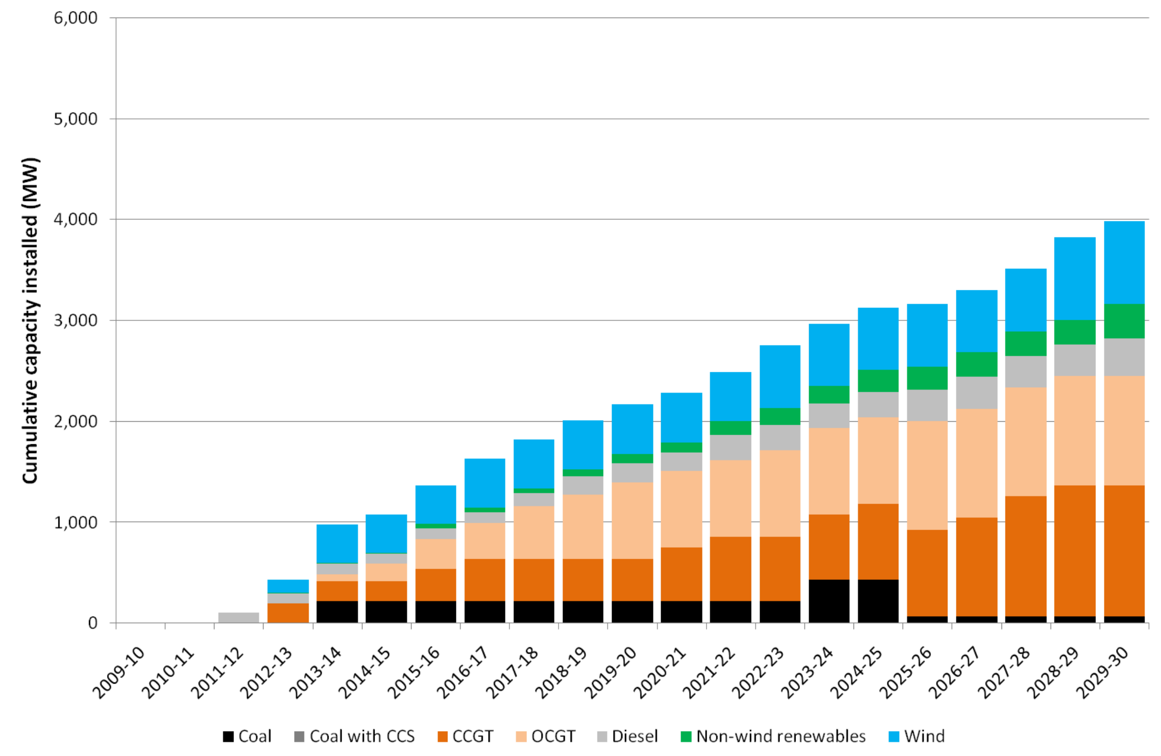
Under Scenario 2 the competition between coal and gas is similar to Scenario 1. Despite a much less ambitious CPRS (5% reduction below 2000 levels by 2020), gas prices are lower, allowing a mixture of gas and coal generation to be installed (Figure 6.8). All installed coal plant is assumed to be "CCS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

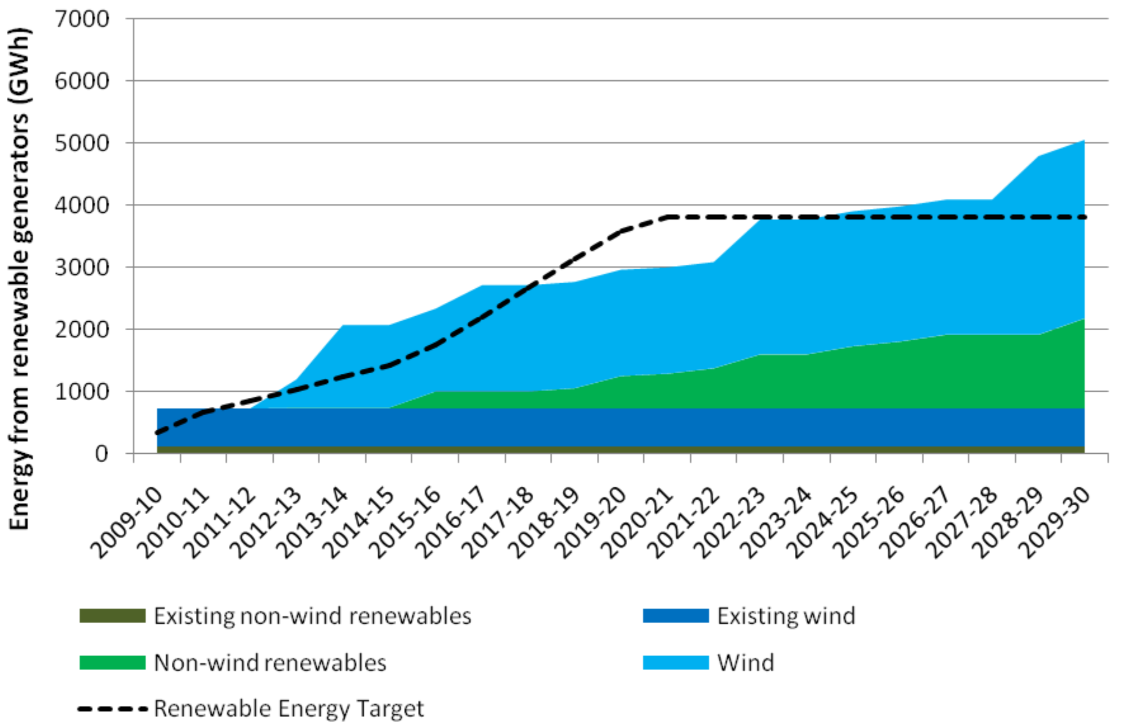


The unambitious CPRS in this scenario causes a relatively low level of investment in renewable technologies, with the SWIS only just achieving its share of the RET (Figure 6.10). Due to lack of incentives the less mature renewable technologies (non-wind) develop slowly and only minor pilot projects in 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

