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Report (WEP00015) to

westernpower

Appendix A: Results of Analysis of future curtailment of wind generation - Original DMO

Public Version

17 December 2009

VERSION HISTORY

Version History					
Revision	**Date Issued**	**Prepared By**	**Approved By**	**Date Approved**	**Revision Type**
0.5	2009-06-03	Jenny Riesz			Input assumptions
1	2009-06-26	Jenny Riesz Joel Gilmore	Matthew Holmes	2009-06-26	Report
1.1		Jenny Riesz Joel Gilmore			Updated Report
1.2	2009-09-08	Joel Gilmore			Additional Scenarios - Draft

This report shows the results of analysis performed by ROAM Consulting for System Management. It should be read in conjunction with the System Management report entitled *Effects of increased penetration of intermittent generation in the SWIS*. Note:

- Two versions of the Dispatch Merit Order (DMO) are considered, and the ROAM report detailing the other DMO should be considered.
- Scenarios 1 and 3, which were variants of scenario 2, have been discarded.

1) Scenarios 2 and 6 Results

1.1) Input assumptions

All cogen plant is "must run", and therefore is the last plant to be decommitted. This includes the following plant:

- Worsley Cogen
- TiWest
- Alcoa Wagerup
- Alinta Pinjara
- Kwinana E
- Alinta Wagerup (once converted)
- Kwinana Cogen Project (PPP_KCP)
- Mungarra GT1 (must run for voltage support)

All biomass plant is must run.

Selected thermal facilities are also considered must-run:

- Muja 6
- Muja 7
- Muja 8
- Muja A G2
- Muja B
- Collie Power Station
- Bluewaters 1
- Bluewaters 2
- Coal 2 Unit 1
- Coal 1

The above means that 1 out of 4 thermal units are cycled. Therefore the following facilities are cycled (as required):

- All Kwinana thermal units (this is currently occurring)
- Muja A G1
- Muja 5
- Coal 2 Unit 2

1.1.1) Commissioning Schedule

Table 1.1 – Wind farm commissioning schedule			
Year Commissioned	**Location**	**Capacity (MW)**	**Source data**
2010	Merredin	200	BOM data (60min data available) 2007-08
2011	East of Albany	100	Albany wind farm 2007-08
	Albany	100	Albany wind farm 2007-08
2012	Emu Downs	100	Emu Downs wind farm 2007-08
2013	Walkaway	100	Walkaway wind farm 2007-08
2014	Albany	100	Albany wind farm 2007-08
2015	Emu Downs	100	Emu Downs wind farm 2007-08
2016	Walkaway	100	Walkaway wind farm 2007-08
2017	Albany	100	Albany wind farm 2007-08
2018	Emu Downs	100	Emu Downs wind farm 2007-08
2019	Walkaway	100	Walkaway wind farm 2007-08

Table 1.2 – Thermal plant commissioning / retirement schedule – same as Case 2				
Year	**Plant name**	**Market Participant**	**Fuel type**	**Change in status**
2011	Kwinana D	Perth Energy	Gas	Commission (1x120MW)
	Blue Waters 2	Griffin Power 2 Pty Ltd	Coal	Commission (1x200MW)
	Muja A	Verve Energy	Coal	Re-commission (2x60MW)
	Muja B	Verve Energy	Coal	Re-commission (2x60MW)
	Kwinana B – LMS100	Verve Energy	OCGT- Gas	Commission (2x100MW)
2012	Kwinana A	Verve Energy	Thermal	Retire (2x100MW)
2013	OCGT convert to cogen	IPP	Gas/Liquid	Convert OCGT to cogen (2x180MW)
2014	OCGT 1	-	OCGT- Gas	Commission (1x180MW)
2015	Kwinana E	-	Cogen- OCGT- Gas	Commission (2x180MW)
	Kwinana C	Verve Energy	Thermal	Retire (2x200MW)
2016	Coal 1	-	Coal	Commission (2x200MW)
2017	Coal 2	-	Coal	Commission (2x200MW)

Table 1.2 – Thermal plant commissioning / retirement schedule – same as Case 2				
Year	**Plant name**	**Market Participant**	**Fuel type**	**Change in status**
2018	New OCGT 1	-	OCGT-Gas/Liquid	Commission (1x180MW)
2019	New OCGT 2	-	OCGT-Gas/Liquid	Commission (1x180MW)

1.2) WIND CURTAILMENT

Wind curtailment is significantly higher due to the now "must run" coal plant.

Table 1.3 – Wind Curtailment			
Year	**Total Installed Wind (MW)**	**% of Annual wind energy curtailed**	
		Scenario 2	**Scenario 6**
2010-11	391	0.0%	0.0%
2011-12	591	0.0%	0.7%
2012-13	691	0.0%	1.1%
2013-14	791	0.0%	11.2%
2014-15	891	0.1%	18.0%
2015-16	991	1.0%	28.8%
2016-17	1091	2.9%	42.6%
2017-18	1191	3.9%	48.8%
2018-19	1291	9.3%	56.4%
2019-20	1391	14.9%	61.5%

Curtailment by time of day

Wind farms in overnight periods are completely constrained off, due to demand being met by load following gas plant and must run coal plant. However, even some of the "must run" coal plant is forced to cycle during overnight periods due to the large quantity of load following gas plant online (demonstrated below for Coal IPP and Muja A).

Figure 1.1a – Wind curtailment in 2019-20 (Scenario 2) – high levels of curtailment

