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Addendum to Roadmap to QRET Report 2020: ISP Central Scenario at 2040 Queensland only

Dr Lynette Molyneaux
Centre for Policy Futures
University of Queensland

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1. Introduction

Advance Queensland Roadmap to QRET Report 2020 concluded that a managed transition plan was required for Queensland to achieve its Renewable Energy Target (QRET) of 50% by 2030. The requirement for a managed transition plan was a consequence of:

- the challenges associated with a transmission network that was designed for large centralised coal-fired generation requiring adaptation to supply from many small decentralised variable renewable energy (VRE) plants remote from load centres and robust network infrastructure
- investment plans for VRE that will result in high levels of curtailment, should be assessed to avoid over-supply from VRE in locations that will never have the transmission infrastructure to deliver energy generated to demand centres
- the requirement for storage of some form or another to store VRE when generated at periods when surplus energy exists for dispatch at periods when a deficit of energy exists
- the requirement to close coal units to avoid excess supply which results in high levels of curtailment of VRE

Modelling undertaken to consider outcomes of various levels of investment in VRE indicated that high levels of coal generation closure, to avoid excess supply for the majority of the year, results in energy deficits.

This addendum provides further detail of modelling outcomes for the nodal supply demand balance across the rest of the National Electricity Market (NEM). The scenarios that showed evidence of the highest levels of renewable energy within the system in Queensland in 2030, were Pipeline Scenario B and ISP Central Scenario for the year 2040. This addendum will provide details for ISP Central Scenario at 2040 only, **including** new Pump Hydro at Mt Byron and Urannah. For analysis and detail on the assumptions and modelling undertaken refer to Roadmap to Queensland Renewable Energy Target 2020 and ANEM NEM Nodal Modelling Report Final 2020.

2. QUEENSLAND: Nodal Supply-Demand Balance for Summer Weekdays

a) ISP Central Scenario at 2040 (2040C)

i. QLD Underlying assumptions

- N transmission network
- Direction of Flow loss method estimation
- Generation capacity at 2040 with ISP Central scenario demand assumptions
- Coal power will decline to 3136MW in QLD from 8059MW currently (NSW 1400MW from 10210MW; VIC 0 from 4775MW)
- Coal unit closures:
    - QLD: Units 1-2 Callide B; Units 1-6 Gladstone; Units 1-4 & N Tarong;
    - NSW: Units 1-4 Liddell; Units 1-4 Eraring; Units 5-6 Vales Point; Units 1-4 Bayswater
    - VIC: Units 1-4 Yallourn; Units 1-4 Loy Yang A; Units 1-2 Loy Yang B
- Gas power will decline to 2487MW in QLD from 3076MW currently with closure of Swanbank E (NSW 3048MW from 2155MW)
- Wind power will reach 5652MW in QLD (NSW 5450MW; VIC 8470MW; SA 3,652MW; TAS 2302MW)
- Solar power will reach 7242MW in QLD (NSW 11384MW; VIC 2141MW; SA 4213MW)
- Pump hydro (PHES) in 2030 includes notional Mt Byron (1020MW) and Urannah (1020MW) to reach 2860MW in QLD (NSW 3180MW; SA 610MW)
- Table 1 summarises generation capacity assumptions for QLD
- Transmission augmentation assumed for:
    - QNI to 5436MW
    - corridor from Armidale to Newcastle and Sydney to accommodate 5+GW of energy flows
    - Energy Connect from NSW to VIC and SA
    - Kerang-Link in Victoria
    - Battery of the Nation augmentation VIC to TAS

ii. QLD ANEM nodal structure for 2040C

Figure 1 provides a graphic representation of the generation capacity at each node and transmission corridors between each node in Queensland, for the ANEM model to balance supply and demand for each of 17520 periods in the given year.

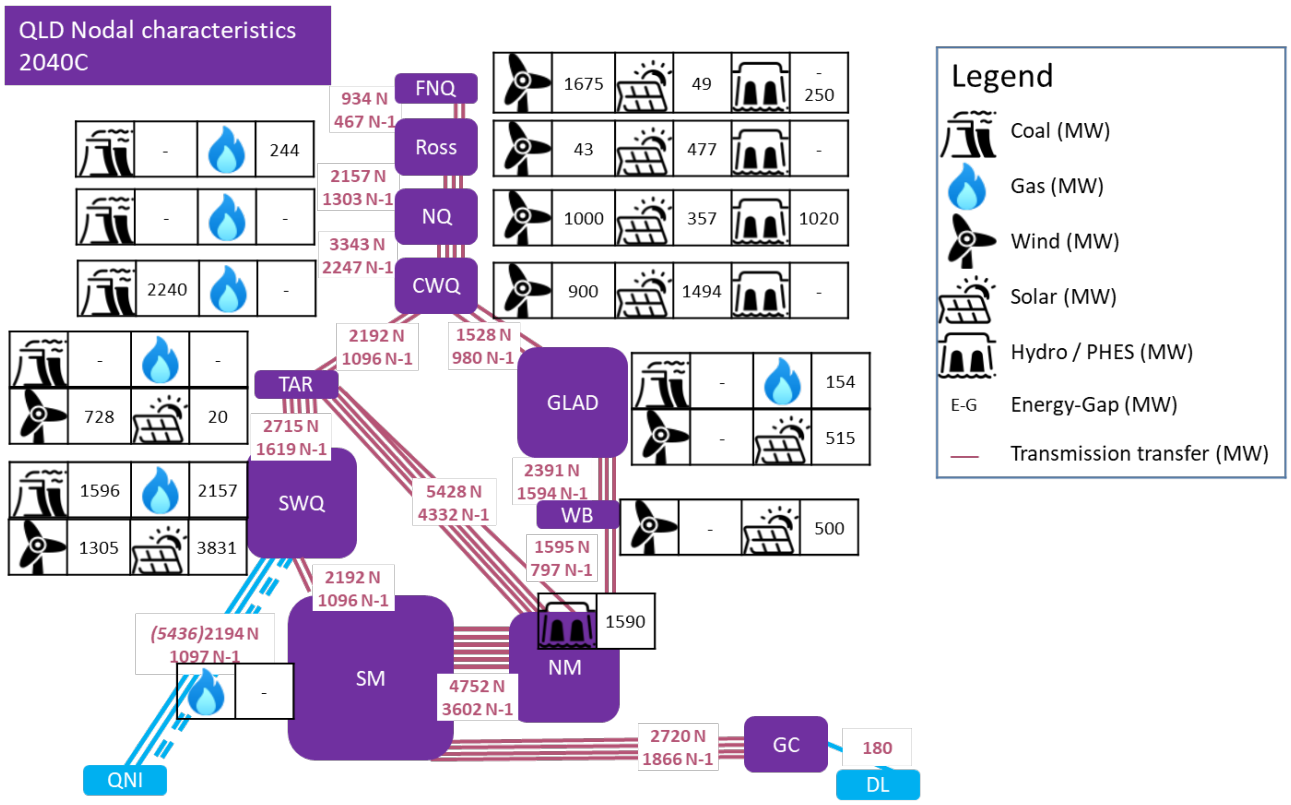

Figure 1: QLD ANEM nodal structure for 2040C

iii. QLD ANEM transmission corridors for 2040C

Table 1 provides a summary of the ANEM network transmission corridors used to determine intra-regional and inter-state trade (by reactance and thermal ratings) for co-optimisation of Optimal Power Flow (OPF) and competitive dispatch of identified generation.[1]

Table 1: QLD ANEM transmission corridors for 2040C

Nodes		N[2] (MW)	N-1[3] (MW)
FNQ – ROSS	Chalumbin – Ross	934	467
ROSS – NQ	Ross – Strathmore	2157	1303
NQ – CWQ	Nebo – Bouldercombe Nebo - Broadsound	3343	2247
CWQ - GLAD	Bouldercombe – Glad Larcom Creek – Glad Wurdong – Calvale	1528	980
GLAD - WB	Gladstone – Gin Gin Wurdong – Gin Gin	2391	1594
CWQ - TAR	Calvale – Tarong	2192	1096
WB - NM	Woolooga – South Pine Woolooga – Palmwoods	1595	797
TAR – NM	Tarong – South Pine Tarong – Mt England Tarong - Blackwall	5428	4332
TAR - SWQ	Tarong - Middle Ridge Tarong – Braemar Tarong – Western Downs	2715	1619
NM – SM	Mt England – Abermain South Pine – Rocklea Blackwall – Swanbank Blackwall – Belmont Blackwall – Greenbank	4752	3602
SWQ - SM	Greenbank– Middle Ridge	2192	1096
SM - GC	Greenbank – Molendinar Greenbank - Mudgeeraba	2720	1866
SWQ-ARM	***(QNI Major)*** Dumesq – Bulli	***(5436)*** 2194	***(5436)*** 1097
GC - LIS	DirectLink: Lismore – Mullumbimby	180	180

[1] See ANEM NEM Nodal Modelling Report Final 2020 for further detail.
[2] Assumes no line outages occur, and that the transmission lines are always operational - providing an ideal setting for dispatch
[3] Assumes the subtracting of the largest individual line from the group of transmission lines connecting nodes -matches transmission planning frameworks and how AEMO manages the grid in practice

iv. QLD ANEM generation capacity assumptions for 2040C

Table 2: Queensland capacity assumptions under 2040C

Queensland Capacity	Current [4] (MW)	2030 (MW)	Notes
Coal	8,059	3,136	Closures: Callide B 700MW, Gladstone 1-6 1680MW, Tarong 1-4 &N 1843MW Capacity factor: 81% (full year); 86% (SummWD)
Gas	3,076	2,487	Closures: Swanbank E 385MW Capacity factor: 52% (full year); 50% (SummWD)
Hydro	148	60	Closures: Kareeya 88MW Capacity factor: 22% (full year); 15% (SummWD)
Solar	1,784	7,242	Capacity factor: 29% (full year); 32% (SummWD) Curtailment SummWD 10%, Max 4652MW
Wind	641	5,652	Capacity factor: 39% (full year); 44% (SummWD) Curtailment SummWD: 5%, Max 2092MW
PHES	570	2,860	Capacity factor: 19% (full year); 15% (SummWD)
Storage/Other	-	13,078 (full year) 5908 (SummWD)	Capacity factor; 12% (full year); 12% (SummWD) Incidences: EPeak 600 (100%); ONight 1080 (100%); Daylight 1200 (100%)
TOTAL	14,242	34,515	

[4] Source: AEMO Generation Information July 2020

v. QLD modelling outcomes for Summer Weekdays (SummWD)