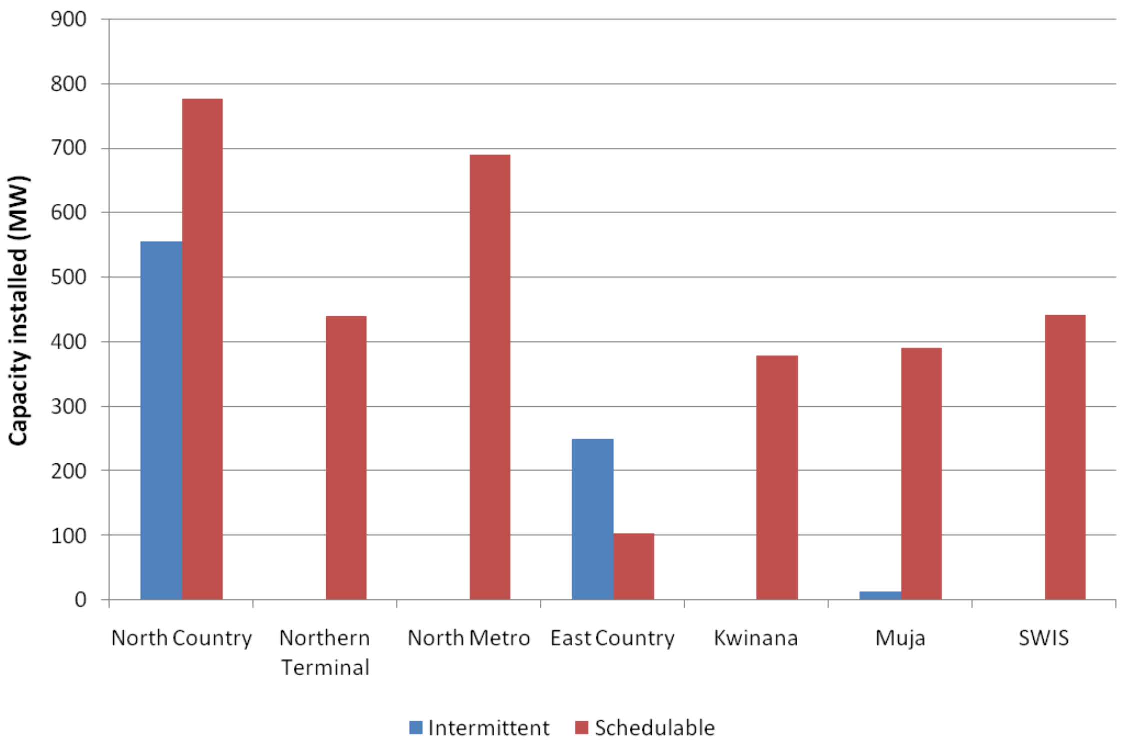
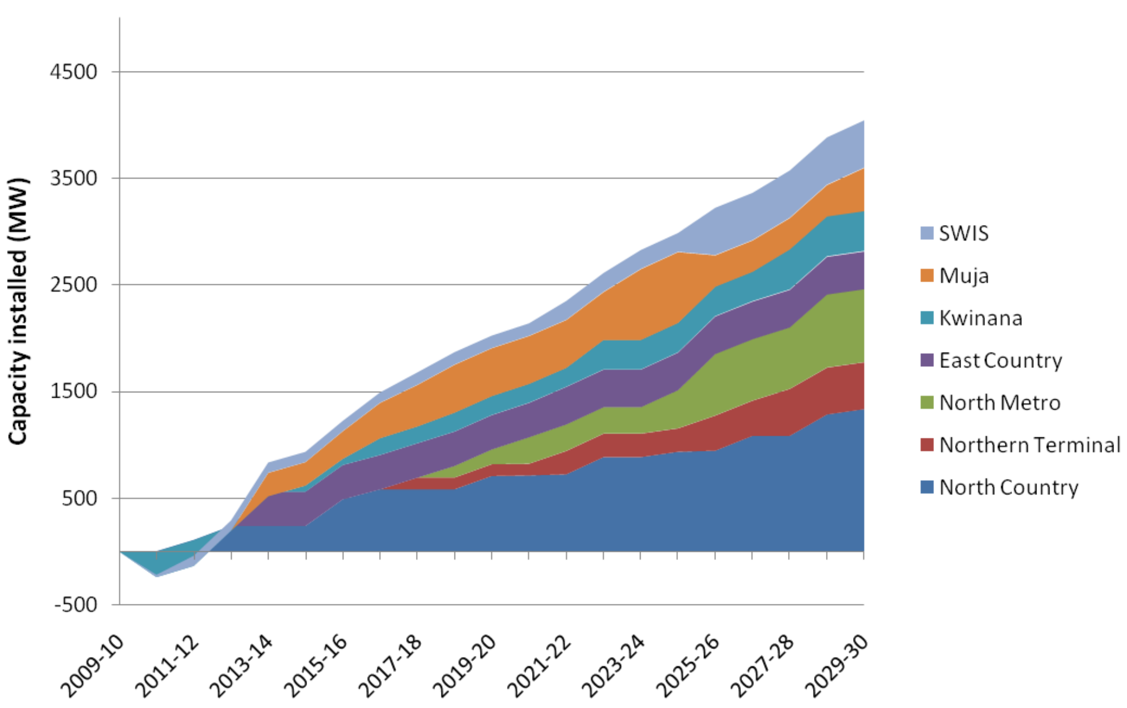


Figure 6.12 – Scenario 2 – New capacity installed by location (stacked)