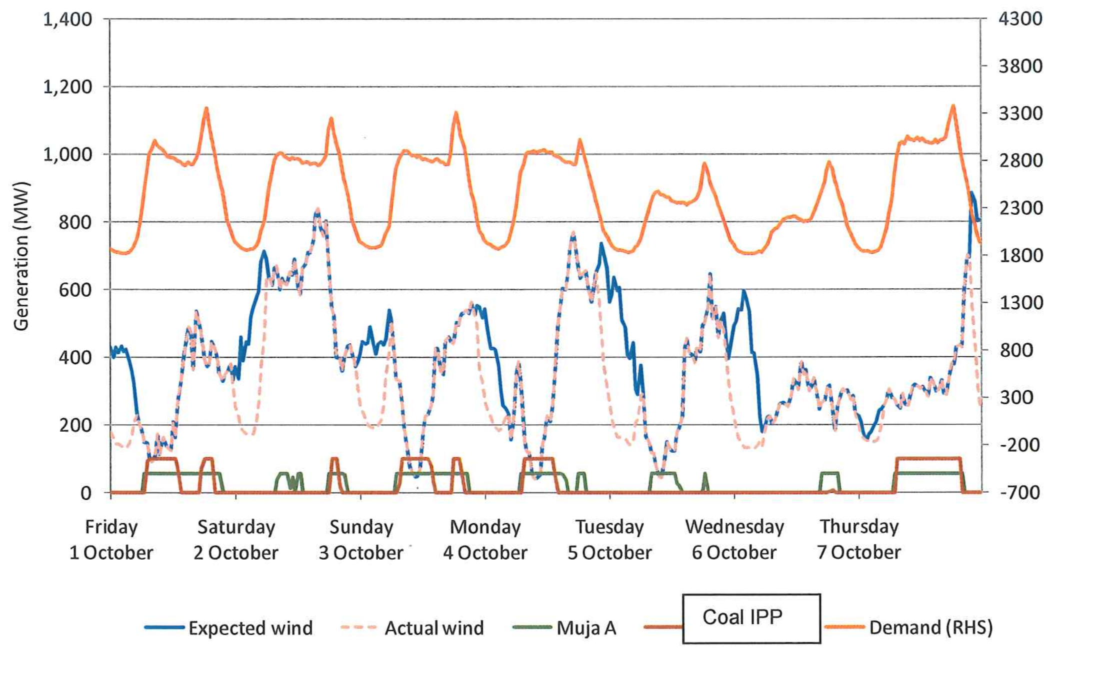
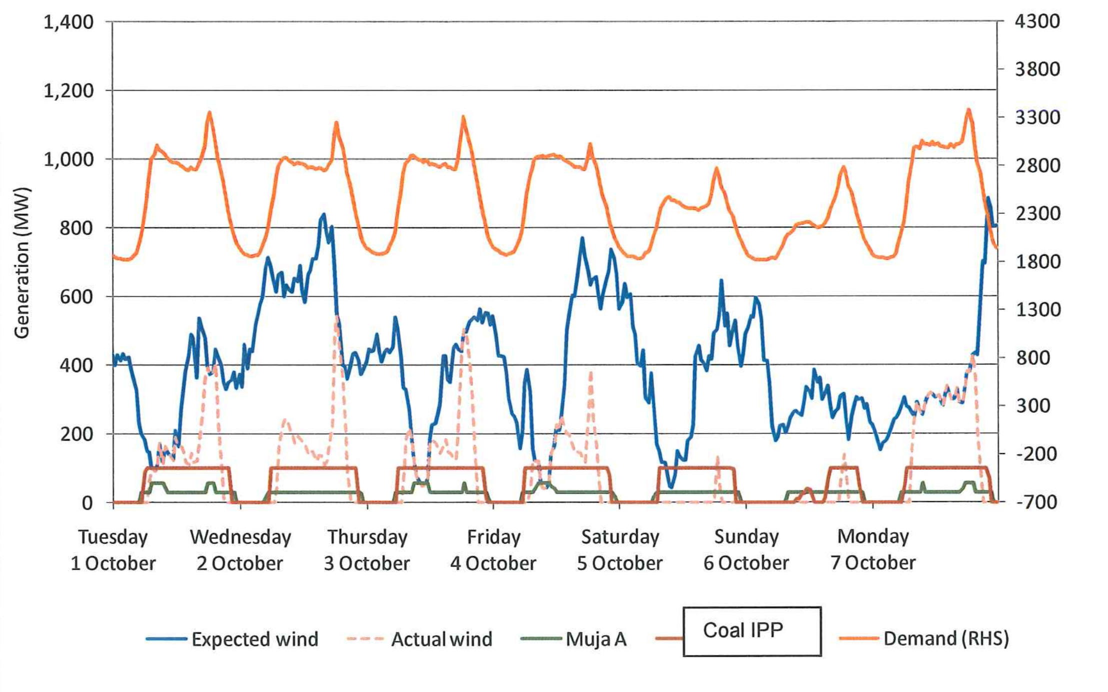
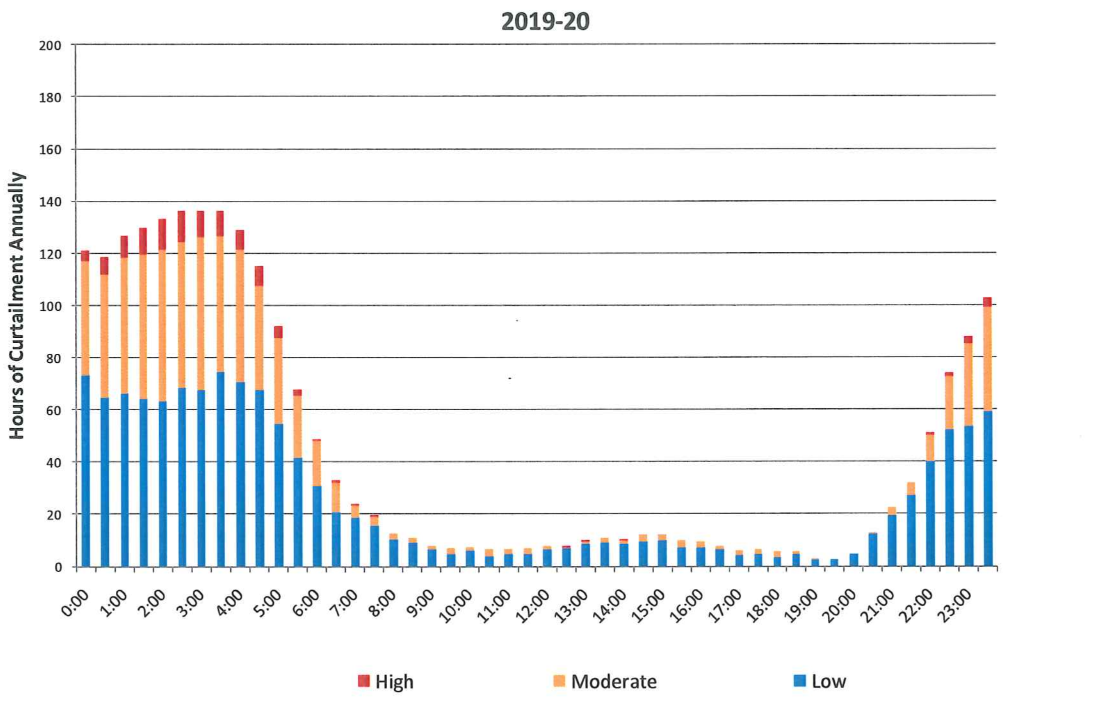


Figure 1.2b – Wind curtailment in 2019-20 (Scenario 6) – high levels of curtailment



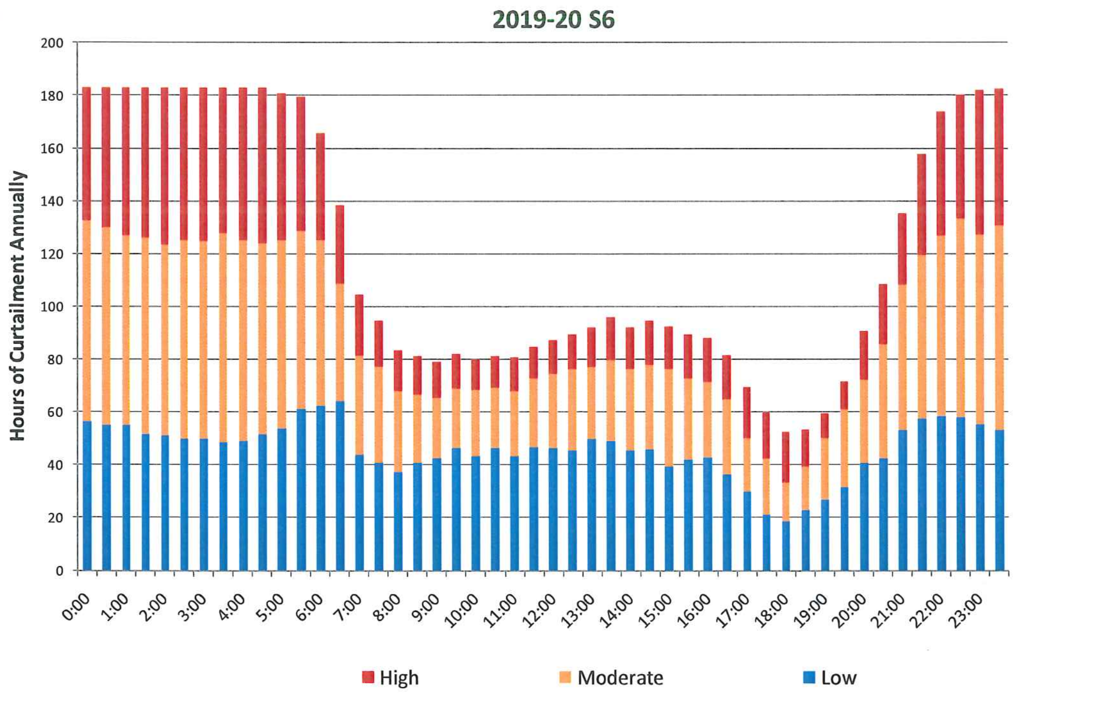
Significant curtailment in overnight periods, and moderate curtailment in daytime periods, is now observed.

Figure 1.3a – Hours of curtailment by time of day (Scenario 2, 2019-20)



High – More than 50% of the wind capacity was curtailed
Moderate – Between 25% and 50% of the wind capacity was curtailed
Low – Between 0% and 25% of the wind capacity was curtailed

Figure 1.4b – Hours of curtailment by time of day (Scenario 6, 2019-20)



High – More than 50% of the wind capacity was curtailed
Moderate – Between 25% and 50% of the wind capacity was curtailed
Low – Between 0% and 25% of the wind capacity was curtailed

1.3) GENERATION

Figure 1.5 – Energy production in the SWIS (Scenario 6)