1. QLD Fuel share of electricity generated

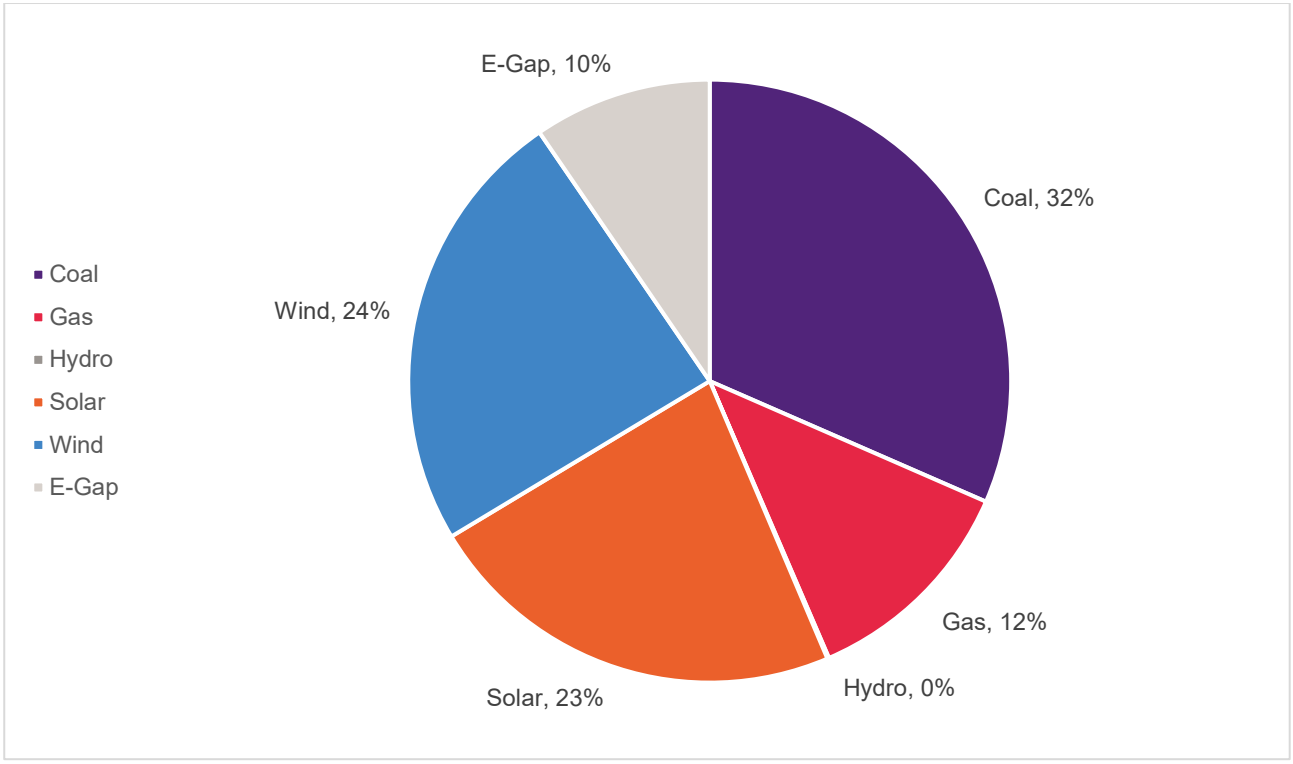

Figure 2: QLD Fuel share during summer weekdays under 2040C

Modelling outcomes predict that 32% of electricity generated in QLD is sourced from coal, 23% from solar, 24% from wind, 12% from gas and 0% from hydro as shown in Figure 2. Under these assumptions it is possible to achieve QRET for QLD energy supplied to the NEM. However, the Energy-Gap (E-G)[5] that emerges is sizeable, at 1419GWh or 9% of energy generated, 192GWh of which occurs during the evening peak, 810GWh overnight and 416GWh during daylight.

[5] The dispatch of last resort generation (that is generation additional to identified supply) for the model to solve the co-optimisation of optimal power flow and competitive dispatch

2. QLD Energy Flows (SummWD)

Figure 3 provides detail on the flow of energy through QLD nodes by time-of-day period by type of supply and demand for all of QLD. Of note:

- the steel grey coloured series indicates QLD demand, an average of 7,311MW
- the navy coloured series indicates exports to NSW which are small and occur throughout the day
- the light grey coloured series indicates coal generation within QLD which declines during sunlight hours
- the green and yellow coloured series indicate solar and wind generation
- the cyan coloured series indicate pump hydro (PHES) dispatch when positive and pumping load when negative
- the purple coloured series indicates Energy-Gap (E-G)

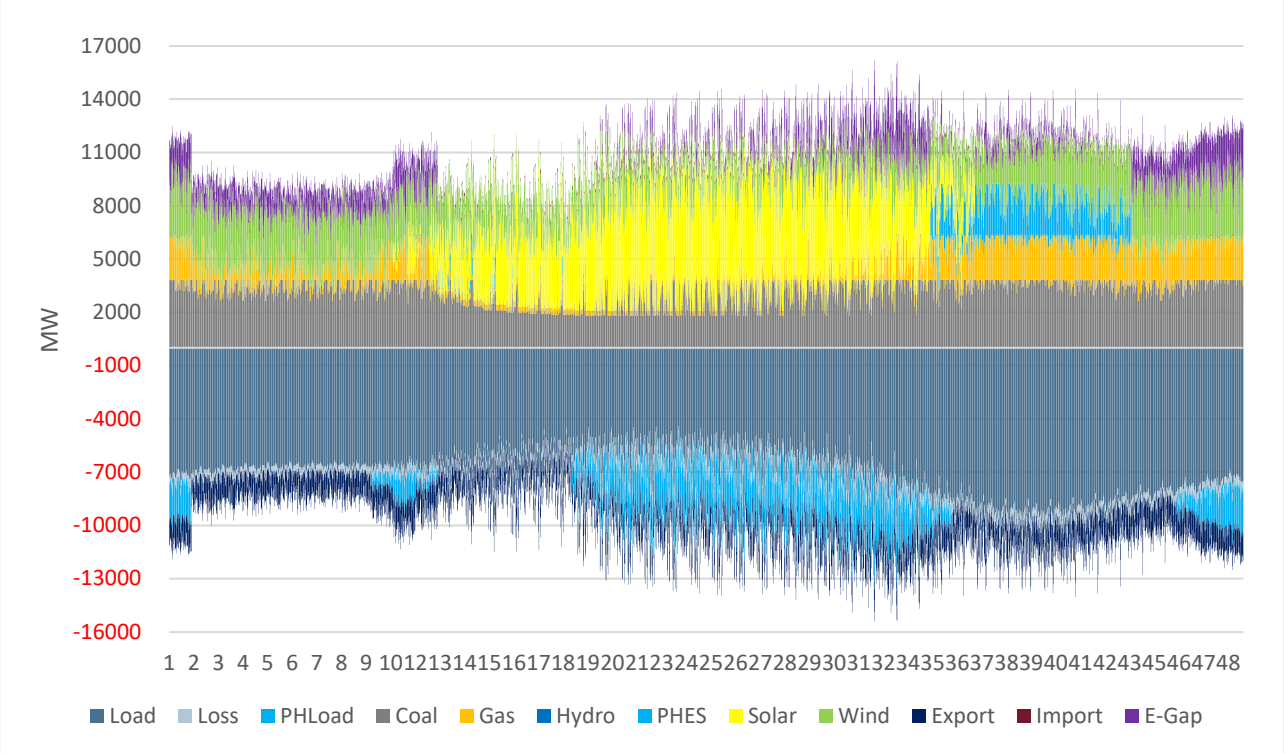

Figure 3: QLD energy flows for SummWD under 2040C

Table 3 provides totals and averages of SummWD energy flows. Coal generation across the state, with the removal of 4.2GW of capacity, achieves 85% capacity factor. Gas generation capacity factor reaches 50%. With 10% curtailment of solar energy from potential dispatch, solar generation achieves a capacity factor of 32%. Curtailment of wind energy from potential dispatch is lower than solar at 4%, ensuring that wind generation state-wide achieves 35% capacity factor. E-G is persistent throughout today, and occasionally highly elevated to a maximum of 5208MW. QLD exports to NSW (2168GWh) with very low levels of imports from NSW to QLD (147GWh), which suggests the important role that imports from QLD play in supporting energy flows to Newcastle when Liddell, Eraring and Bayswater close.

Table 3: QLD Salient statistics under 2040C

NSW Energy Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(10,528)	(8,989)	(7,311)	(11,192)	65%	(7,035)
PH_Load	(1,570)	(564)	(1,090)	(2,760)	40%	(290)
Coal	4,683	3,651	3,252	3,836	85%	3,534
Gas	1,778	2,144	1,235	2,504	49%	995
Hydro	13	26	9	102	9%	0
PH_Disp	635	1,801	441	2,860	15%	0
Solar	3,379	1,189	2,347	7,096	33%	1,448
Wind	3,572	2,457	2,481	5,303	47%	2,543
E-G	1,419	891	985	5,208	19%	744
Exports	(2,168)	(1,666)	(1,506)	(2,808)	54%	(1,487)
Imports	147	113	102	180	57%	148
Solar_spill	357	4	248	4,652	5%	0
Wind_spill	155	20	108	2,092	5%	2
PH_Spill	737	487	512	2,860	18%	0
Solar spill %	10%	0%	10%	40%		0
Wind spill %	4%	1%	4%	28%		0

3. QLD Generation adqequacy

The maximum for coincident E-G is 5.2GW, although the median E-G is 746MW, and a capacity factor of 19%, indicating some persistence. Pumping for PHES elevates the E-G. This is prevalent when PHES pumping occurs overnight when solar resource is non-existent and wind resource is low. In the analysis conducted here, PH dispatch outside of morning and evening peak, is classified as E-G and PH dispatch that fails to occur during morning and evening peak is detailed in Table 3 as PH spill. While the PHES pumping and dispatch present a modelling challenge, this highlights the reality that storage introduces significant additional load which can exacerbate the E-G. Other than PH pumping and dispatch, the periods of elevated E-G are associated with varying combinations of significantly elevated demand, significantly depressed wind energy and lower levels of imports from QLD. Table 4 provides coincident detail of E-G. Figure 4 details the flow of energy required for pumping and the E-Gs across all QLD nodes by time-of-day period by type of supply and demand.

Table 4: Count of QLD co-incident Energy-Gap under 2040C

Energy-Gap	Periods	>5000	>4000	>3000	>2000	>1000	>500	>0	=0
Total		1	8	74	358	803	534	342	760
% of periods		0%	0.3%	3%	12%	28%	19%	12%	26%
Overnight	43-48, 0-12	-	1	32	217	499	275	23	33
Evening Peak	34-42	-	2	9	25	101	146	151	106
Daylight	20-29	1	5	33	116	203	113	168	621

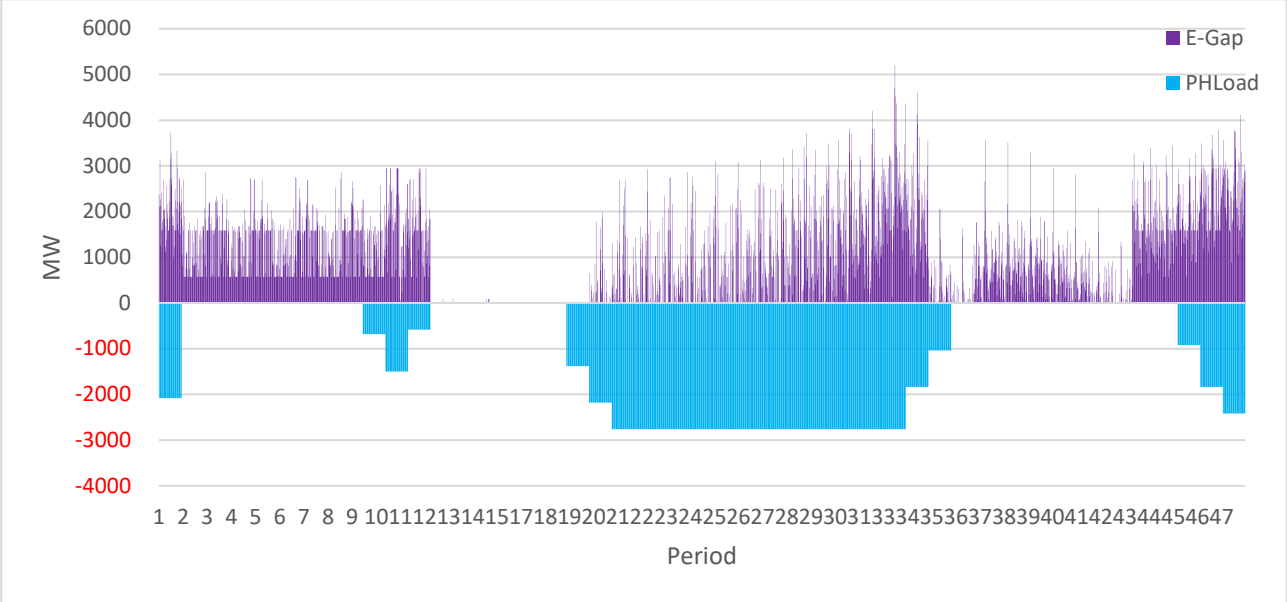

Figure 4: QLD Coincident Energy Gap under 2040C

4. QLD Variable Renewable Energy (VRE) Resource

Solar achieves 32% capacity factor because of 10% curtailment from potential resource due to excess wind and coal generation available during the day as detailed in Figure 5 below. Wind provides a less predictable resource as detailed in Figure 6 below. The QLD coincident wind resource figure below shows a concerning trend to lower wind in evidence overnight which impacts on PH pumping activities overnight and the ability to meet overnight demand, resulting in E-G's overnight.