6.4) SCENARIO 3 – LOW EMISSIONS

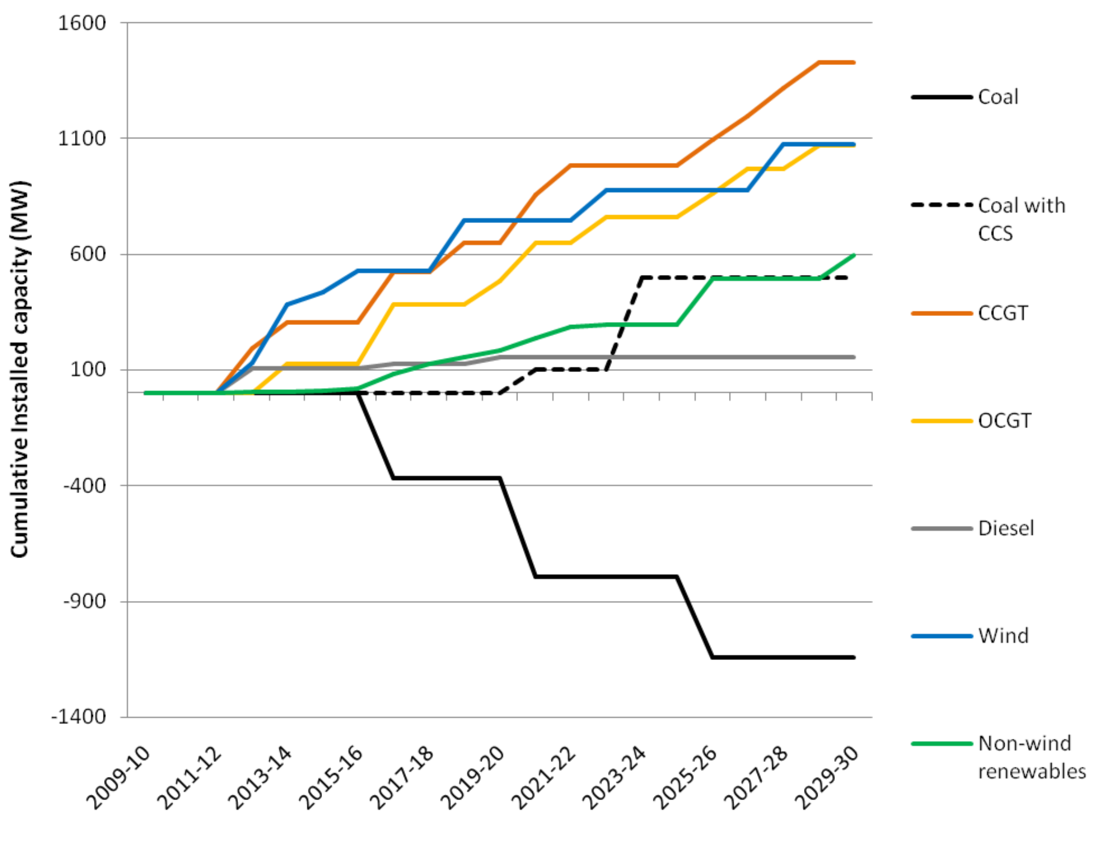
The planting schedule outcome for Scenario 3 is listed in Appendix C and explored further in the figures below.

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.

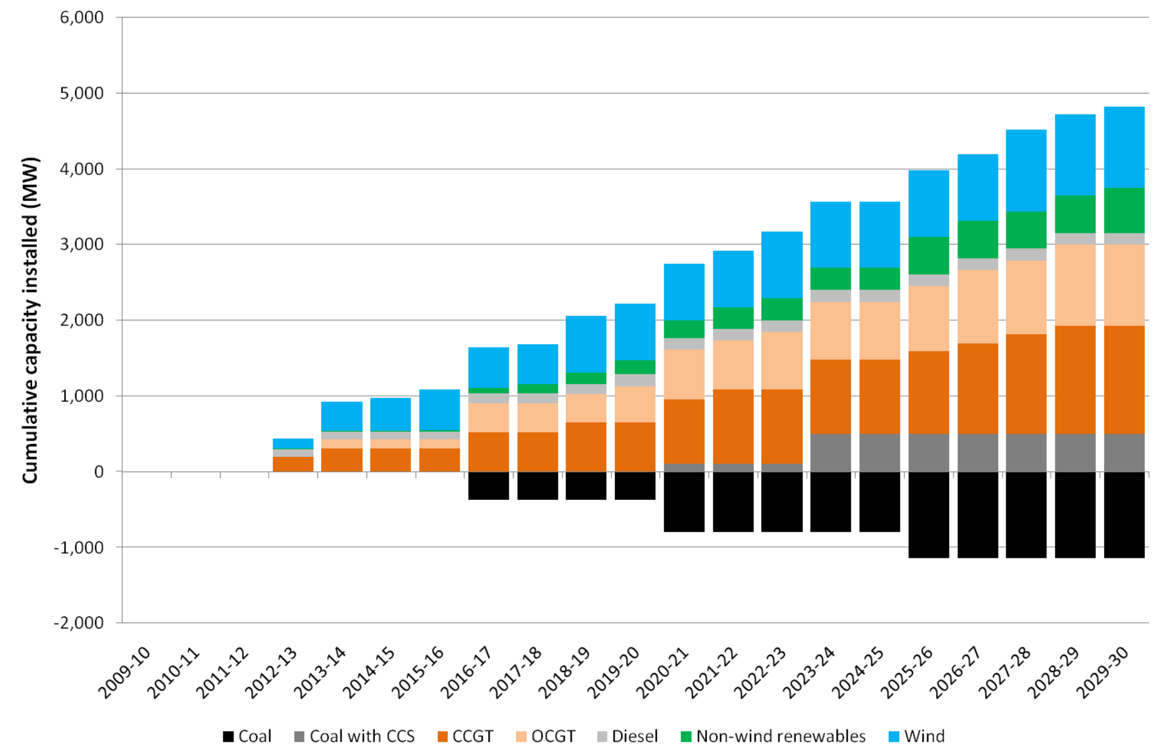
The high cost of coal technologies drives investment towards gas, further incentivised by the moderate gas prices in this scenario. Investment favours CCGTs in early years of the study due to the lack of other types of low short run marginal cost (SRMC) generation. In the later parts of the study OCGTs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