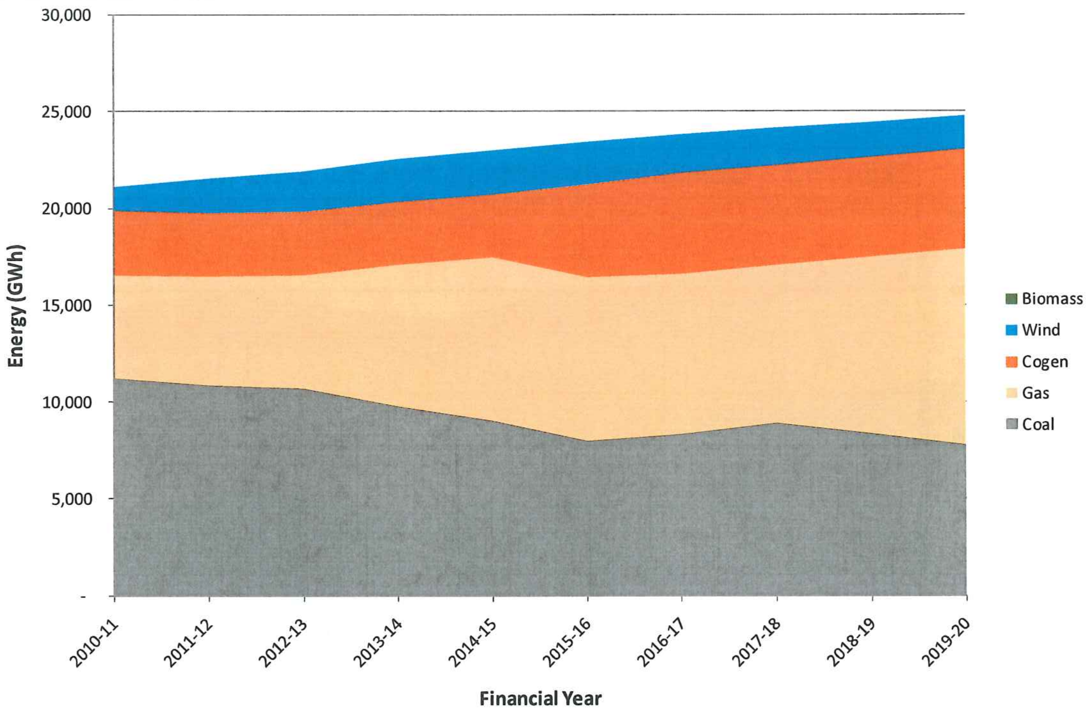
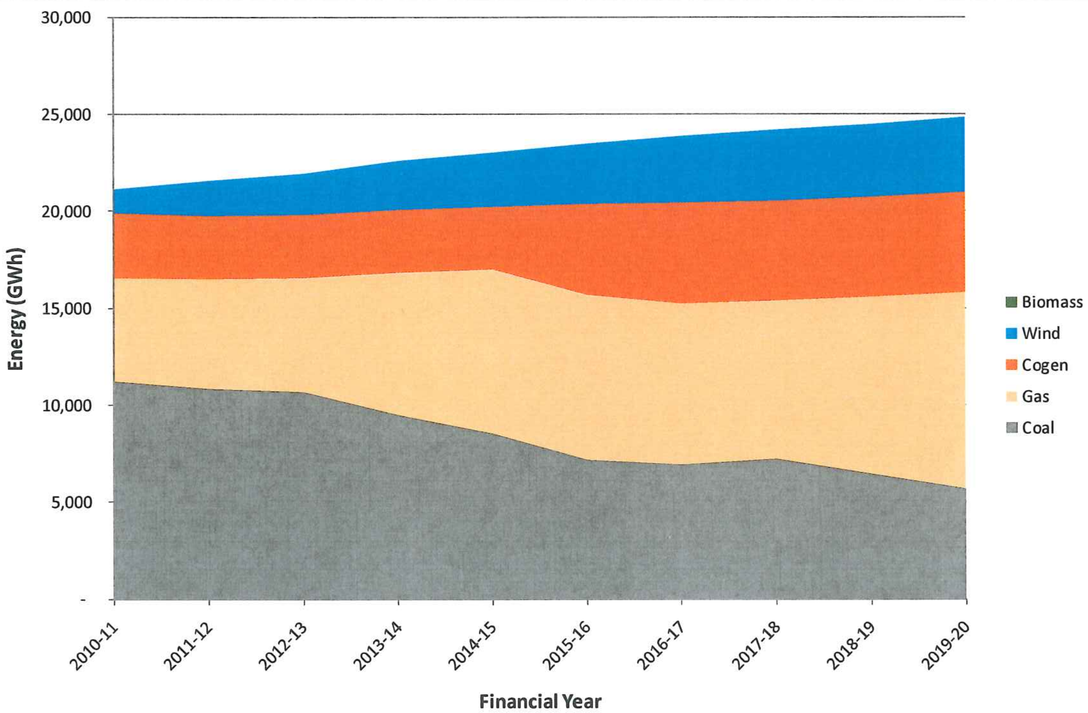


Figure 1.6 – Energy production in the SWIS (Scenario 2, for comparison)



1.4) GREENHOUSE EMISSIONS

Figure 1.7 – Greenhouse emissions from the SWIS (Scenario 6)

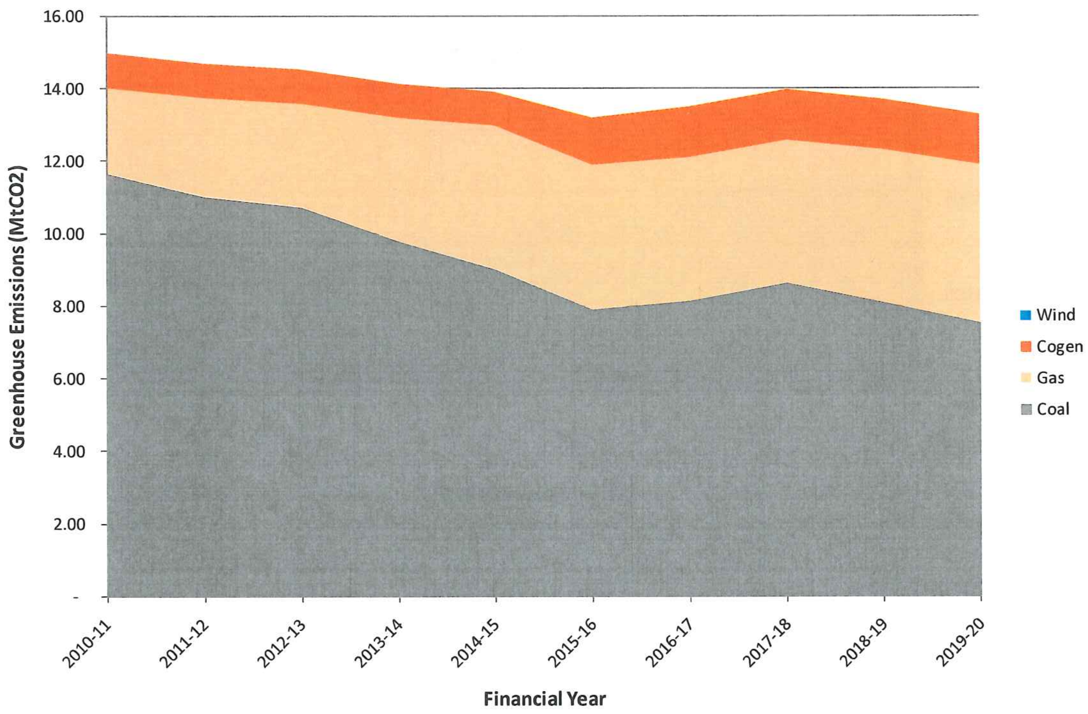
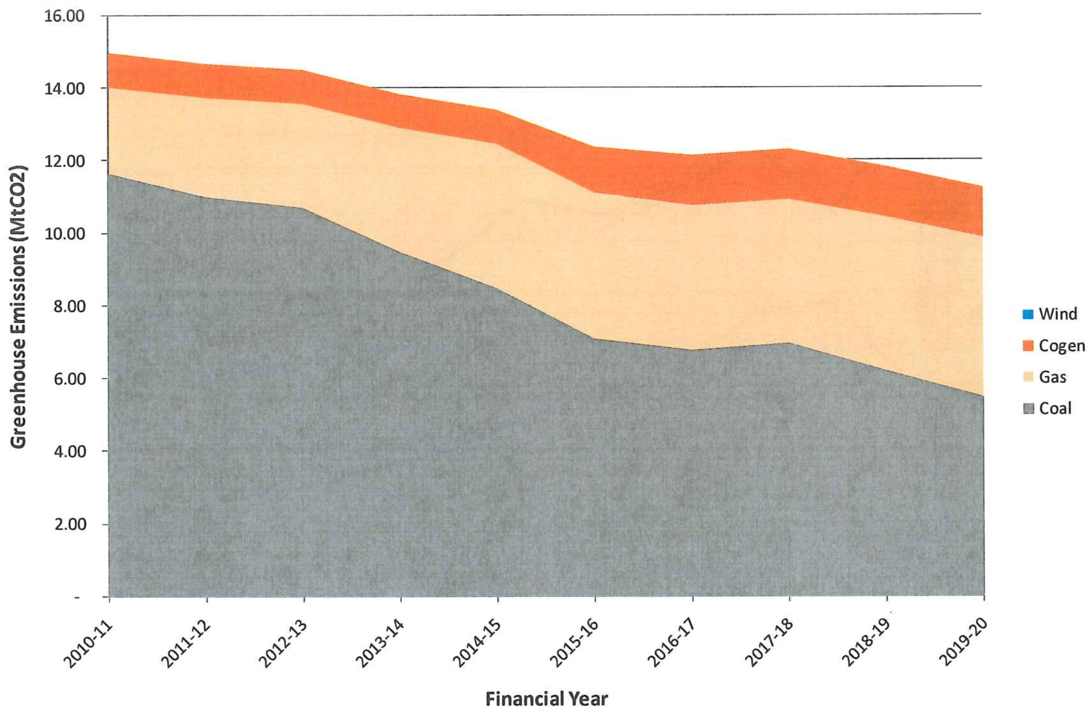
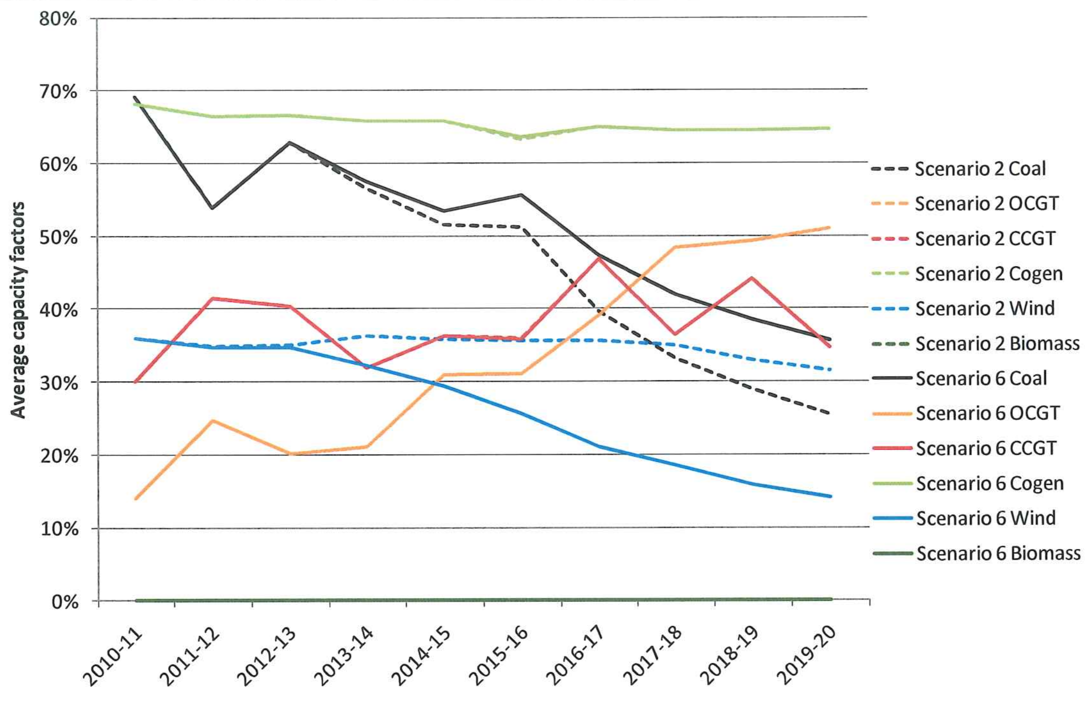