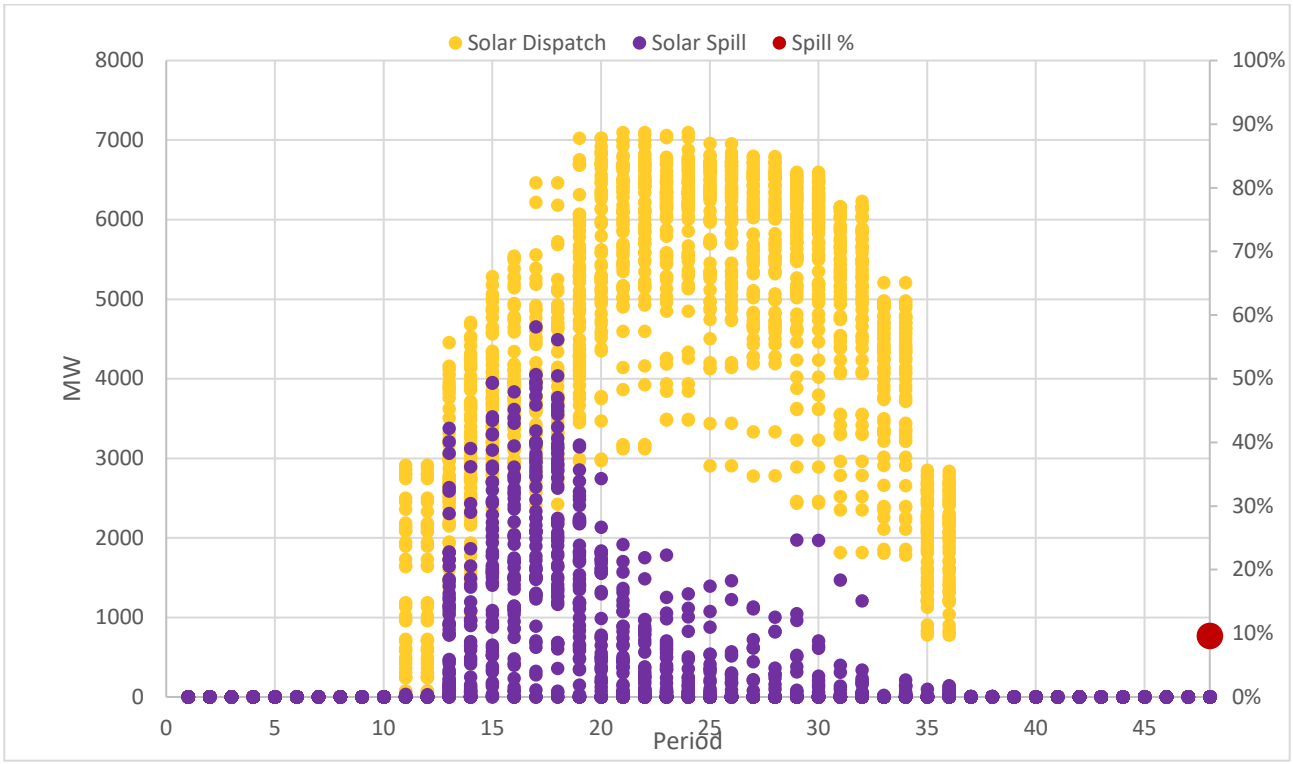

Figure 5: QLD Coincident solar dispatch and curtailment under 2040C

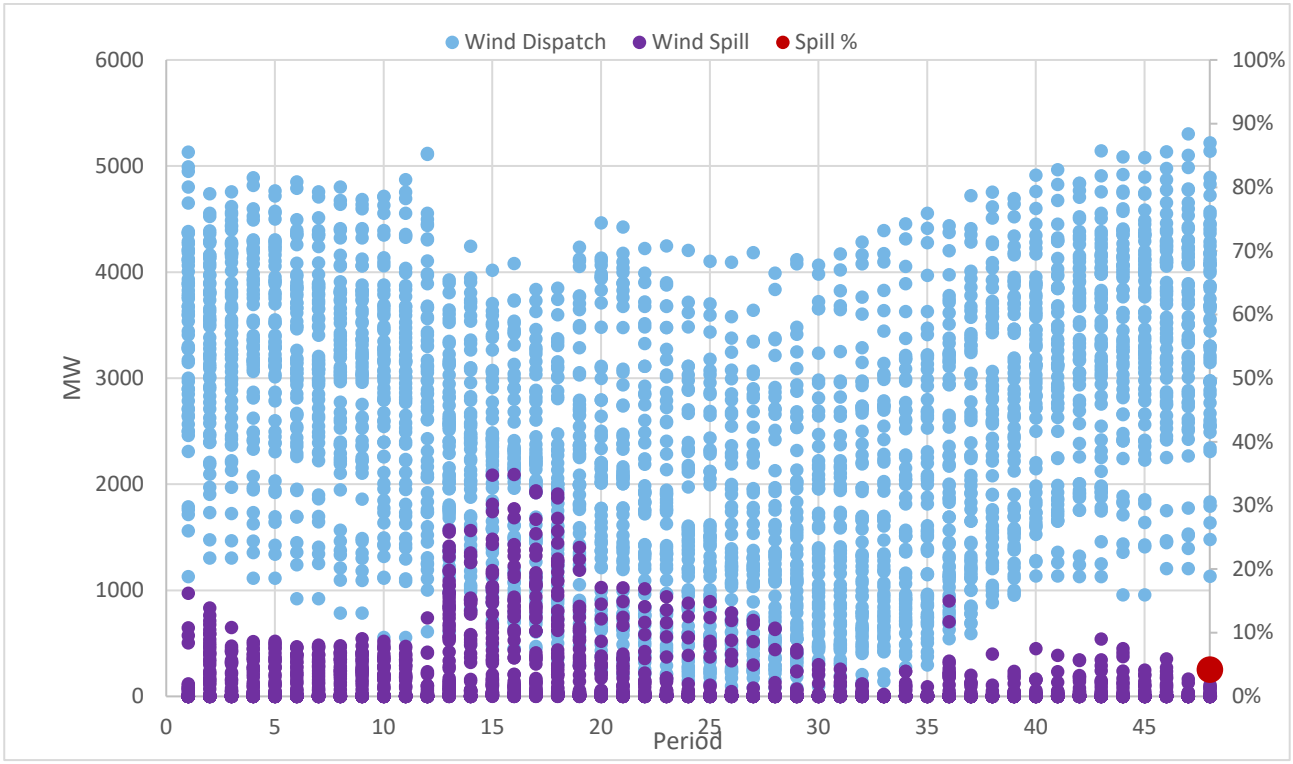

Figure 6: QLD Coincident wind dispatch and curtailment under 2040C

5. QLD exports/imports to NSW

There are no imports to QLD from NSW. Energy flows from QLD to NSW at an average of 1506MW and a maximum of 2.8GW. Figure 7 gives detail.

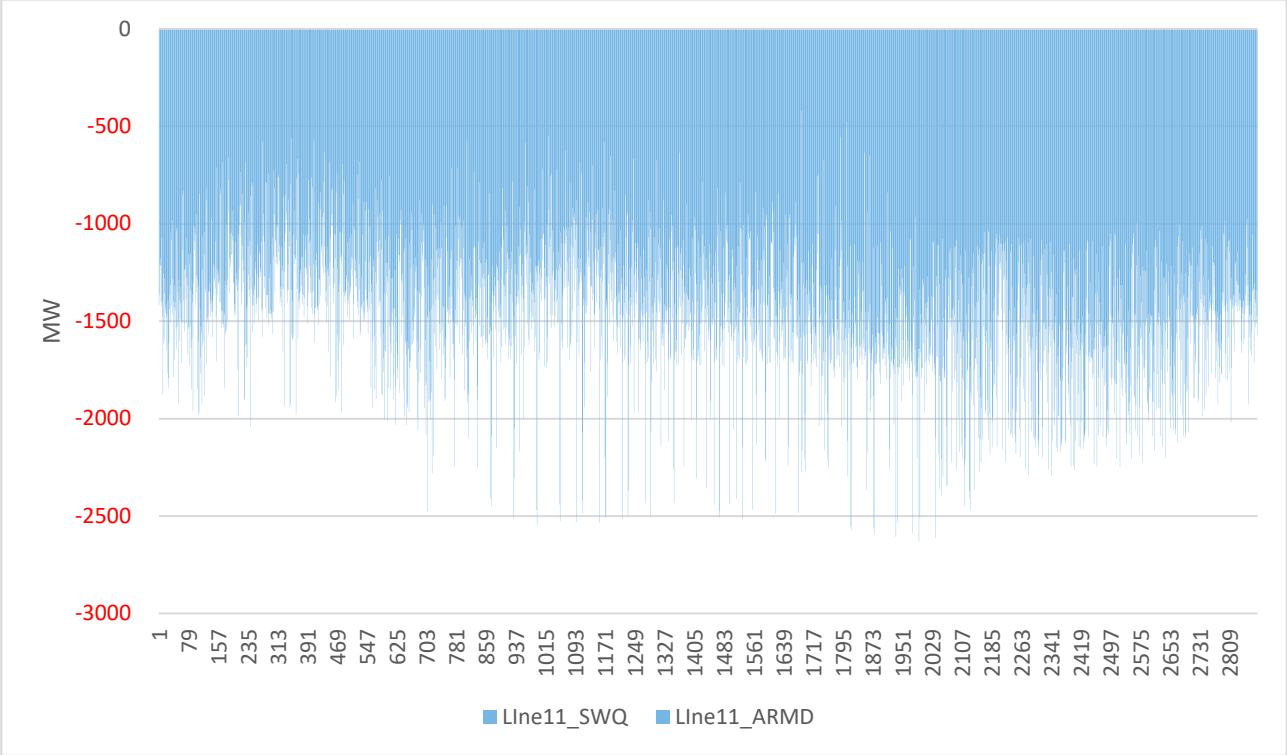

Figure 7: Energy flows to and from NSW on QNI for SummWD under 2040C

6. FNQ details for summer weekdays

Assumptions for Far North Queensland (FNQ) generation capacity are detailed in Table 5.