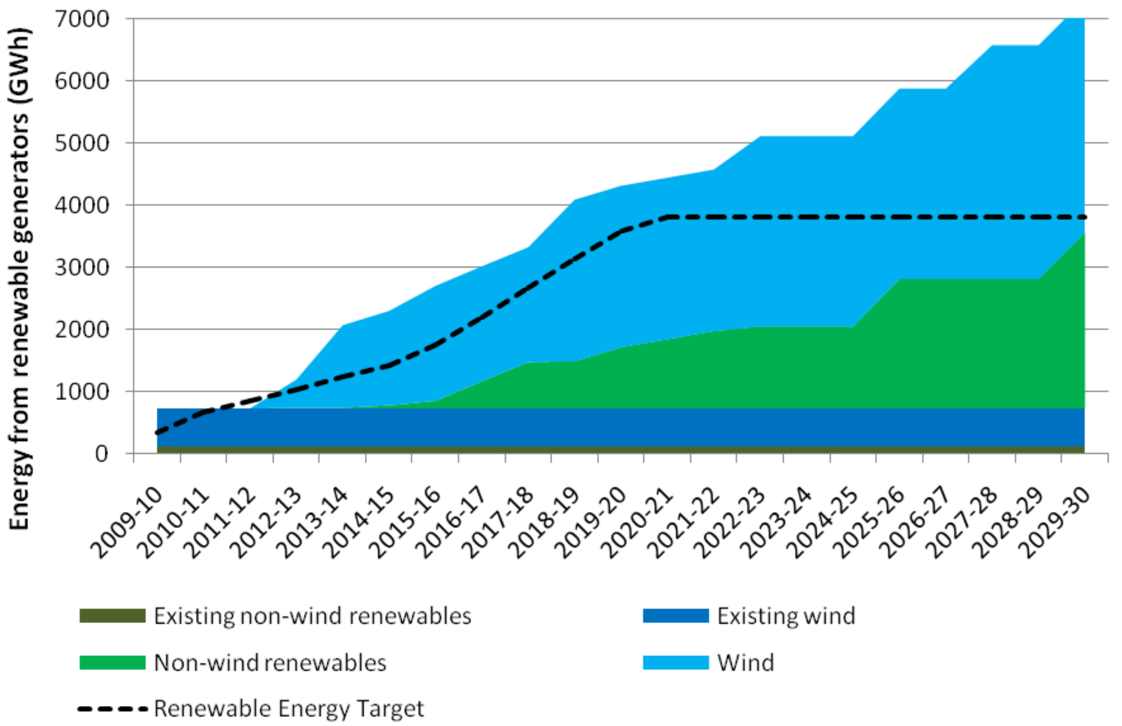
Figure 6.14 – Scenario 3 – Installed capacity by technology type (stacked)



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

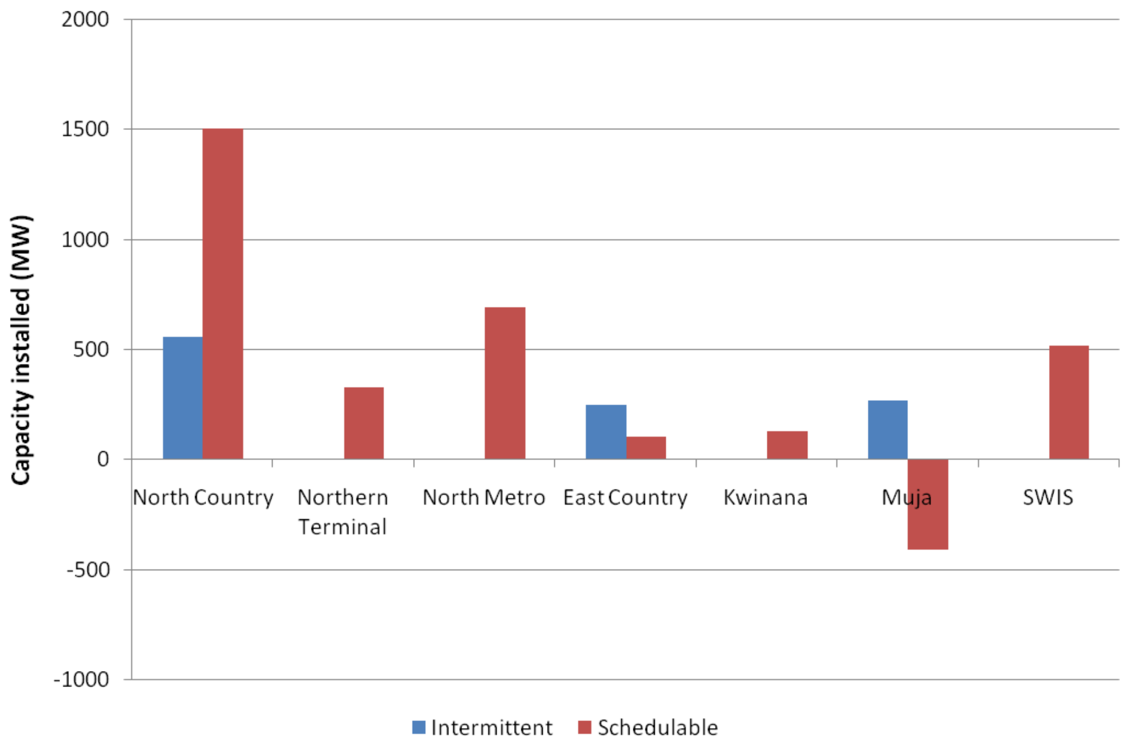
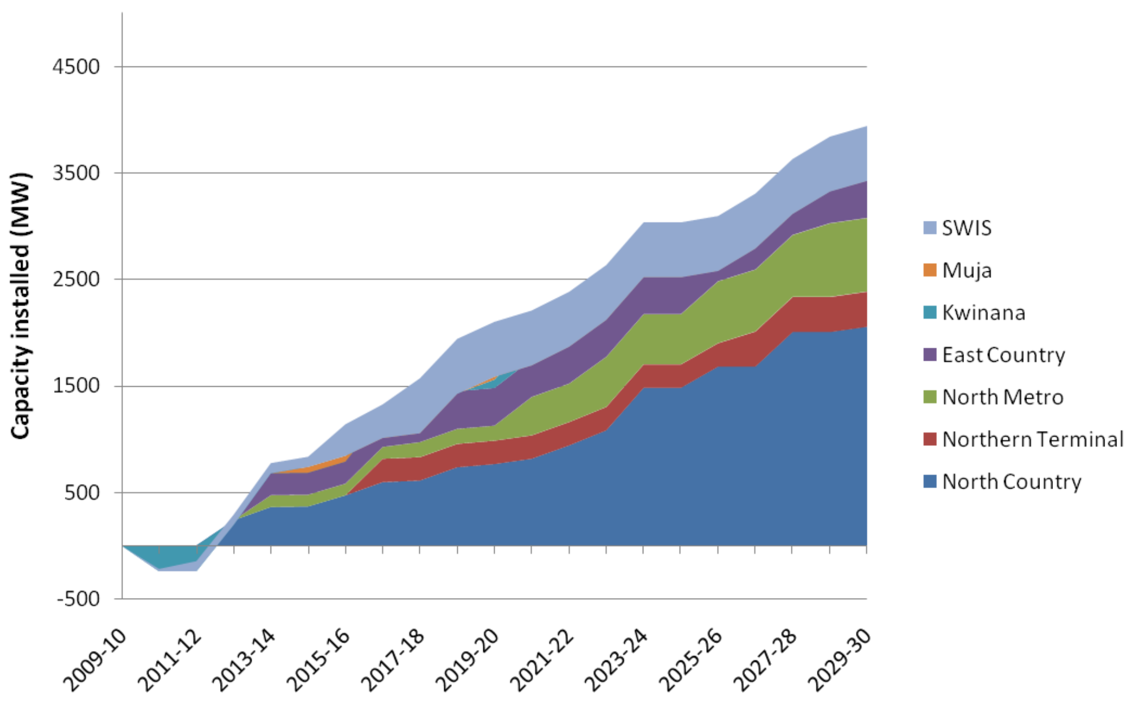