Figure 1.8 – Greenhouse emissions from the SWIS (Scenario 2, for comparison)



1.5) Operational modes of plants

Figure 1.9 – Capacity Factors of plants in the SWIS



Coal fired plant increases generation at the expense of wind and OCGT plant. Capacity factors for load following plant remain relatively unchanged from the original study (Scenarios 1-3).

Plant cycling

The figures below show periods in both Scenario 2 and Scenario 6 where cycling of coal plants occur. In Scenario 2, cycling occurs on a regular basis.

Figure 1.10 – Time-sequential generation of coal-fired plant in 2019-20 (Scenario 2)

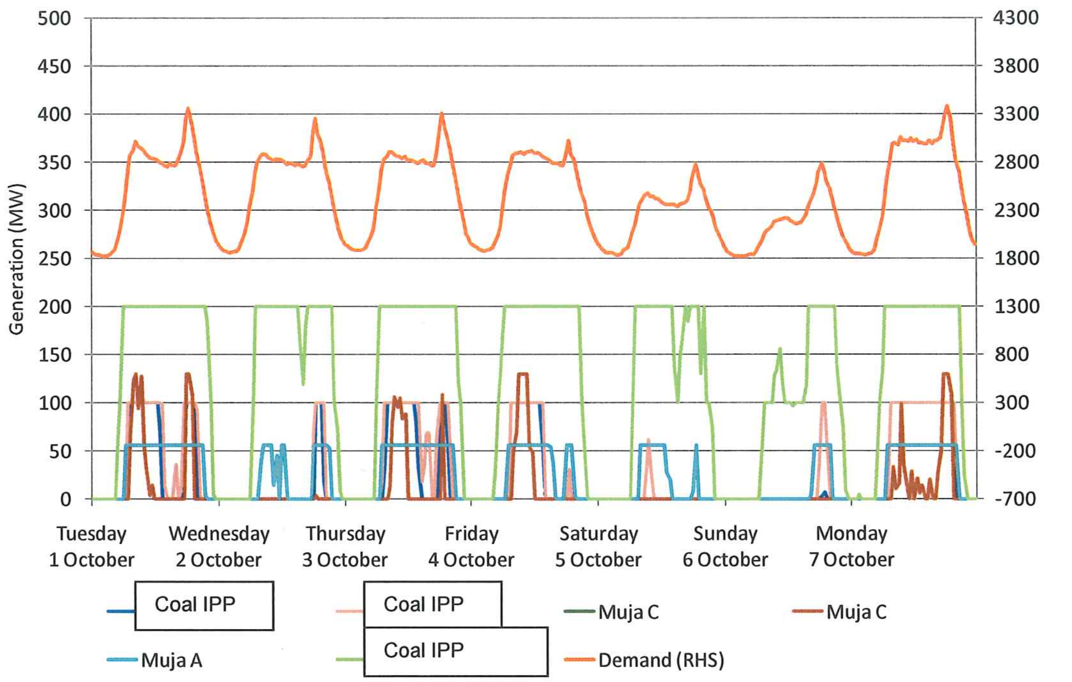
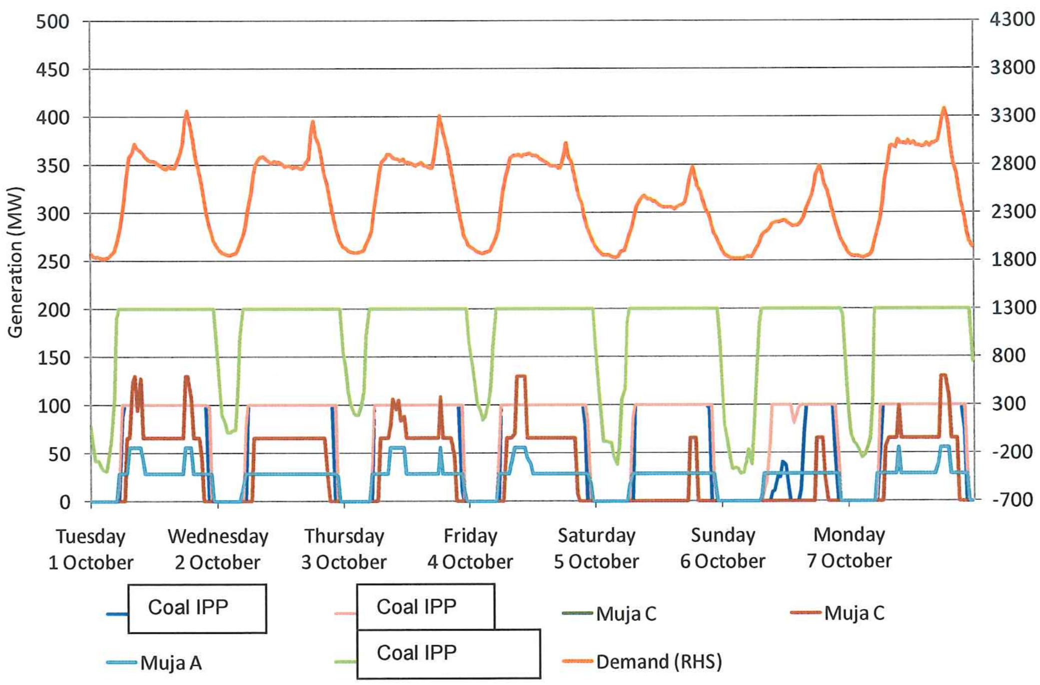


Figure 1.11 – Time-sequential generation of coal-fired plant in 2019-20 (Scenario 6)



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In Scenario 6, several coal power stations are still required to cycle despite their "must-run" status, during periods of high wind/low demand. The large amount of wind combined with the correspondingly large amount of load following gas plant exceeds demand on a regular basis.

2) Scenarios 4 and 5 Results

2.1) Input Assumptions

All cogen plant is "must run", and therefore is the last plant to be decommitted. This includes the following plant:

- Worsley Cogen
- TiWest
- Alcoa Wagerup
- Alinta Pinjara
- Kwinana Cogen Project (PPP_KCP)
- Mungarra GT1 (must run for voltage support)

All biomass plant is must run.