Table 5: Far North Queensland capacity assumptions under 2040C

FNQ Capacity	Current [6] (MW)	2030 (MW)	Notes
Hydro	148	60	Capacity factor (CF): 15%
Wind	192	1675	CF AllYear 40%, CF SummWD 35% Curtail SummWD 1%, Max curtail 153MW
Solar	50	49	CF AllYear 29%, CF SummWD 30% Curtail SummWD 1%, Max curtail 59MW
PHES	-	250	CF AllYear 19%, CF SummWD 17%
Storage/E-G		296	CF AllYear 19%, CF SummWD 17%
TOTAL	390	2330	

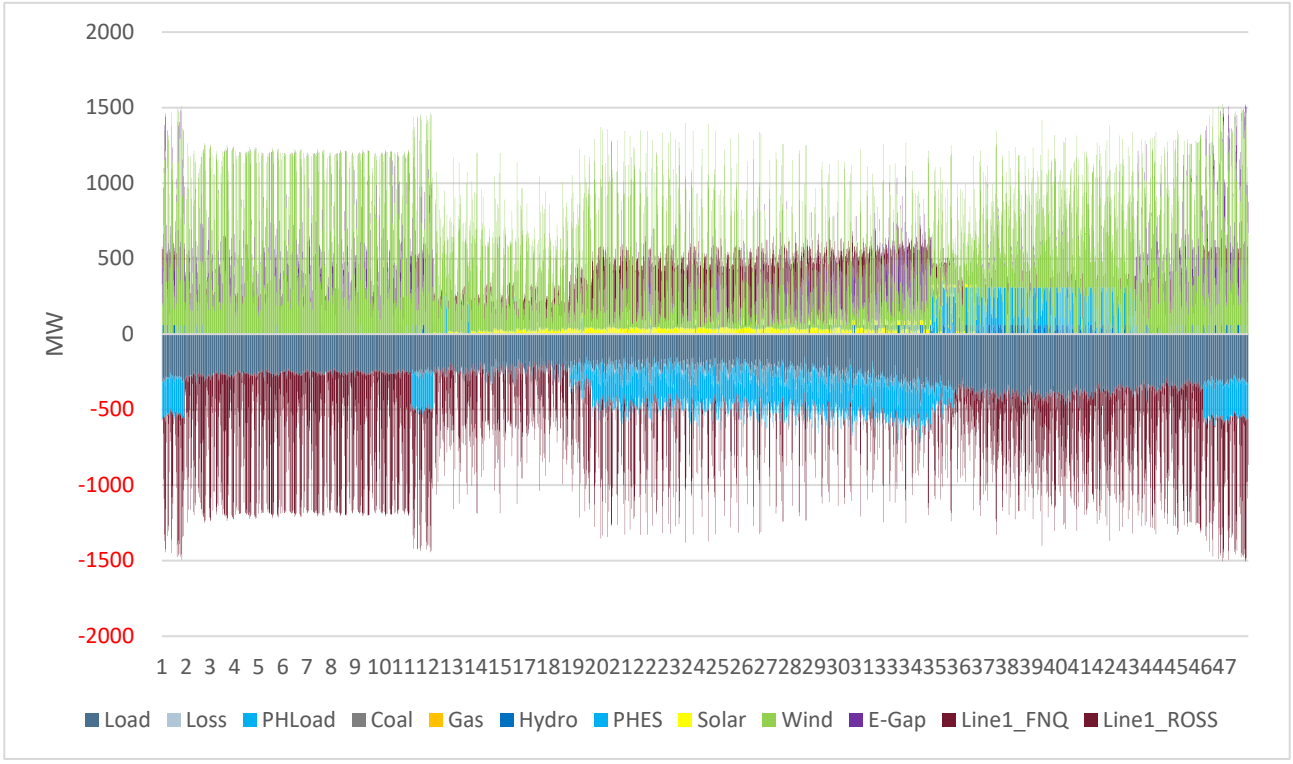

Figure 8: Far North Queensland energy flows for SummWD under 2040C

Figure 8 provides detail on the flow of energy through FNQ node by time-of-day period by type of supply and demand for FNQ. Of note:

[6] Source: AEMO Generation Information July 2020

- the steel grey coloured series indicates FNQ demand, an average of 291MW
- the maroon coloured series indicates imports-exports from and to Ross node. FNQ tends to export overnight and during morning and evening peaks, and tends to import during daylight to sustain PHES pumping
- the green and yellow coloured series indicate solar and wind generation which should provide adequate energy for PH pump load. However inadequate available supply overnight leads to sustained E-Gs. Solar reaches a capacity factor of 30% over SummWDs. Wind reaches a capacity factor of 35%.
- 8% of potential dispatch from solar is curtailed in FNQ node, as shown in Figure 10
- 12% of potential dispatch from wind is curtailed in FNQ node, as shown in Figure 11
- the purple coloured series indicates E-G. E-G occurs sporadically, as is shown in Figure 9. E-G maximises at 269MW with an average of 51MW, and a capacity factor of 19%
- Table 6 provides the salient statistics on FNQ energy flows

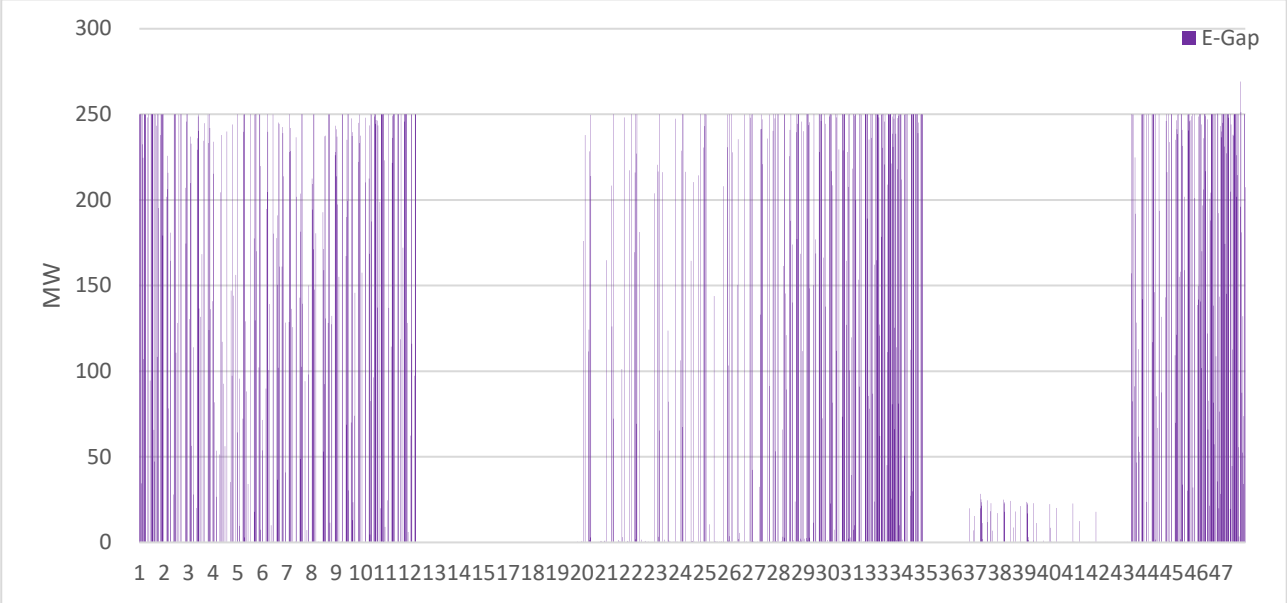

Figure 9: Far North Queensland Energy Gap during SummWD in 2040C

This clustering of E-G overnight from 10pm to 6am is evidence of a lack of wind resource to meet demand both for consumption and for pumping. There is also evidence of insufficient generation to meet demand during daylight especially pre-evening peak during periods 30-35 when the ANEM model is set to pump but solar resource is reducing and native demand is increasing. This is evident in Figure 10 where solar generation falls sharply from period 33 and Figure 11 where wind generation does not show evidence of consistent generation as solar resource declines in FNQ.

Apart from the above-mentioned persistent E-G's, there is evidence of small E-G during evening peak.

Table 6: Far North Queensland salient statistics under 2040C

FNQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(419)	(380)	(291)	(502)	58%	(276)
PH Load	(144)	(60)	(100)	(240)	42%	0
Hydro	13	26	9	102	9%	0
PHES	42	126	29	250	12%	0
Solar	21	8	14	49	30%	0
Wind	847	523	588	1,520	39%[7] *(35%)*[8]	500
E-G	73	30	51	269	19%	0
Exports (node)	(493)	(292)	(343)	(934)	37%	(281)
Imports (node)	73	26	51	519	10%	0
Solar_spill	2	0	1	22	5%	0
Wind_spill	112	8	78	1,523	5%	0
PH_spill	78	74	54	250	22%	0
Solar spill %	8%	4%	8%	31%		
Wind spill %	12%	2%	12%	50%		

[7] Capacity factor based on maximum dispatch during SummWD
[8] Capacity factor based on nameplate capacity