Figure 6.17 – Scenario 3 – New capacity installed by location (stacked)



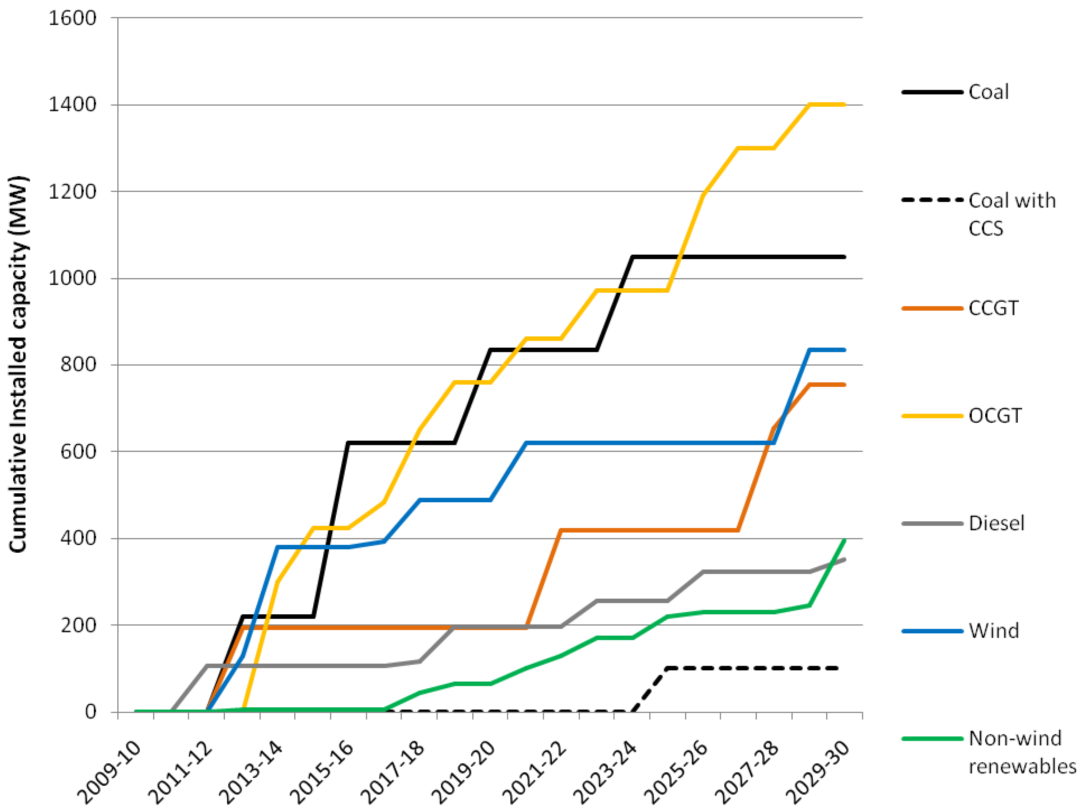
6.5) *SCENARIO 4 – COAL DEVELOPMENT*

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.