In Scenario 5, selected thermal facilities are also considered must-run:

- Muja 6

- Muja 7
- Muja 8
- Muja A G2
- Muja B
- Collie Power Station
- Bluewaters 1
- Bluewaters 2

The above means that 1 out of 4 thermal units are cycled. Therefore the following facilities are cycled (as required):

- All Kwinana thermal units (this is currently occurring)
- Muja A G1
- Muja 5

2.1.1) Commissioning Schedule

Table 2.1 – Plant commissioning / retirement schedule

Year	Plant name	Market Participant	Plant type	Change in status
2009	Newgen Neerabup	Newgen	OCGT- gas	Commission (2x165MW)
2009	Kwinana Power Station A G1	Verve Energy	Thermal	Reduce maximum capacity from 111.5 to 94.5 MW (ie reduction of 17MW)
2009	Blue Waters 2	Griffin Power 2 Pty Ltd	Coal	Commission (1x200MW)
2010	Kwinana D	Perth Energy	OCGT- gas	Commission (1x120MW)
2011	WA Biomass	WA Biomass	Biomass	Commission (1x40MW)
2011	Merriden WF	Collgar	Wind farm	Commission (1x200MW)
2011	Muja A	Verve Energy	Coal	Re-commission (2x50MW)
2011	Muja B	Verve Energy	Coal	Re-commission (2x60MW)
2011	Kwinana B – LMS100	Verve Energy	OCGT- gas	Commission (2x90MW)
2011	Kwinana A	Verve Energy	Thermal	Retire (2x100MW)
2012	Biomass 1	IPP	Biomass	Commission (1x25MW)
2012	OCGT 1	IPP	OCGT- liquid	Commission (2x125MW)
2013	Albany WF2	Verve Energy	Wind farm	Commission (1x100MW)
2013	OCGT 2	IPP	OCGT- liquid	Commission (2x150MW)
2014	OCGT 3	IPP	OCGT- liquid	Commission (1x100MW)
2014	Pinjar 2	Verve Energy	OCGT	Reduce maximum capacity from 37.2 to 20 MW (ie reduction of 17MW)
2015	Biomass 2	IPP	Biomass	Commission (2x25MW)
2015	EDWF2	IPP	Wind farm	Commission (1x100MW)
2015	OCGT 4	Verve Energy	OCGT- gas	Commission (1x150MW)

Table 2.1 – Plant commissioning / retirement schedule				
Year	**Plant name**	**Market Participant**	**Plant type**	**Change in status**
2016	Kwinana C	Verve Energy	Thermal	Retire (2x200MW)
2016	Renewable 1	IPP	Biomass	Commission (1x20MW)
2016	WWF 2	Alinta	Wind farm	Commission (1x100MW)
2016	Albany WF 3	IPP	Wind farm	Commission (1x100MW)
2016	EDWF WF 3	IPP	Wind farm	Commission (1x105MW)
2016	OCGT 4	IPP	OCGT- liquid	Commission (4x150MW)
2016	OCGT 5	IPP	OCGT- liquid	Commission (1x50MW)
2016	Pinjar 9	Verve Energy	OCGT	Retire (1x116MW)
2016	Pinjar 1	Verve Energy	OCGT	Retire (1x37.2MW)
2017	OCGT 6	IPP	OCGT- liquid	Commission (2x100MW)
2018	WWF 3	IPP	Wind farm	Commission (1x55MW)
2018	OCGT 7	IPP	OCGT- liquid	Commission (1x150MW)
2019	OCGT 8	IPP	OCGT- liquid	Commission (2x100MW)

2.1.2) Assumptions: DMO

Based on current Market Rules.

All biomass should be in the same position as WA Biomass. All OCGT should be in the same position as Alinta Wagerup.

2.1.3) Assumptions: minimum capacity

- Removed

Table 2.2 – Scenarios 4 and 5 load following requirements	
	Load following required (MW)
2010-11	62.7
2011-12	89.0
2012-13	89.0
2013-14	105.1
2014-15	105.1
2015-16	125.3
2016-17	198.1
2017-18	196.1

2018-19	206.2
2019-20	206.2

2.2) Wind curtailment

Wind curtailment is significantly higher due to the now "must run" coal plant.

Table 2.3 – Wind Curtailment			
Year	**Total Installed Wind (MW)**	**% of Annual wind energy curtailed**	
		Scenario 4	**Scenario 5**
2010-11	190.7	0%	0.0%
2011-12	390.7	0%	0.0%
2012-13	390.7	0%	0.0%
2013-14	490.7	0%	0.0%
2014-15	490.7	0%	0.0%
2015-16	590.7	0%	0.2%
2016-17	895.7	0%	5.0%
2017-18	895.7	0%	4.5%
2018-19	950.7	0%	5.4%
2019-20	950.7	0%	4.6%

Curtailment by time of day

Wind farms exhibit no constraints under this planting schedule in Scenario 4. Under Scenario 5, with the coal must-run plant, short periods of constraints are observed during early morning periods.

Figure 2.1 – Wind curtailment in 2019-20 (Scenarios 4)

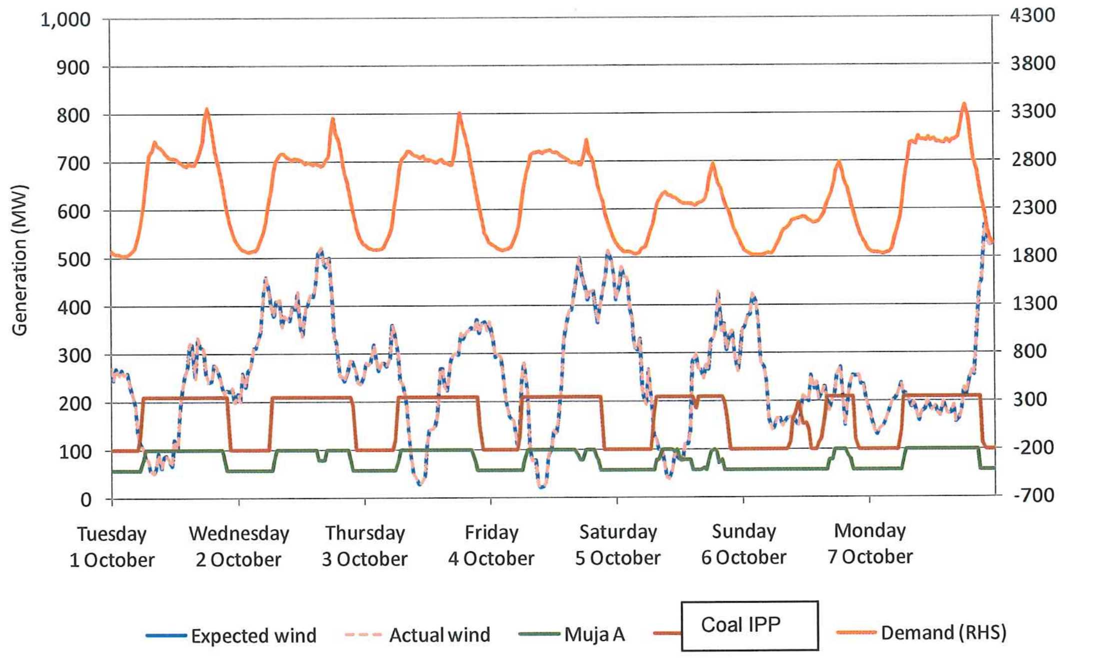
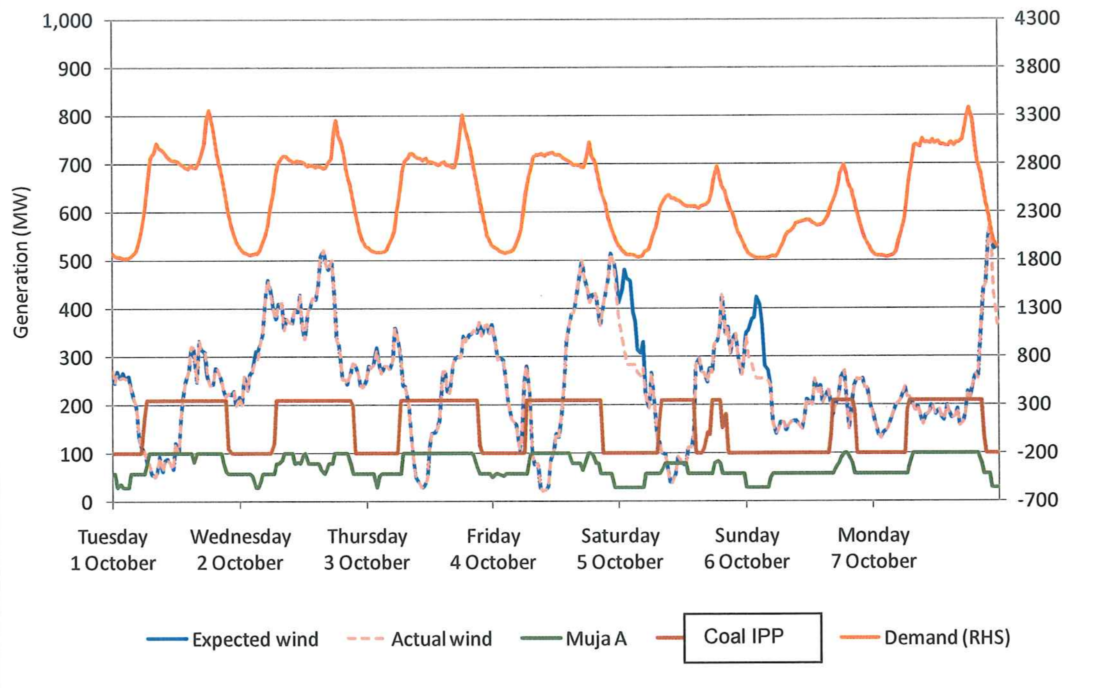
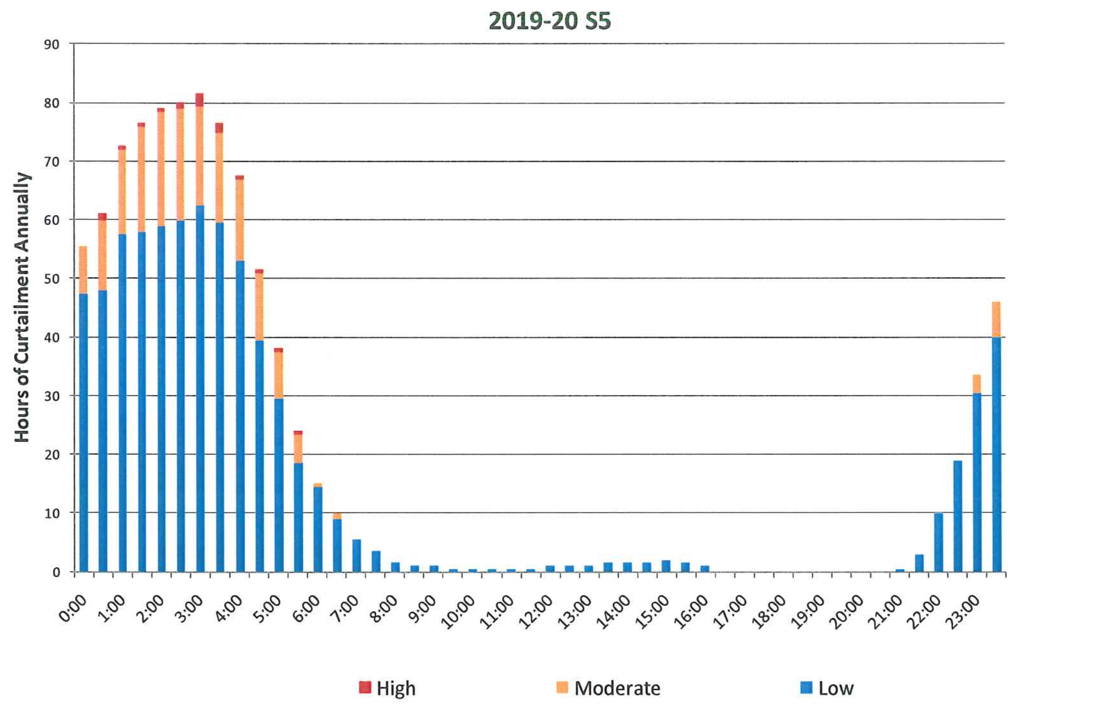