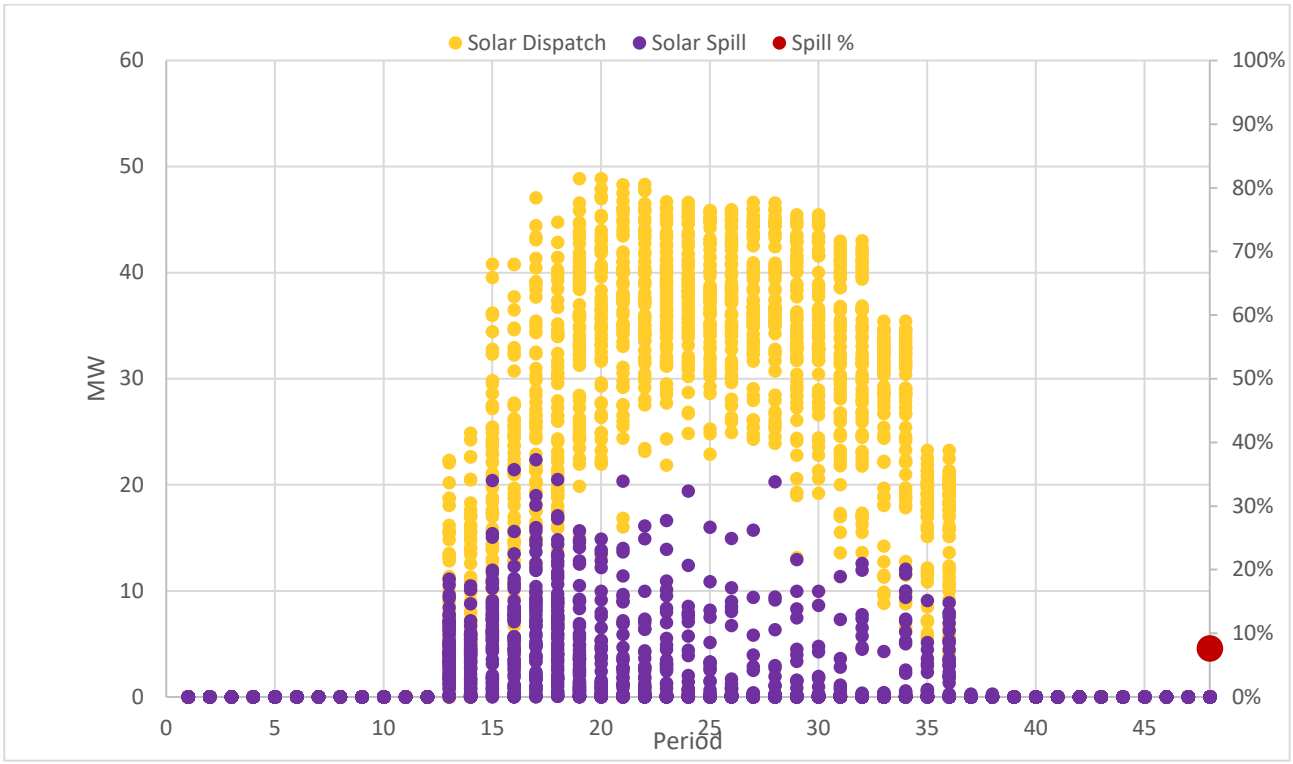

Figure 10: Far North Queensland solar dispatch and curtailment under 2040C

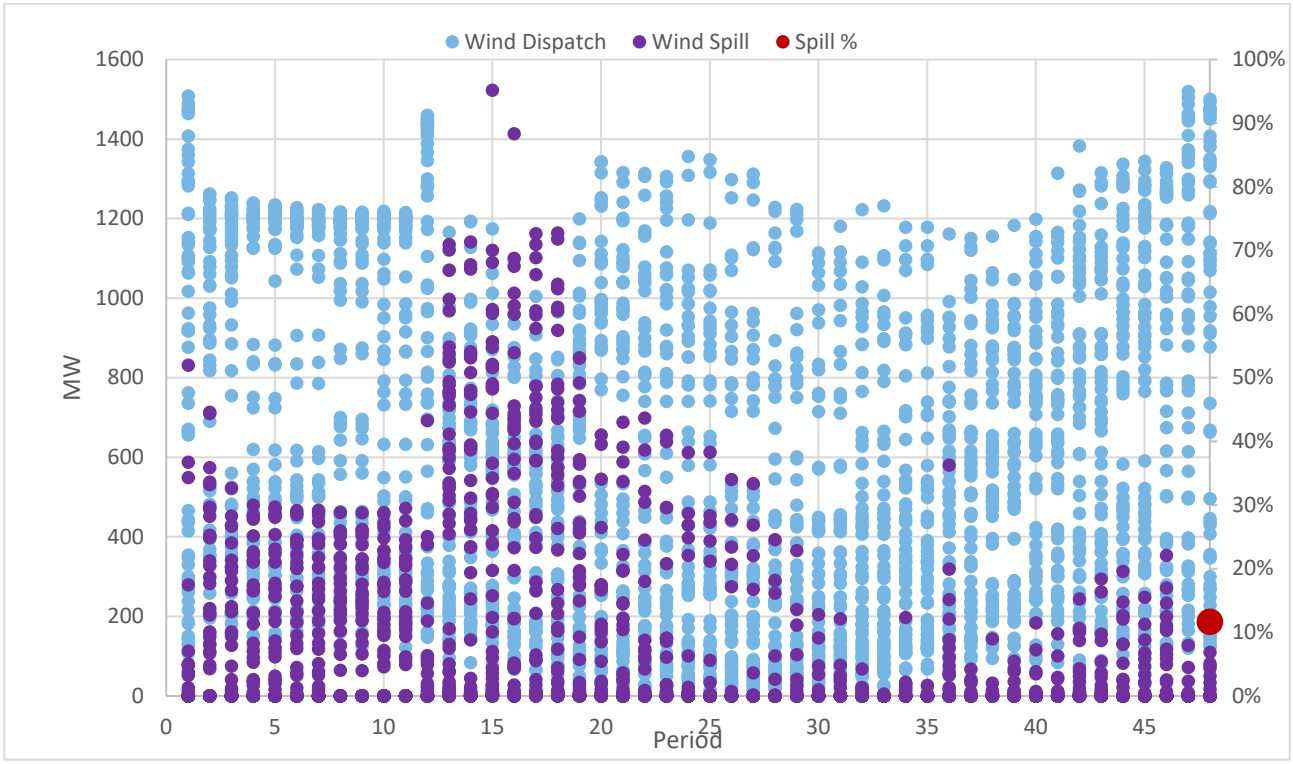

Figure 11: Far North Queensland wind dispatch and curtailment under 2040C

7. ROSS details for summer weekdays

Table 7 provides a summary of Ross generation capacity assumptions

Table 7: Ross capacity assumptions under 2040C

ROSS Capacity	Current [9] (MW)	2030 (MW)	Notes
Gas	244	244	CF AllYear 41%; CF SummWD 37%
Wind	-	43	CF AllYear 36%; CF SummWD 31% Curtail SummWD 11%; Max 21MW
Solar	497	477	CF AllYear 31%; CF SummWD 33% Curtail SummWD 2%; Max 312MW
Storage/Other/ E-G	-	272 (Summ) 487 (Year)	CF AllYear 1%; CF SummWD -% SummWD Incidences: EPeak 181 (30%); ONight 72 (7%); Daylight 37 (3%)
TOTAL	741	1251	

[9] Source: AEMO Generation Information July 2020

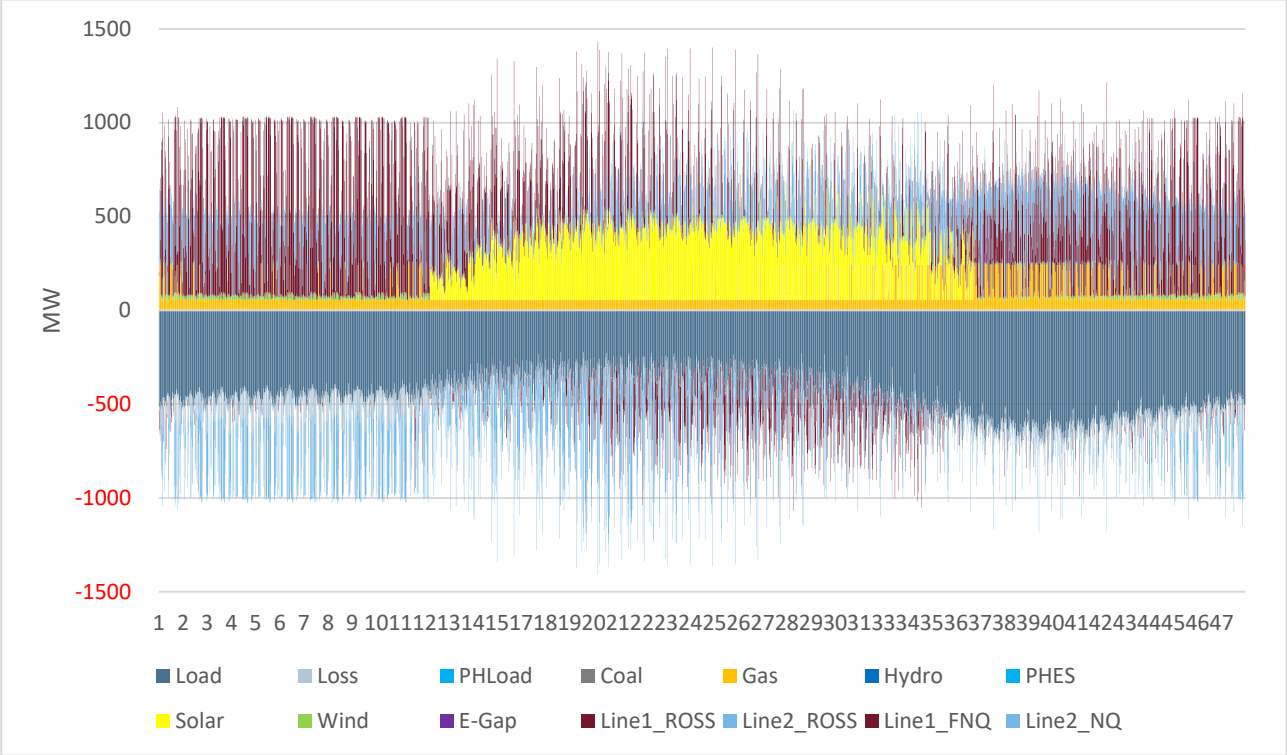

Figure 12: Ross energy flows for SummWD under 2040C

Figure 12 provides detail on the flow of energy through ROSS node by time-of-day period by type of supply and demand for ROSS. Of note:

- the maroon coloured series indicates imports (primarily) from FNQ predominantly during morning and evening peak, and some exports to FNQ
- the light blue coloured series indicates exports-imports to or from North Queensland
- the steel-blue coloured series indicates demand in Ross node which averages 465MW
- the gold coloured series indicates gas generation from 244MW. Gas generation achieves capacity factor of 37%, which is dispatched throughout the day
- the yellow coloured series indicates solar generation from 477MW. Solar generation achieves a capacity factor of 33% with 2% curtailment from potential dispatch. Figure 14 provides detail.
- the green coloured series indicates wind generation from 43MW. Wind generation achieves a capacity factor of 31% indicating a modest wind resource in ROSS. Figure 15 provides detail.
- the purple coloured series indicates Energy-Gap (E-G). There are a handful of large E-G in ROSS during evening peak at 100-250MW. Figure 13 provides detail

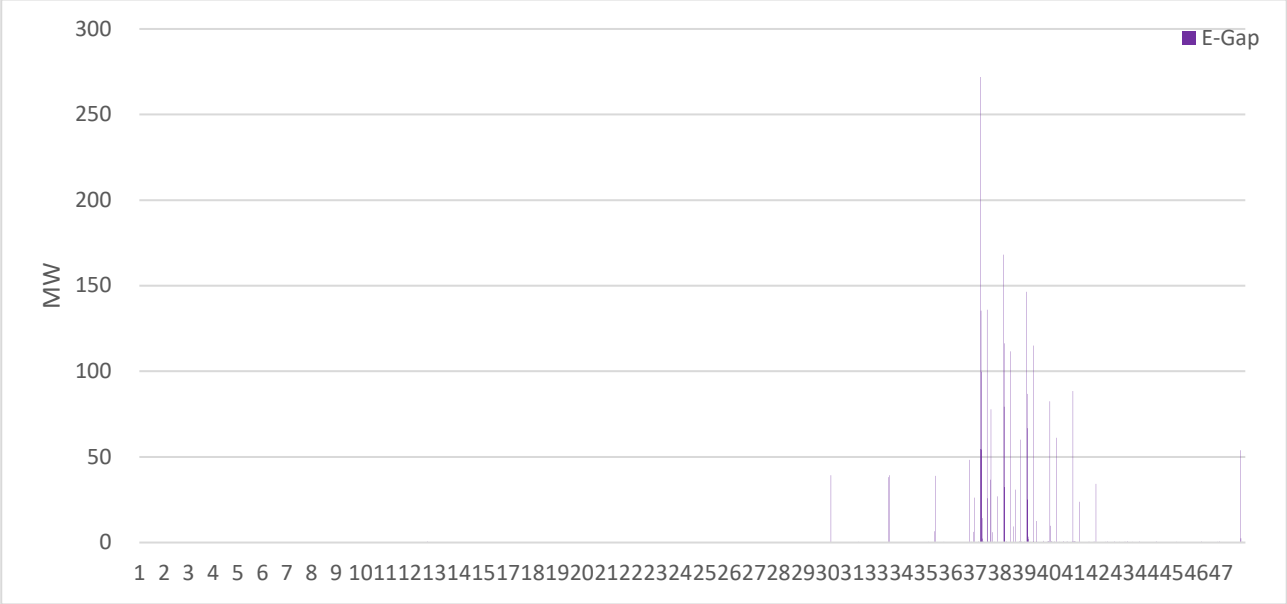

Figure 13: Ross energy gap for SummWD under 2040C

Table 8 details statistics for Ross energy flows

Table 8: ROSS salient statistics under 2040C

ROSS Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(670)	(595)	(465)	(807)	58%	(462)
Gas	130	146	90	242	37%	56
Solar	227	86	158	474	33%	16
Wind	19	11	13	43	31%	11
E-G	1	4	1	272	0%	0
Exports (node)	(289)	(65)	(201)	(996)	20%	(151)
Imports (node)	671	466	466	943	49%	436
Solar_spill	4	1	3	312	1%	0
Wind_spill	2	1	2	21	8%	0
Solar spill %	2%	1%	2%	40%		
Wind spill %	11%	11%	11%	33%		