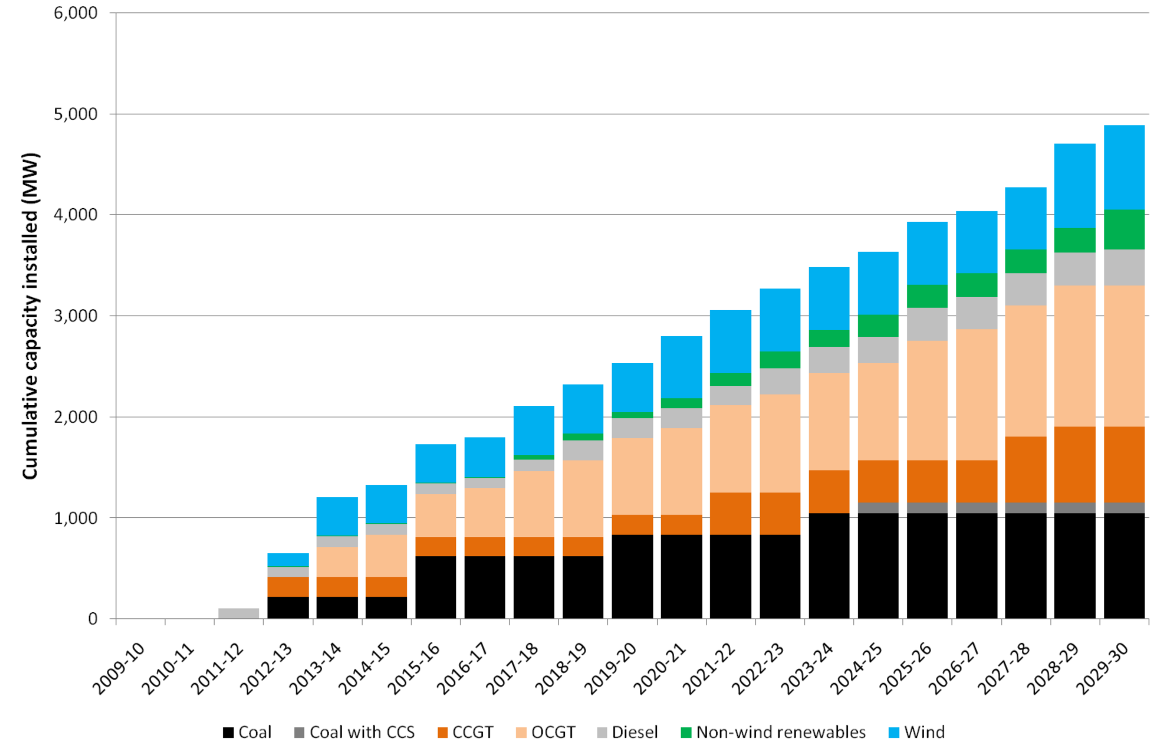
Investment in gas generation is also required to meet the very high demand growth in this scenario. OCGTs are favoured due to the large investment in low short run marginal cost coal-fired generation, but CCGTs are incentivised above further development in coal in the later parts of the study as the 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



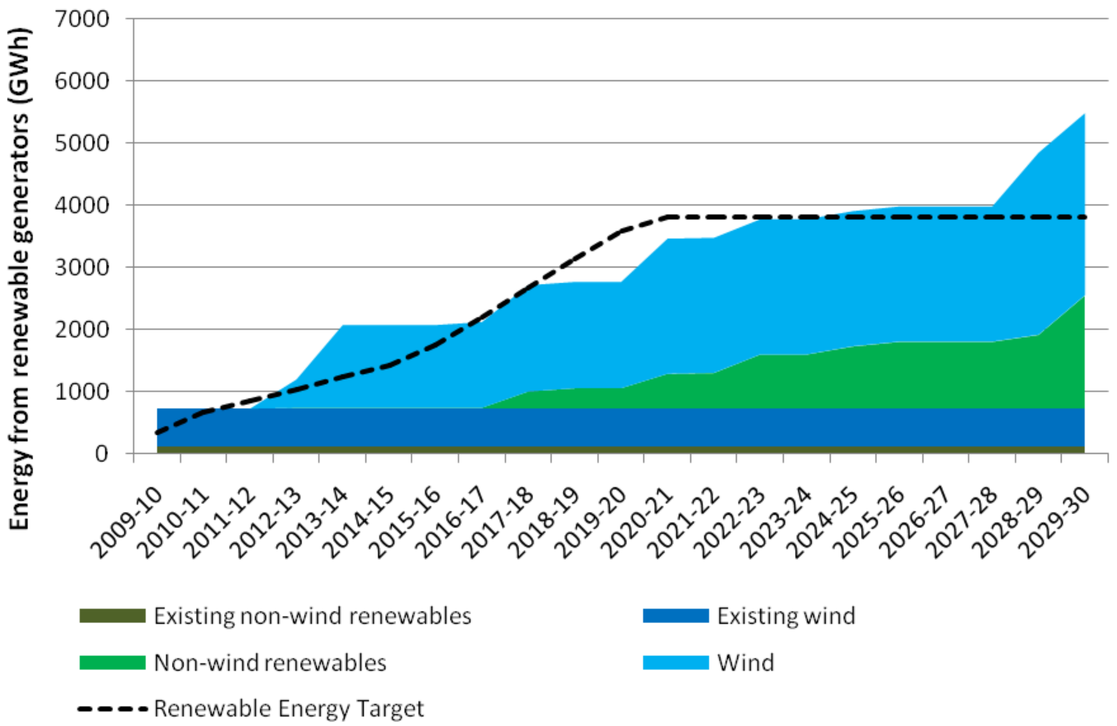
This is illustrated in stacked form in Figure 6.19.