Figure 2.2 – Wind curtailment in 2019 (Scenarios 5)



The figure below shows the level of curtailment for each period of the day for Scenario 5. Note, however, that the curtailment level is as a proportion of total wind installed and the chart therefore has a different scale than the Scenario 1-3 and 6 results. Note that Scenario 4 exhibits no wind constraints.

Figure 2.3 – Hours of curtailment by time of day (Scenario 5, 2019-20)



High – More than 50% of the wind capacity was curtailed
Moderate – Between 25% and 50% of the wind capacity was curtailed
Low – Between 0% and 25% of the wind capacity was curtailed

2.3) GENERATION

Figure 2.4 – Energy production in the SWIS (Scenario 4)

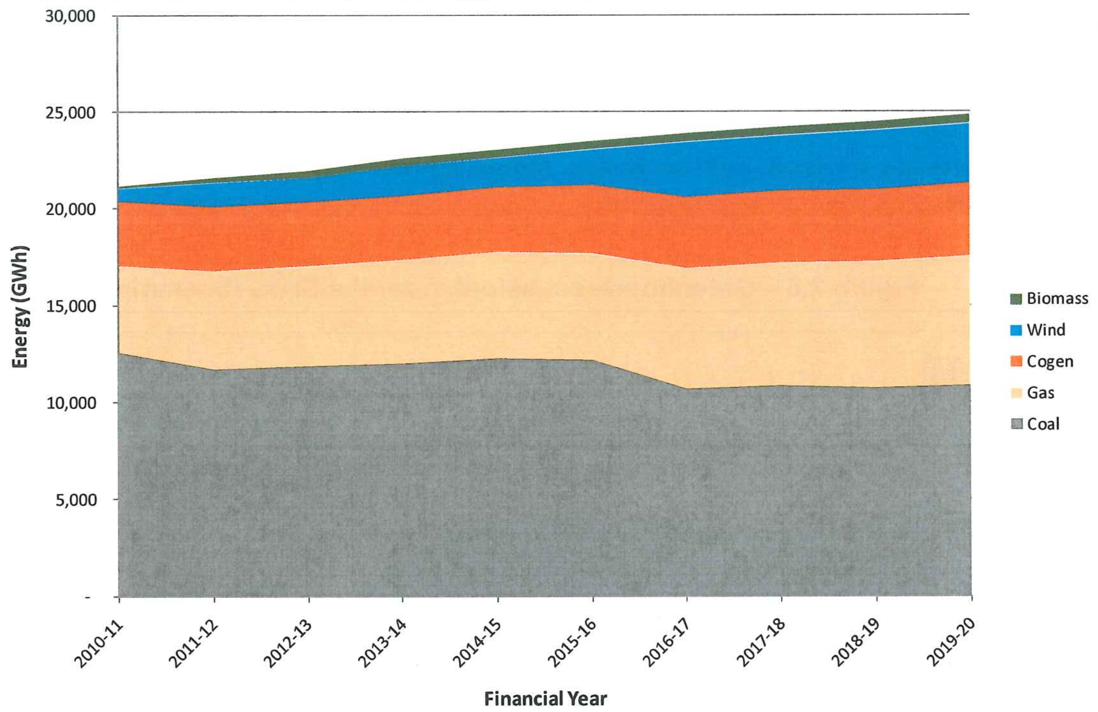
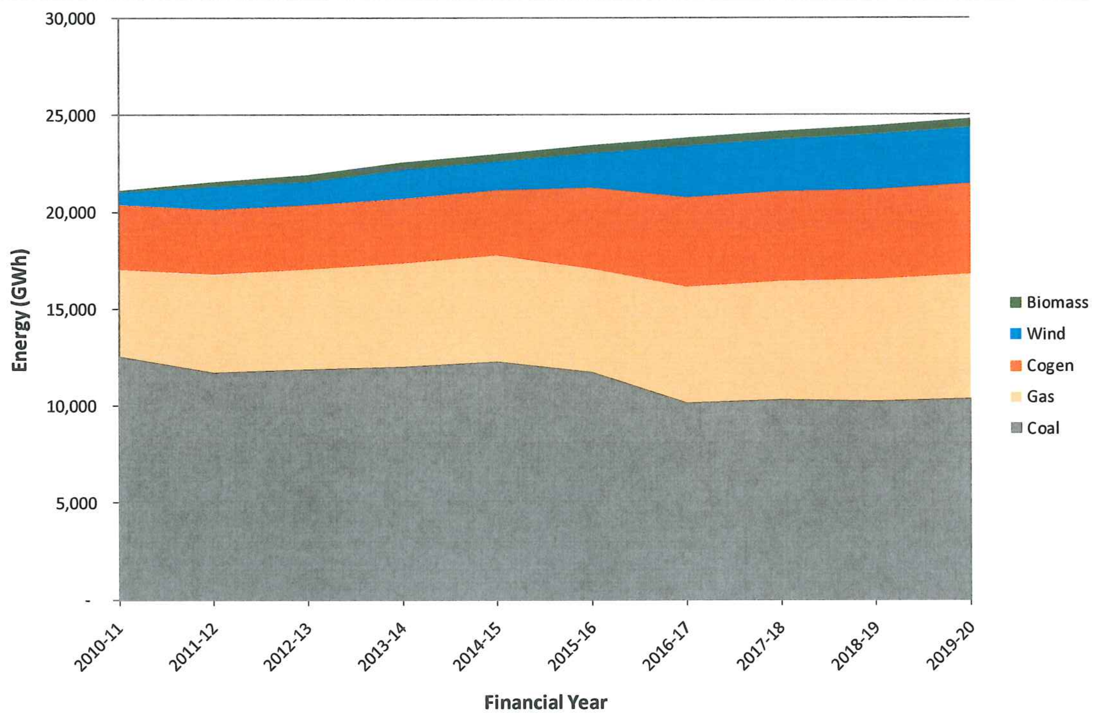


Figure 2.5 – Energy production in the SWIS (Scenario 5)



2.4) GREENHOUSE EMISSIONS

Emissions are similar in both scenarios, remaining relatively constant over the duration of the study.