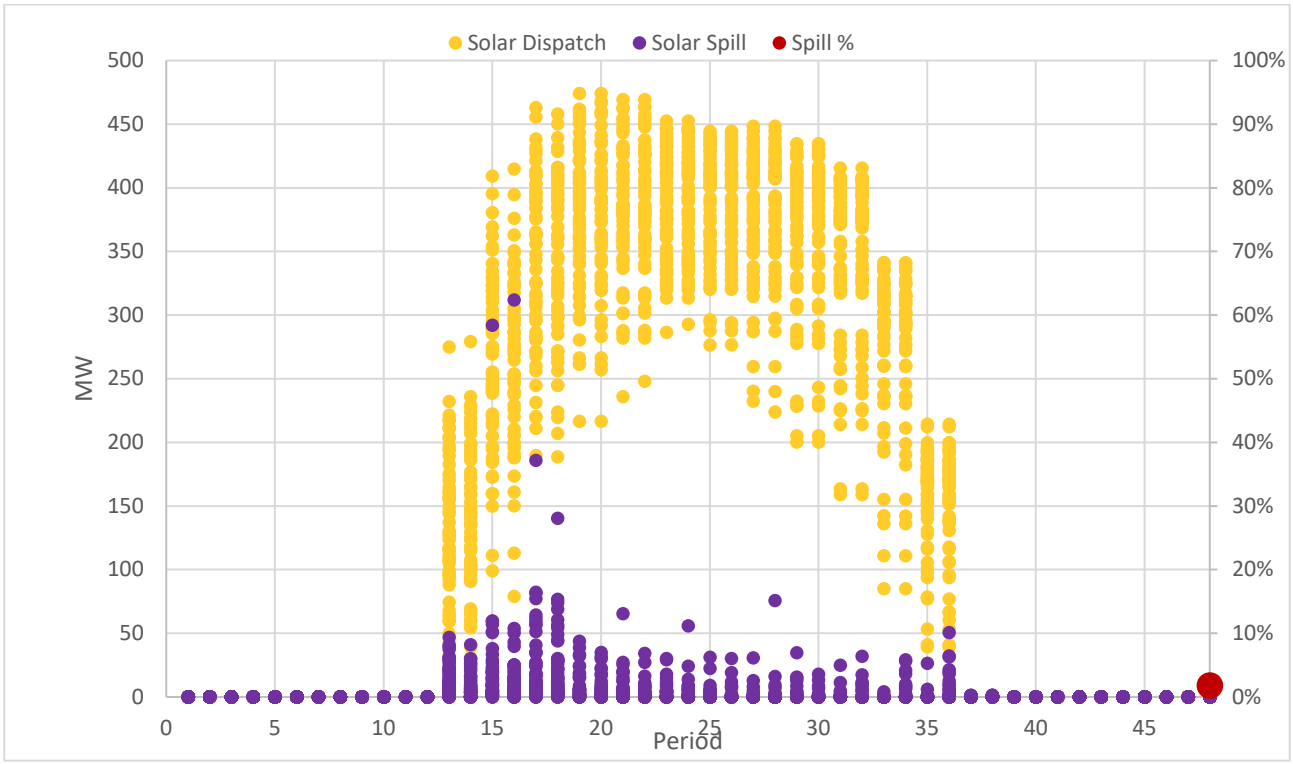

Figure 14: Ross solar dispatch and curtailment under 2040C

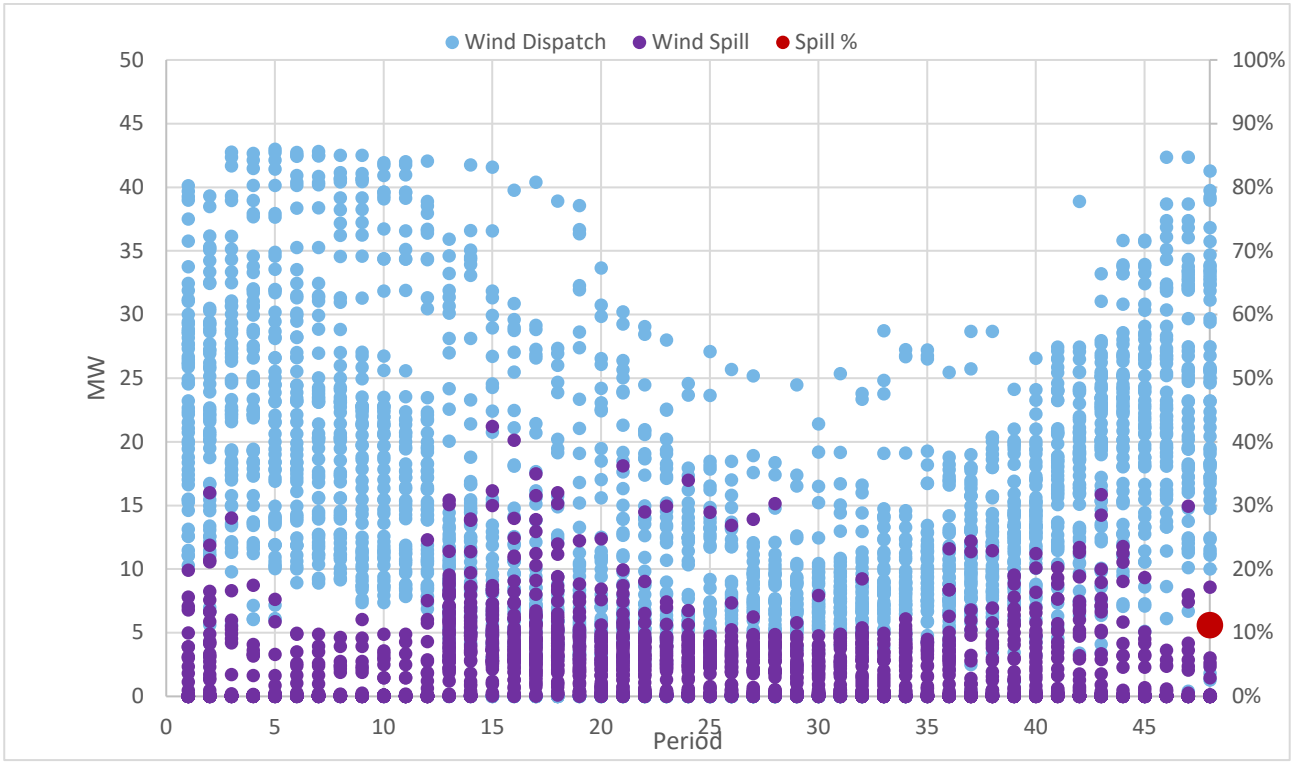

Figure 15: Ross wind dispatch and curtailment under 2040C

8. NORTH QUEENSLAND details for summer weekdays

Table 9 summarises the generating capacity assumptions for North Queensland (NQ)

Table 9: North Queensland capacity assumptions under 2040C

NQ Capacity assumptions	Current [10] (MW)	2030 (MW)	Notes
Wind	-	1000	CF AllYear 36%; CF SummWD 42% Curtail SummWD 3%; Max 527MW
Solar	382	357	CF AllYear 30%; CF SummWD 31% Curtail SummWD 2%; Max 187MW
PHES	-	1020	CF AllYear 15%; CF SummWD 10%
Storage/E-G	-	1147 (Summ) 1248 (Year)	CF AllYear 18%; CF SummWD 13% SummWD Incidences: EPeak 357 (60%); ONight 1025 (95%); Daylight 770 (64%)
TOTAL	382	3625	

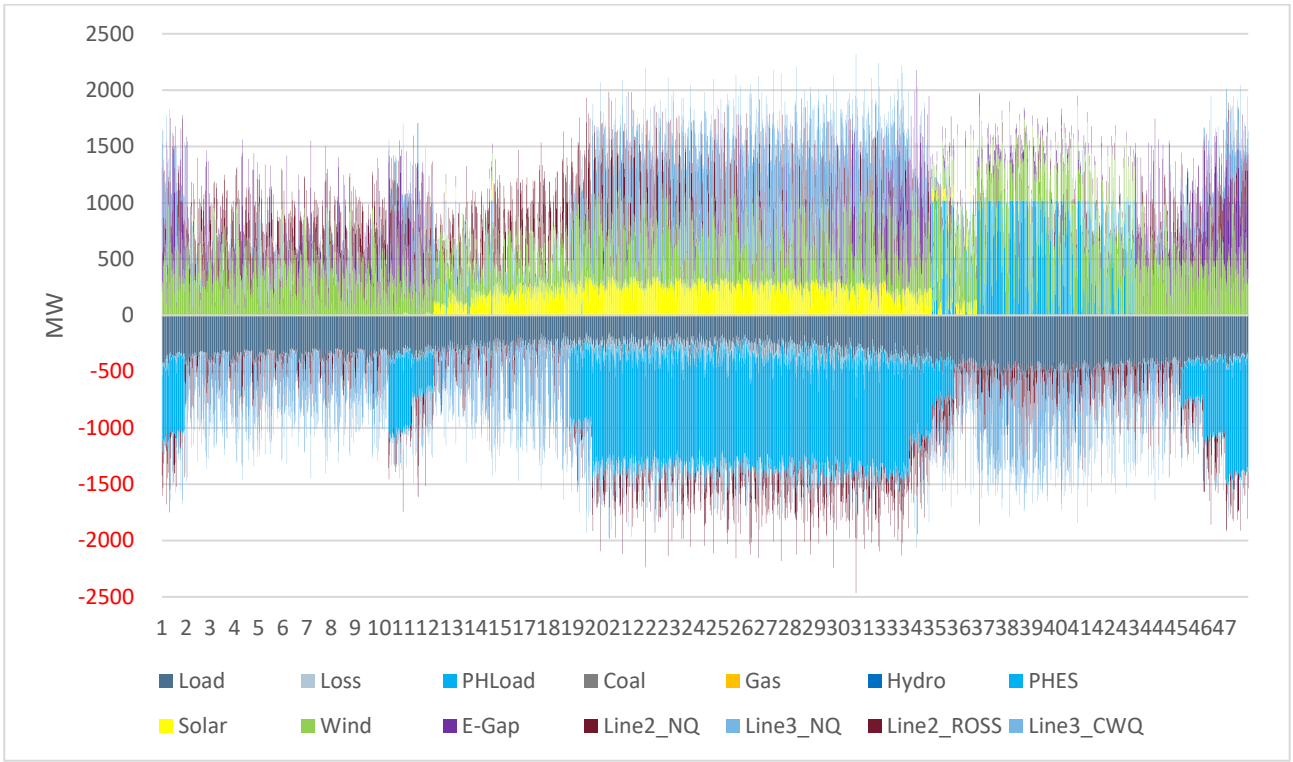

Figure 16: North Queensland energy flows for SummWD under 2040C

[10] Source: AEMO Generation Information July 2020

Figure 16 provides detail on the flow of energy through NQ node by time-of-day period by type of supply and demand for NQ. Of note:

- the maroon coloured series indicates imports from ROSS and occasionally exports to ROSS.
- the light blue coloured series indicates imports from and exports to CWQ, importing primarily during daylight, and exporting overnight and during morning and evening peak.
- the steel-blue coloured series indicates demand in NQ which averages 352MW
- the yellow coloured series indicates solar generation from 357MW. Solar generation achieves a capacity factor of 31% with 2% curtailment from potential dispatch. Figure 18 provides detail.
- the green coloured series indicates wind generation from 1000MW. Wind generation achieves a capacity factor of 42% with modest curtailment (3%) from potential dispatch. Figure 19 provides detail.
- there is a persistent E-G in the NQ node, due to the PH load overnight and during pre-Evening peak (periods 31-33). Figure 17 provides detail.