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

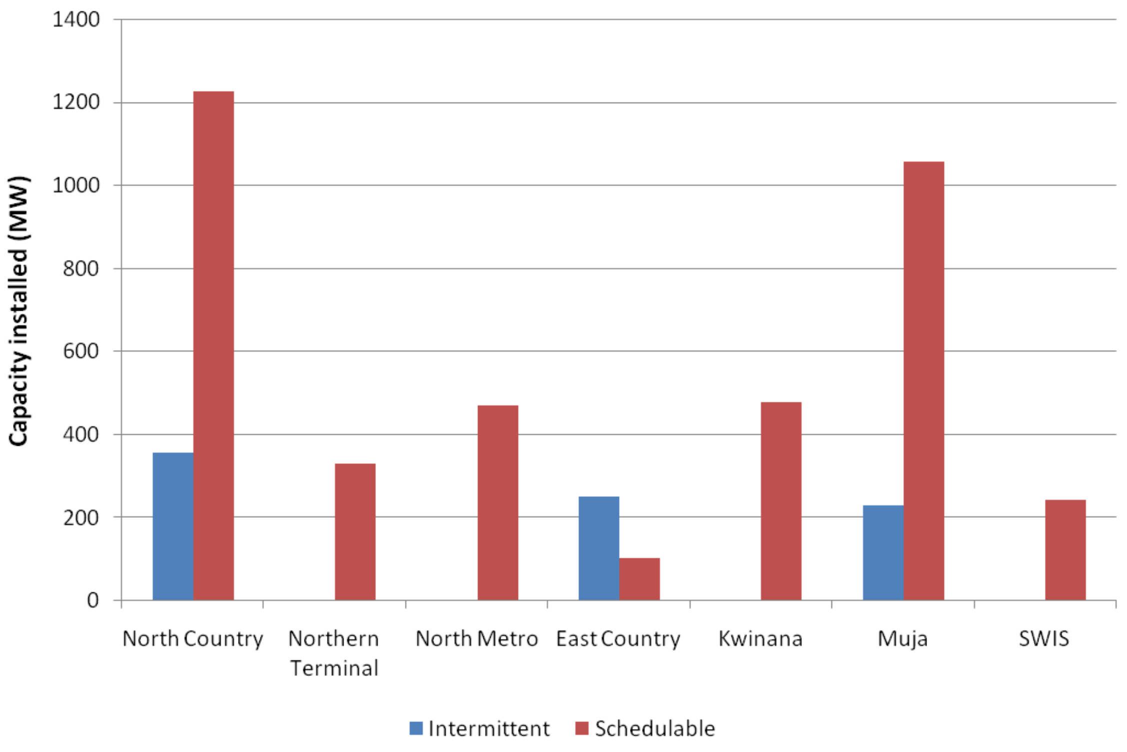
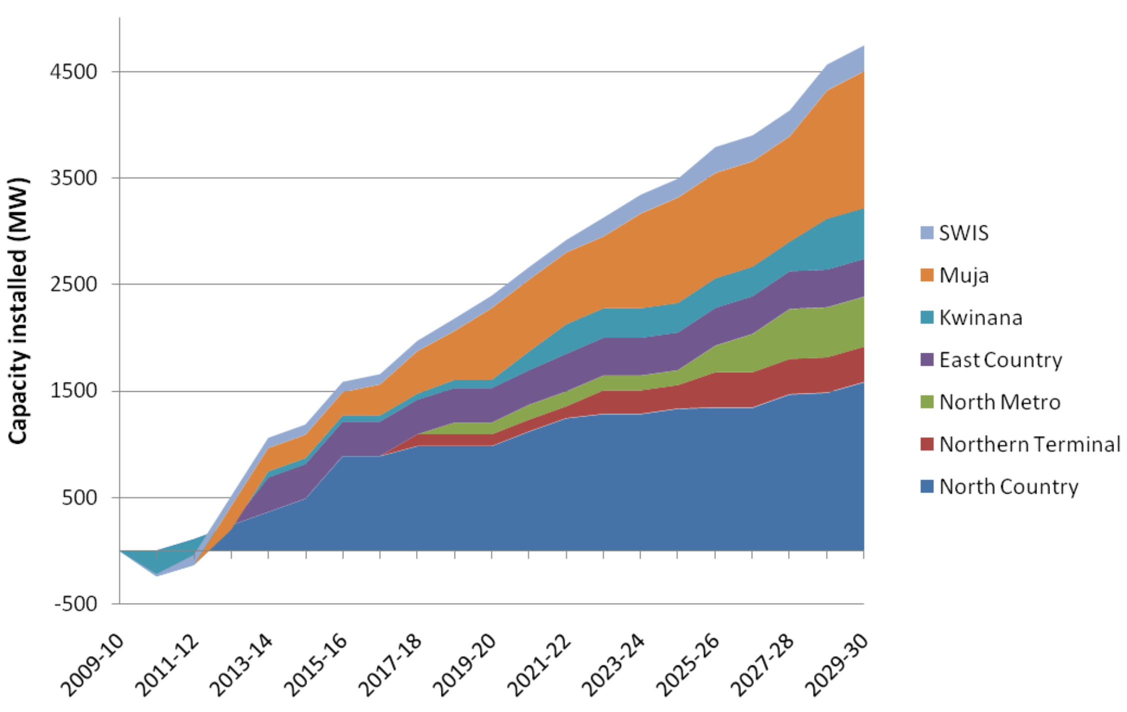


Figure 6.22 – Scenario 4 – New capacity installed by location (stacked)



6.6) GREENHOUSE EMISSIONS

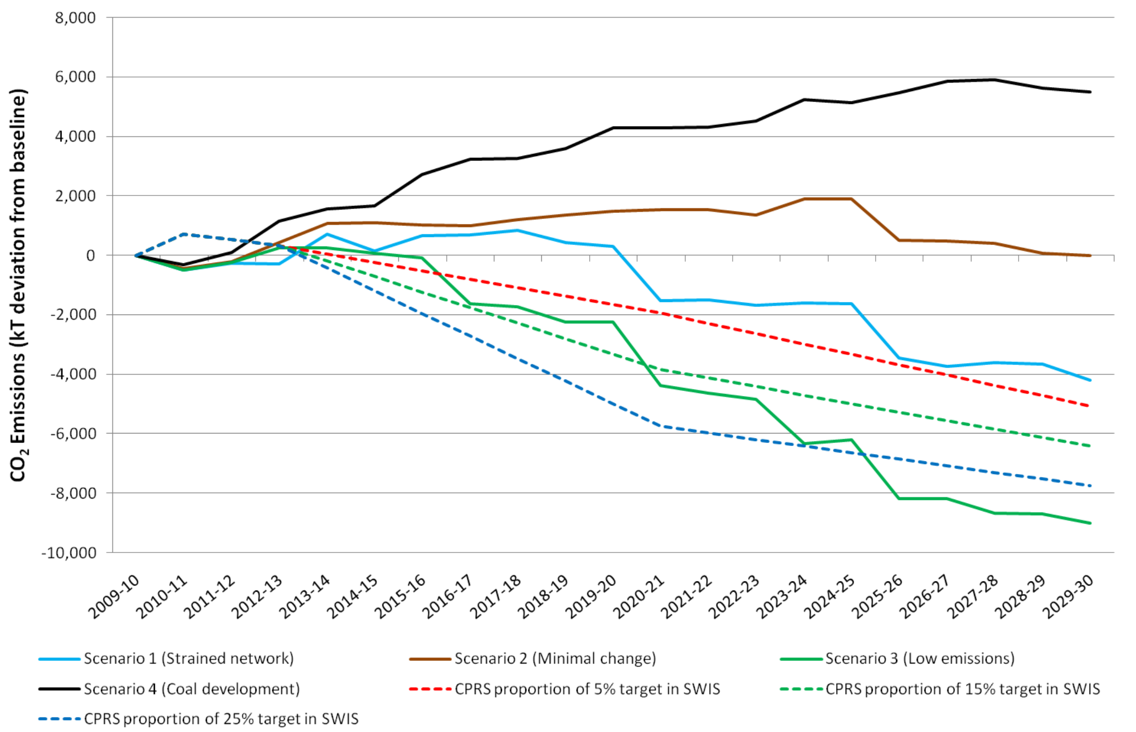
Full dispatch simulation modelling is required to accurately predict the greenhouse emissions resulting from any scenario. However, with some assumptions an estimate of the likely emissions for each scenario can be made. This is illustrated in Figure 6.23.