Figure 2.6 – Greenhouse emissions from the SWIS (Scenario 4)

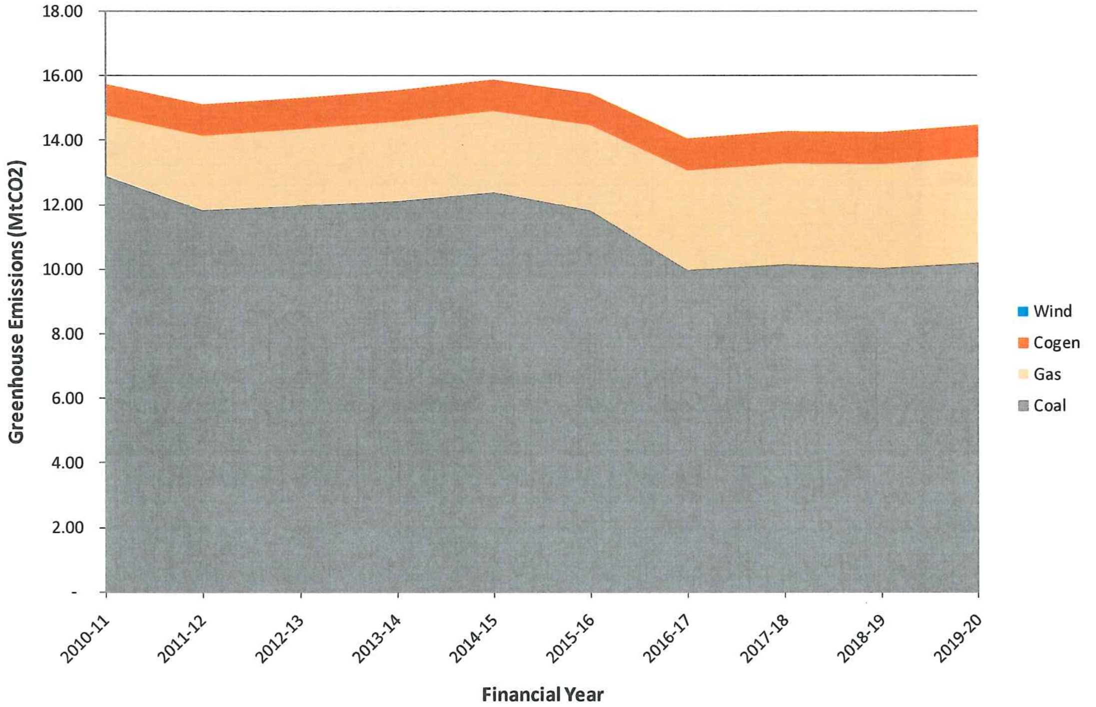
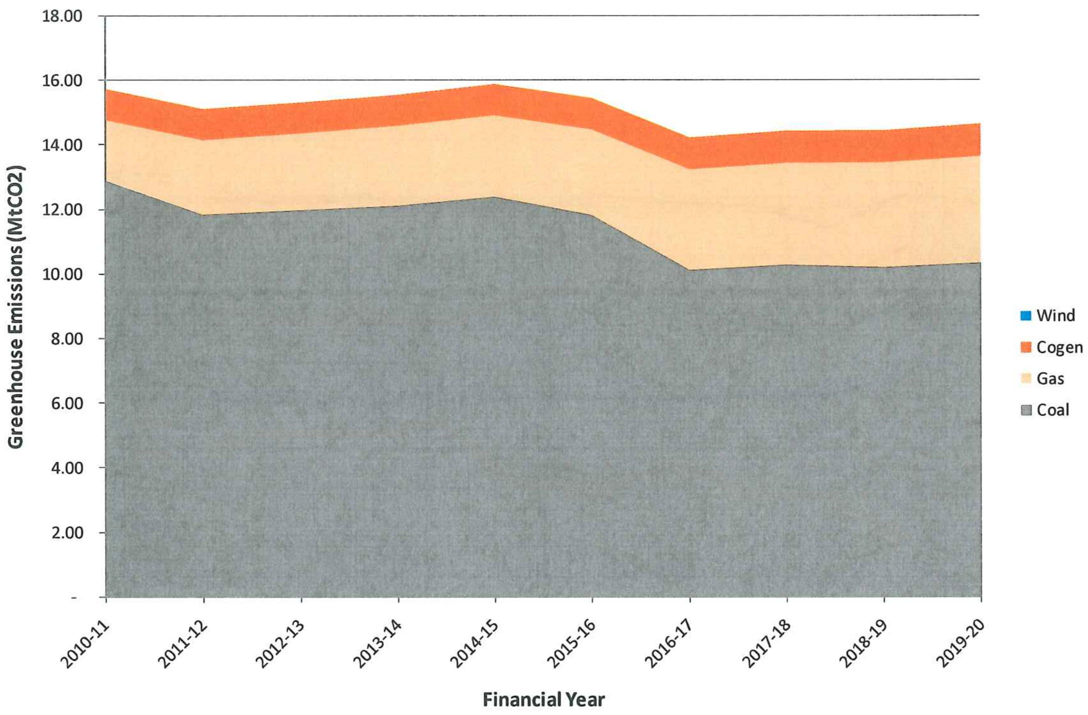
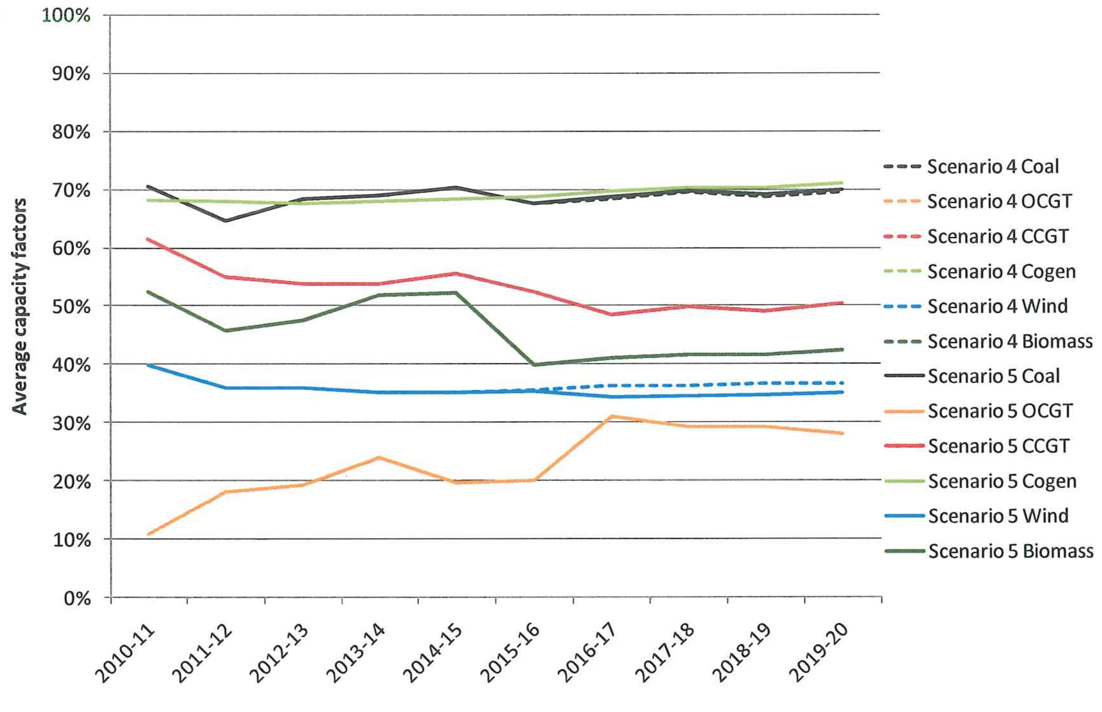


Figure 2.7 – Greenhouse emissions from the SWIS (Scenario 5)



2.5) OPERATIONAL MODES OF PLANTS

Figure 2.8 – Capacity Factors of plants in the SWIS (Scenarios 4 and 5)



Plant cycling

Figure 2.9 – Time-sequential generation of coal-fired plant (Scenario 4)

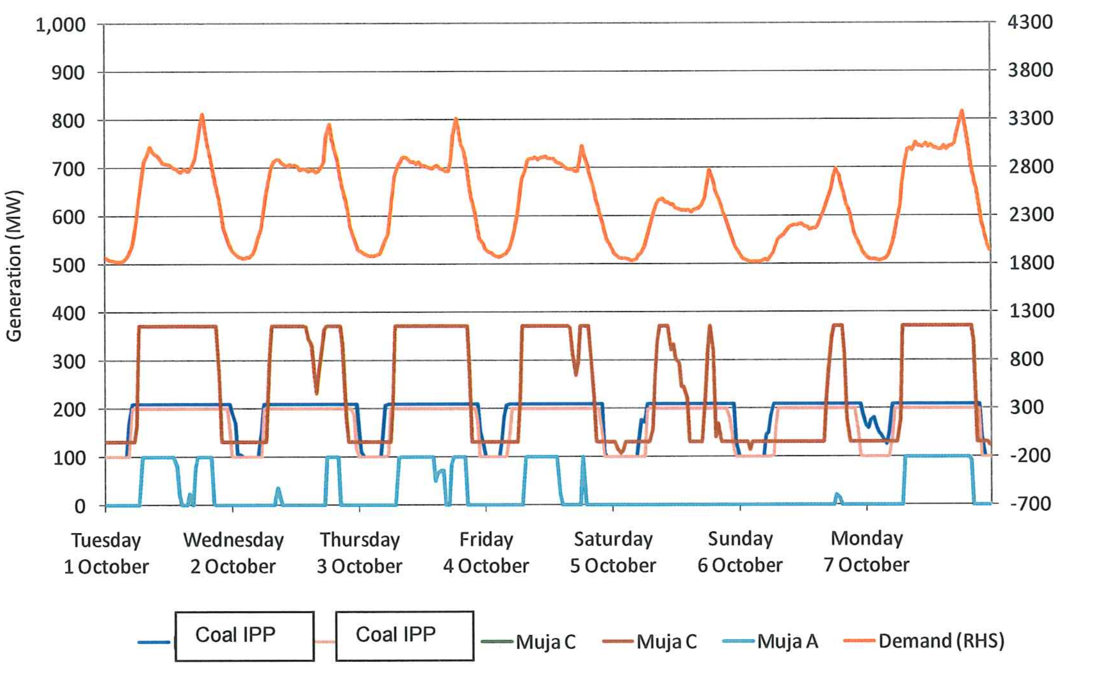
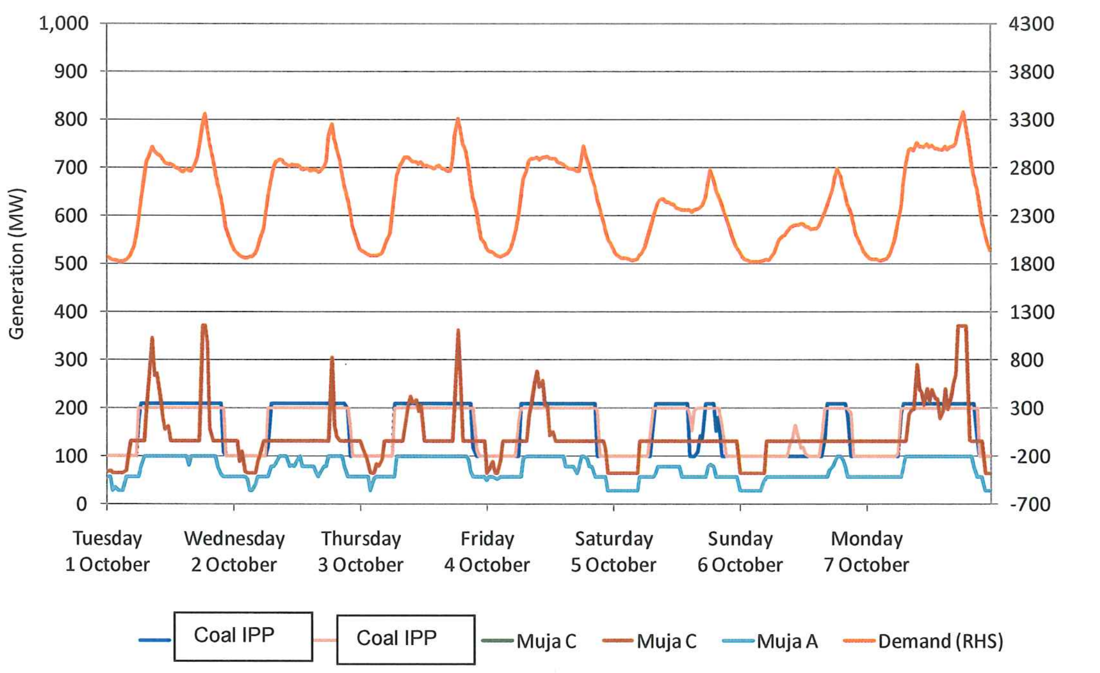


Figure 2.10 – Time-sequential generation of coal-fired plant (Scenario 5)



In Scenario 4, coal fired plant is required to cycle occasionally (as in the case of Muja C above, shown for both Scenario 4 and Scenario 5 for comparison). In Scenario 5, the wind is curtailed first in every period and no cycling occurs. The generation is also spread more evenly between stations.

3) Fuel Usage

ROAM has estimated the fuel usage for each year of each scenario. ROAM has determined best estimates for heat rates for plants in the SWIS and has calculated fuel usage accordingly (in petajoules). The figures below refer to fuel used during operation at typical levels and do not include fuel required for plant start-ups, e.g., for cycling coal plant. As such, these figures may be underestimates of true SWIS fuel usage.

Figure 3.1 – Fuel usage (PJ)

		2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Scenario 2	Gas	55	59	56	54	59	56	57	57	58	55
	Liquid	5.6	3.0	3.5	2.2	1.9	1.9	1.0	0.4	10.5	24.1
	Coal	110	109	111	99	89	78	74	75	67	59
Scenario 4	Gas	47	49	50	51	52	59	63	64	65	66

	Liquid	2.4	2.0	2.3	2.9	3.6	3.3	4.6	5.4	5.8	6.5
	Coal	125	121	123	125	127	123	109	111	109	111
Scenario 5	Gas	47	49	50	51	52	59	63	64	65	66
	Liquid	2.4	2.0	2.3	2.9	3.6	3.3	4.6	5.4	5.8	6.5
	Coal	125	121	123	125	127	123	110	112	111	113
Scenario 6	Gas	55	59	56	54	59	56	57	57	58	55
	Liquid	5.6	3.0	3.5	2.2	1.9	1.8	1.0	0.4	10.5	24.1
	Coal	110	109	111	102	95	86	88	94	88	81

As expected, requiring coal plants to be must-run significantly increases the coal fuel usage, generally at the expense of wind generation so that gas and liquid usage is not significantly affected.

Figure 3.2 – Fuel usage (Scenario 2 vs Scenario 6)

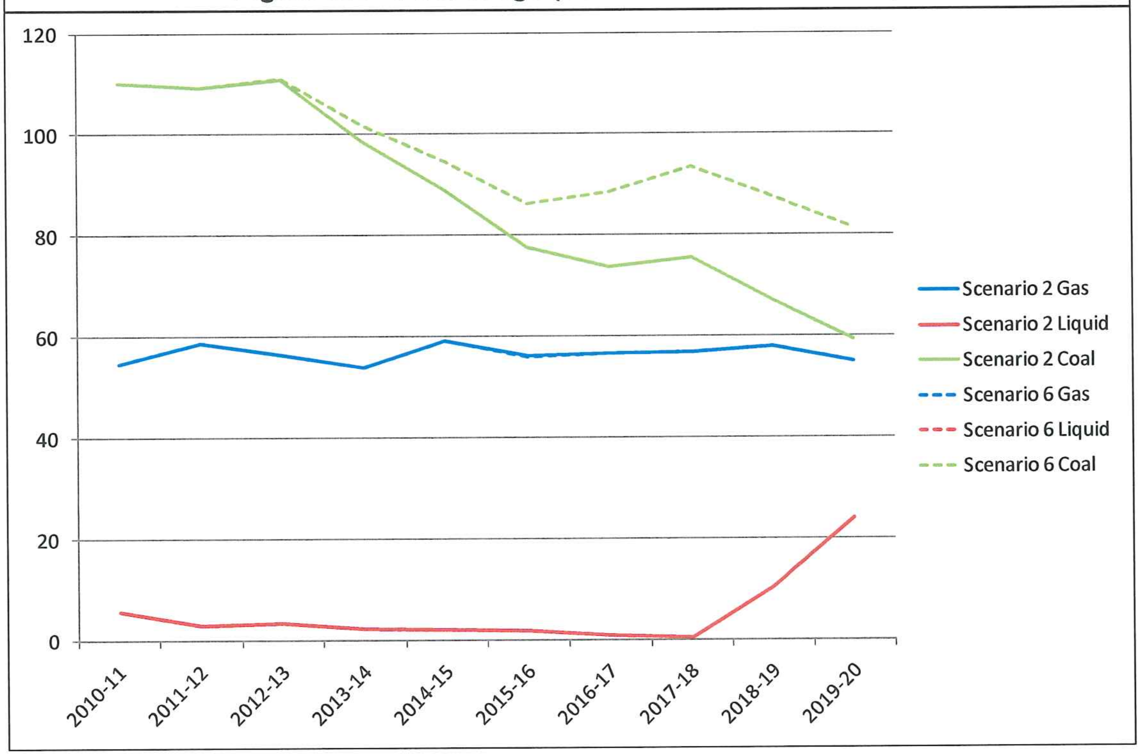


Figure 3.3 – Fuel usage (Scenario 4 vs Scenario 5)