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).

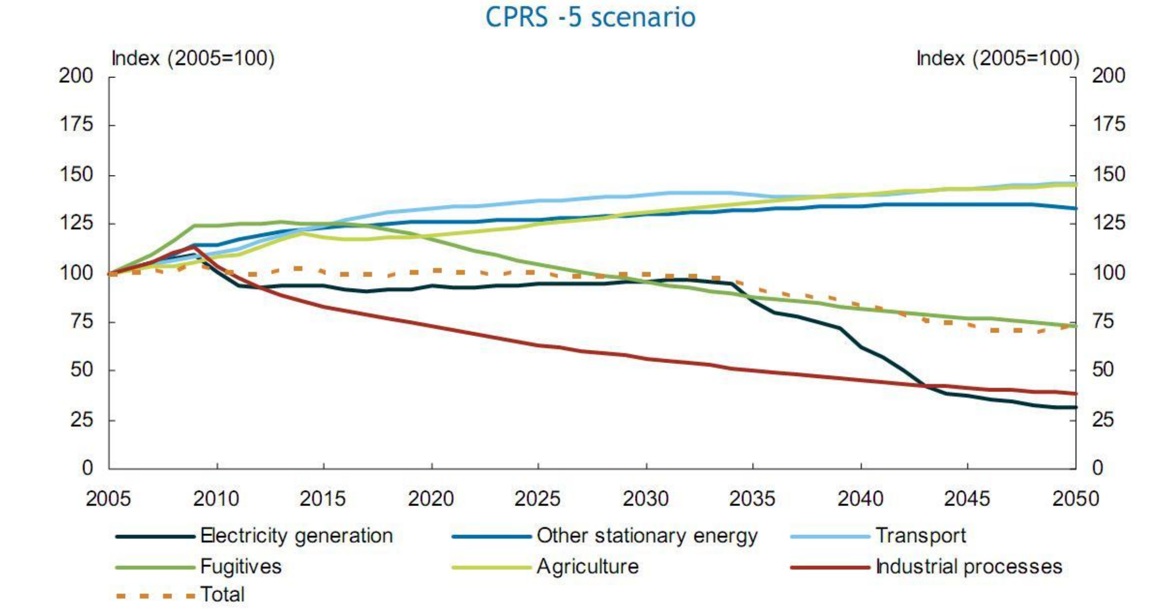
Figure 6.23 - Greenhouse emissions estimate (relative to 2009-10 baseline) [21]



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

Table C.1 – Scenario 1 Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2012-13	5MW	Carnegie Wave 1	Wave	Kwinana
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

Table C.1 – Scenario 1 Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2026-27	110MW	North Metro OCGT 3	OCGT	North Metro
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

Table C.2 – Scenario 2 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2019-20	30MW	Spiritwest Neerabup	Biomass	North Metro
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

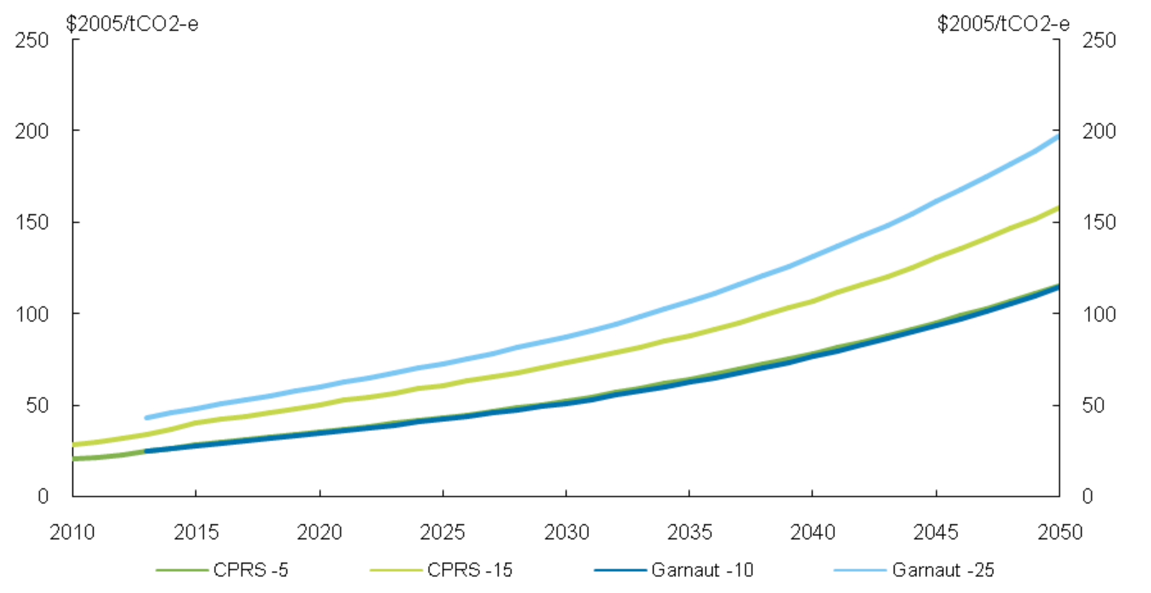
Table C.4 – Scenario 4 - Planting Schedule				
Year	**Capacity (MW)**	**Plant**	**Type**	**Location**
2028-29	215MW	Muja Wind 1	Wind	Muja
2028-29	15MW	Newworld Geothermal 3	Geo	North Country
2028-29	100MW	Kwinana CCGT 2	CCGT	Kwinana
2028-29	100MW	Kwinana OCGT 3	OCGT	Kwinana
2029-30	50MW	Mingenew Solar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