Figure 17: North Queensland energy-gap for SummWD under 2040C

Table 10 details statistics for NQ energy flows

Table 10: North Queensland salient statistics under 2040C

NQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(507)	(445)	(352)	(573)	61%	(351)
PH Load	(592)	(204)	(411)	(1,020)	40%	0
PHES	146	440	102	1,020	10%	0
Solar	162	57	112	353	32%	23
Wind	606	480	421	1,000	42%	410
E-G	238	129	165	1,147	14%	0
Exports (node)	(518)	(529)	(360)	(1,401)	26%	(303)
Imports (node)	542	135	376	2,251	17%	333
Solar_spill	3	1	2	187	1%	0
Wind_spill	18	6	12	527	2%	0
PH_spill	343	376	238	1,020	23%	0
Solar spill %	2%	1%	2%			
Wind spill %	3%	1%	3%			

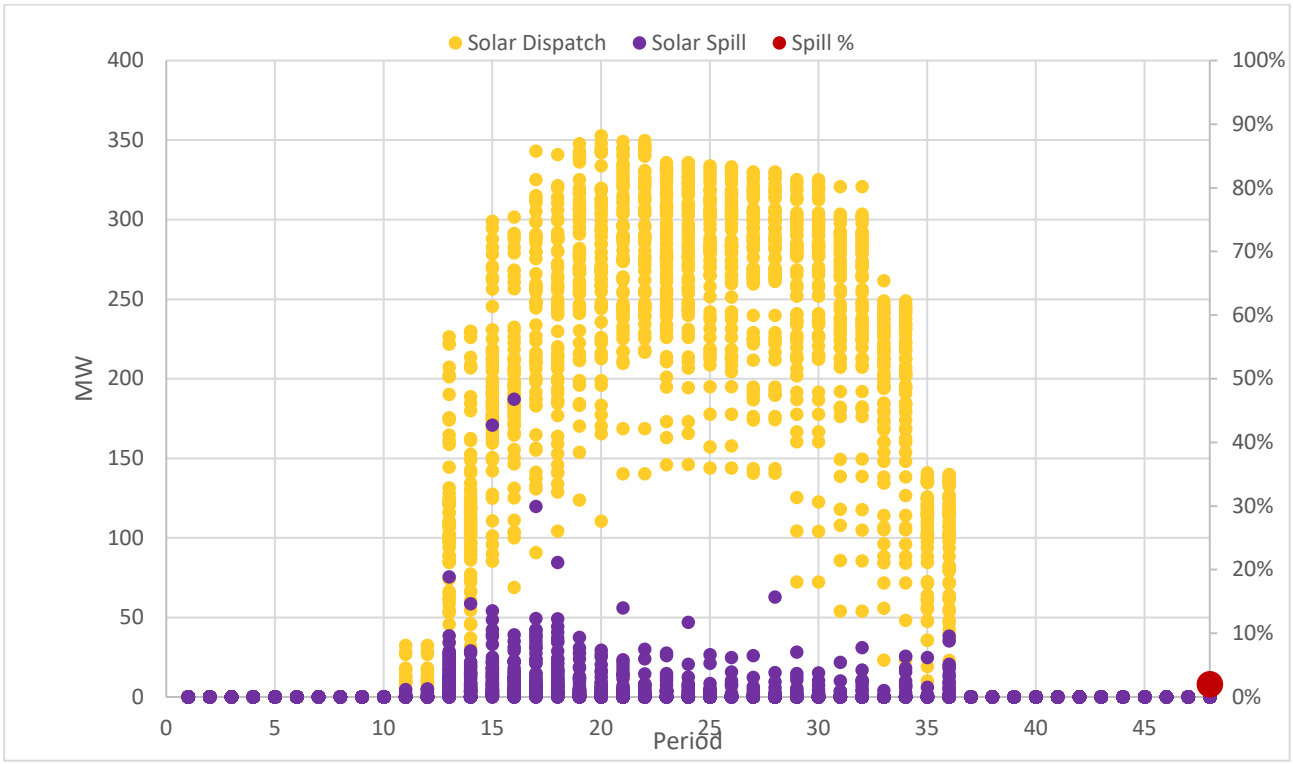

Figure 18: North Queensland solar dispatch and curtailment under 2040C

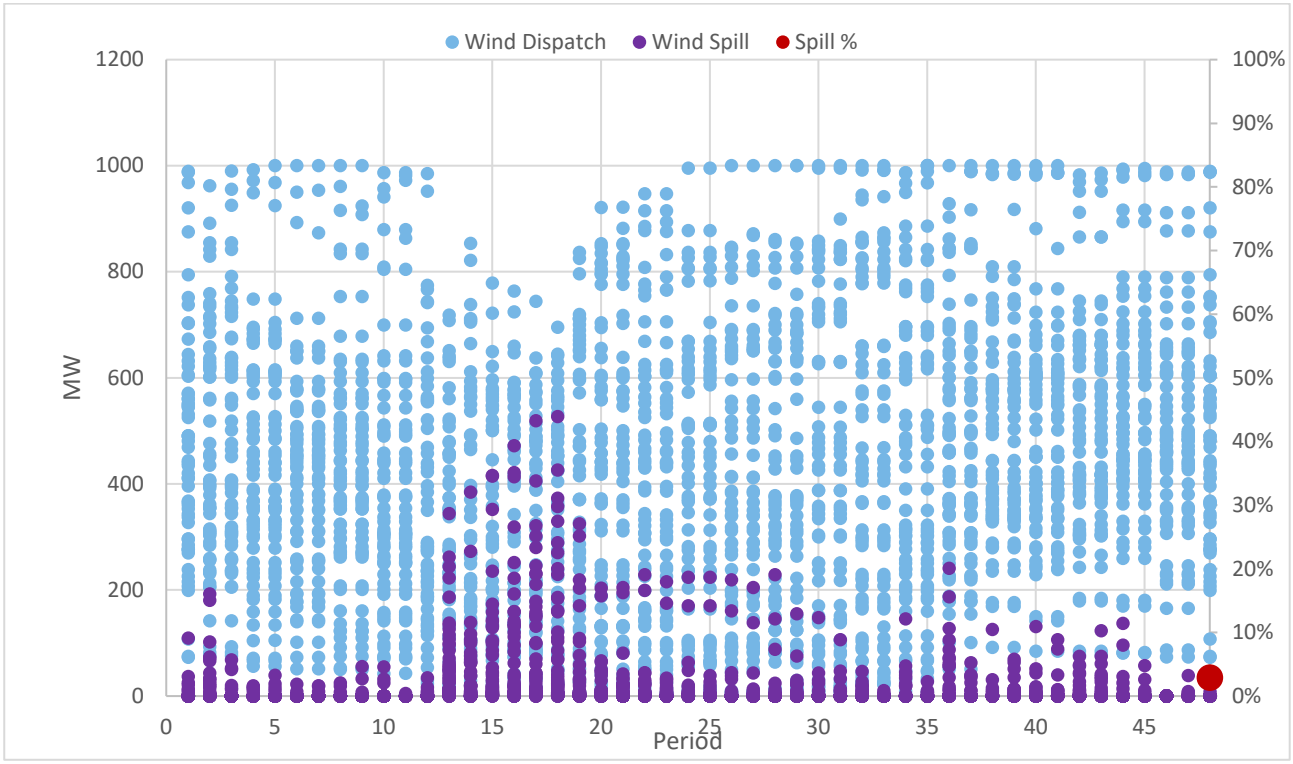

Figure 19: North Queensland wind dispatch and curtailment under 2040C

9. CENTRAL WEST QUEENSLAND details for summer weekdays

Table 11 summarises generating capacity assumptions for Central West Queensland (CWQ)

Table 11: CWQ capacity assumptions under 2040C

CWQ Capacity assumptions	Current [11] (MW)	2030 (MW)	Notes
Coal	2940	2240	CF AllYear 76%; CF SummWD 81%
Gas	56	-	
Wind	-	900	CF AllYear 39%; CF SummWD 49% Curtail SummWD 2%; Max 427MW
Solar	382	1494	CF AllYear 30%; CF SummWD 32% Curtail SummWD 8%; Max 1082MW
Storage/E-G	-	328 (Summ) 987 (Year)	CF AllYear 1%: CF SummWD -% SummWD Incidences: EPeak 600 (100%); ONight 1080 (100%); Daylight 1200 (100%)
TOTAL	3378	5621	

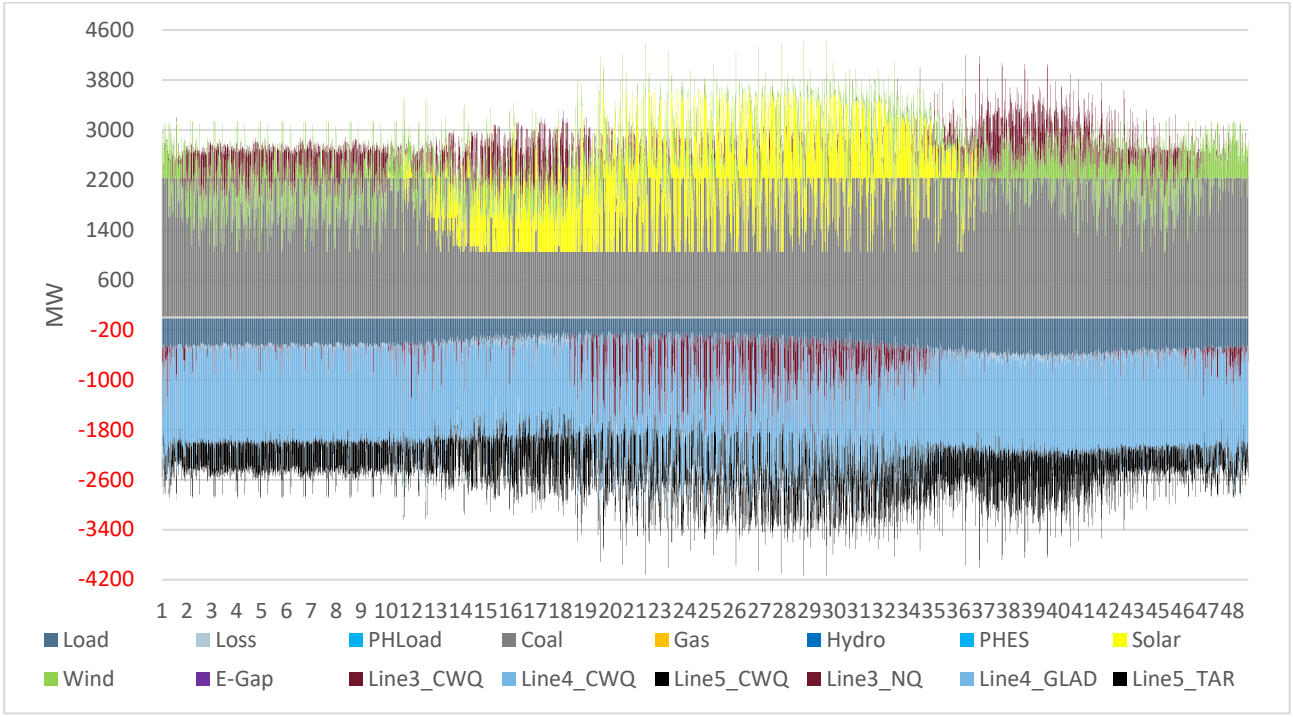

Figure 20: Central West Queensland energy flows for SummWD under 2040C

[11] Source: AEMO Generation Information July 2020

Figure 20 provides detail on the flow of energy through CWQ node by time-of-day period by type of supply and demand. Of note:

- the maroon coloured series indicates imports (primarily) from NQ and the rest of the northern nodes
- the light blue coloured series indicates exports (primarily) to GLAD and potentially Wide Bay and North Moreton
- the black coloured series indicates exports (primarily) to Tarong node and potentially South Moreton.
- the steel blue coloured series indicates CWQ load which averages 448MW
- The light grey coloured series indicates generation from coal capacity of 2240MW. Note the decrease in generation during daylight.
- The gold coloured series indicates generation from gas capacity of which there is none in 2040C
- The yellow coloured series indicates dispatch from solar capacity of 1494MW. Solar dispatch achieves a capacity factor of 32% after curtailment of 8% from potential dispatch. Recall that solar capacity is high during summer. Figure 22 shows dispatch and curtailment of solar
- The light green coloured series indicates dispatch from wind capacity of 900MW. Wind dispatch achieves a capacity factor of 49% after curtailment of 2% from potential dispatch. Figure 23 shows dispatch and curtailment of wind
- there is a small, incidental E-G during evening peak in CWQ node, as a result of a lack of adequate supply in GLAD node. Figure 21 shows detail

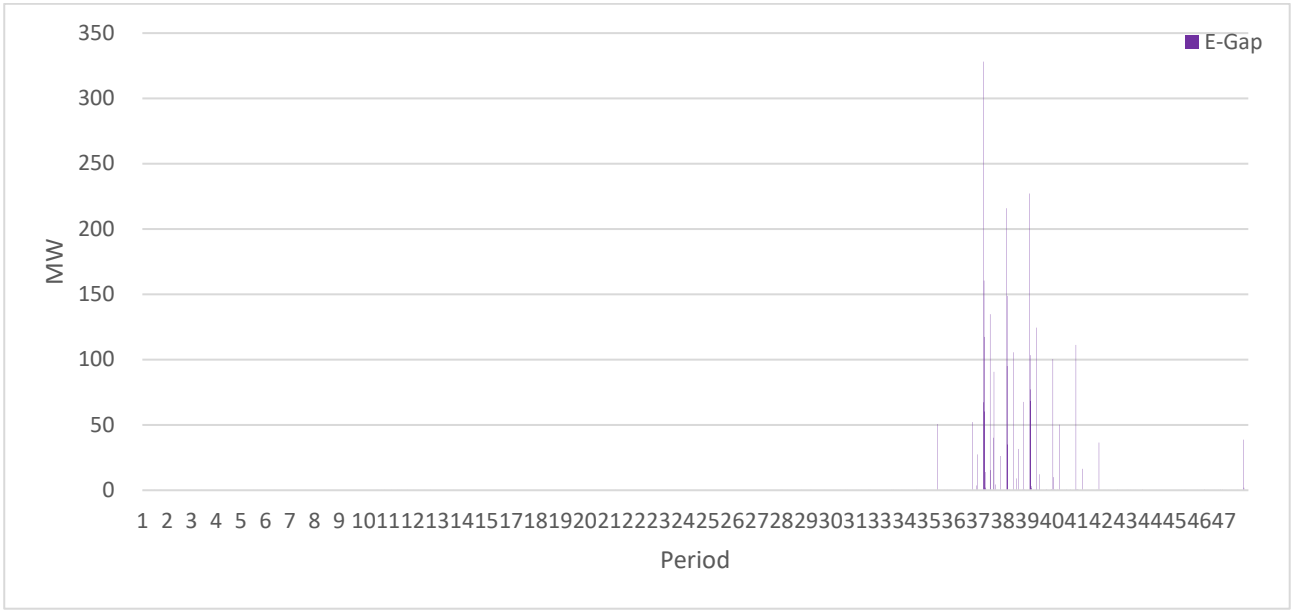

Figure 21: Central West Queensland energy gap for SummWD under 2040C

Table 12 details statistics for CWQ energy flows

Table 12: Central West Queensland salient statistics under 2040C

CWQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(645)	(569)	(448)	(740)	61%	(451)
Coal	2,608	2,074	1,811	2,240	81%	1,988
Gas	0	0	0	5	0%	0
Solar	692	253	480	1,494	32%	221
Wind	631	468	438	900	49%	427
E-G	1	5	1	328	0%	0
Exports (node)	(3,266)	(2,314)	(2,268)	(3,665)	62%	(2,187)
Imports (node)	341	354	237	1,401	17%	90
Solar_spill	57	2	40	1,082	4%	0
Wind_spill	16	5	11	427	3%	0
Solar spill %	8%	1%	8%			
Wind spill %	2%	1%	2%			

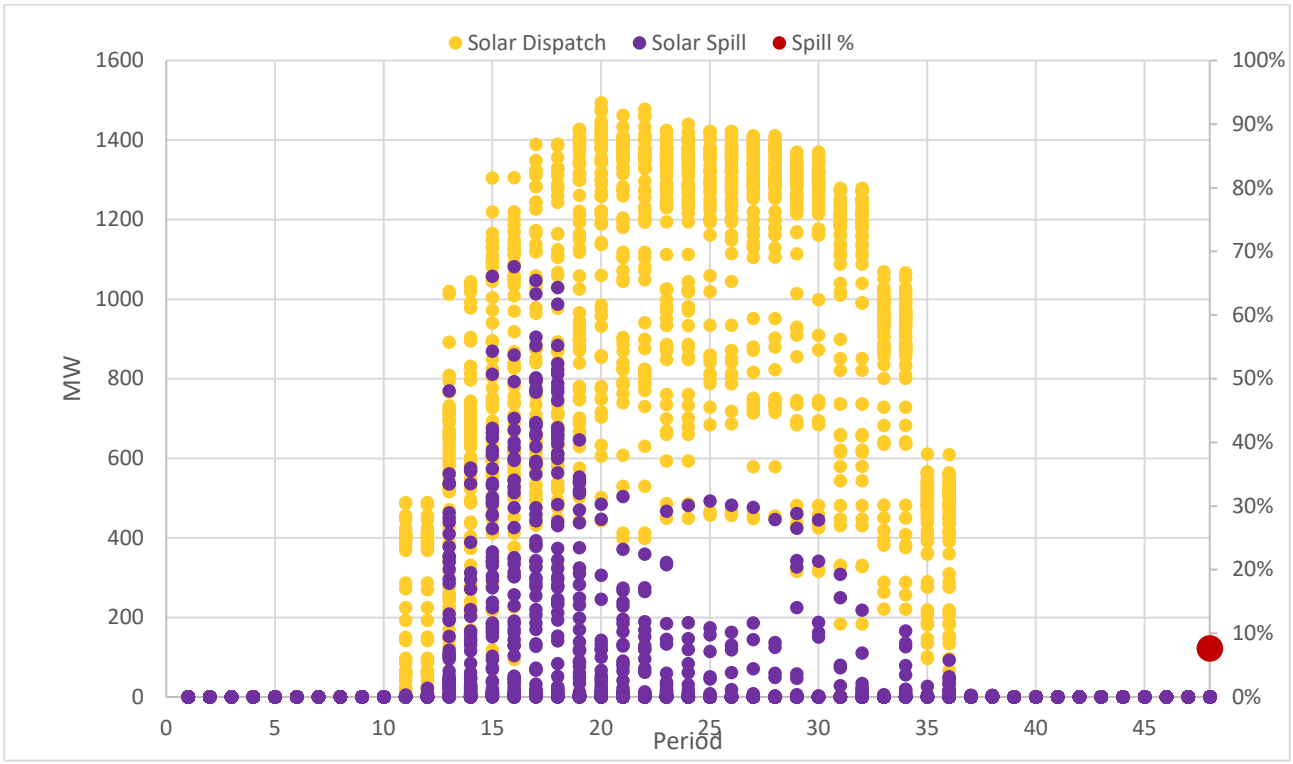

Figure 22: Central West Queensland solar dispatch and curtailment under 2040C

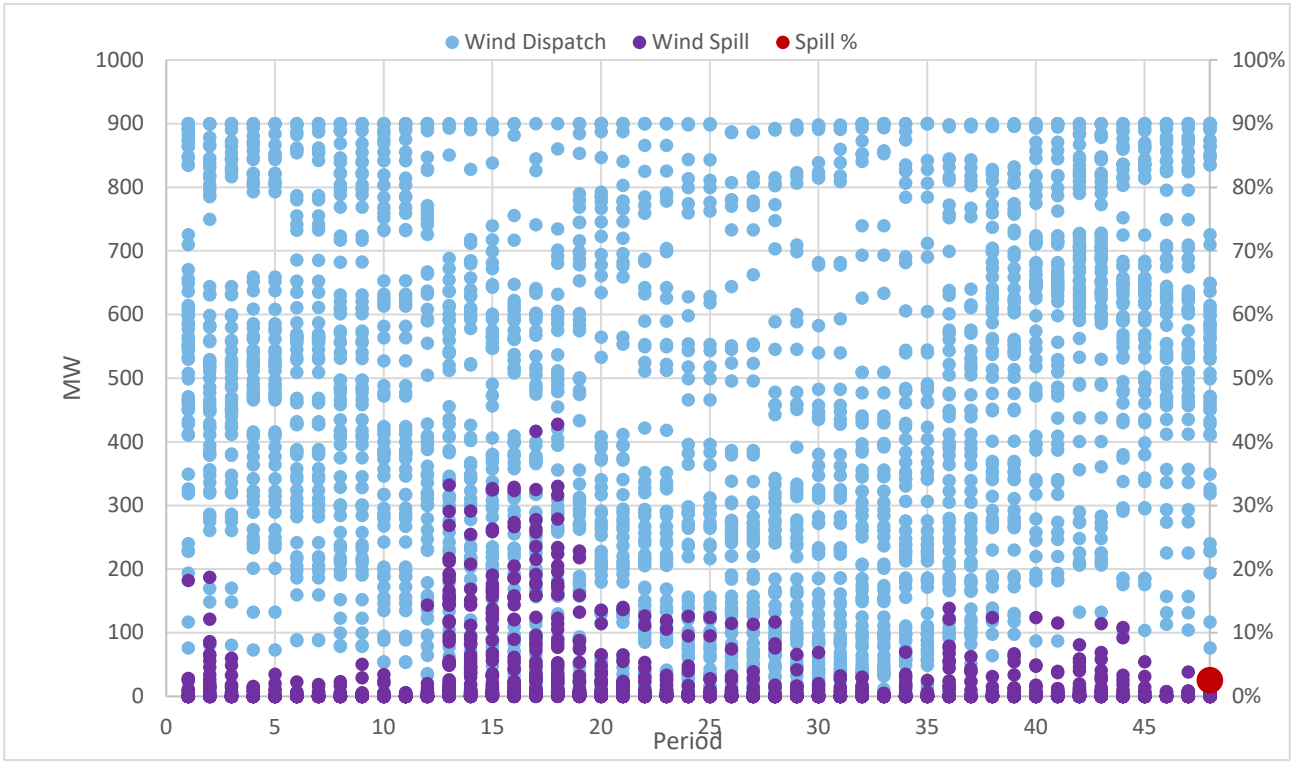

Figure 23: Central West Queensland wind dispatch and curtailment under 2040C

10. GLADSTONE details for summer weekdays

Table 13 summarises generating capacity assumptions for Gladstone (GLAD) node

Table 13: Gladstone capacity assumptions under 2040C

GLAD Capacity assumptions	Current [12] (MW)	2030 (MW)	Notes
Coal	1680	-	
Gas	154	154	CF AllYear 69%; CF SummWD 75%
Solar	-	515	CF AllYear 31%; CF SummWD 35% Curtail SummWD 1%; Max 405MW
Storage/E-G		1664	CF AllYear 4%; CF SummWD 4% SummWD Incidences: EPeak 419 (70%); ONight 102 (9%); Daylight 86 (7%)
TOTAL	1834	2333	

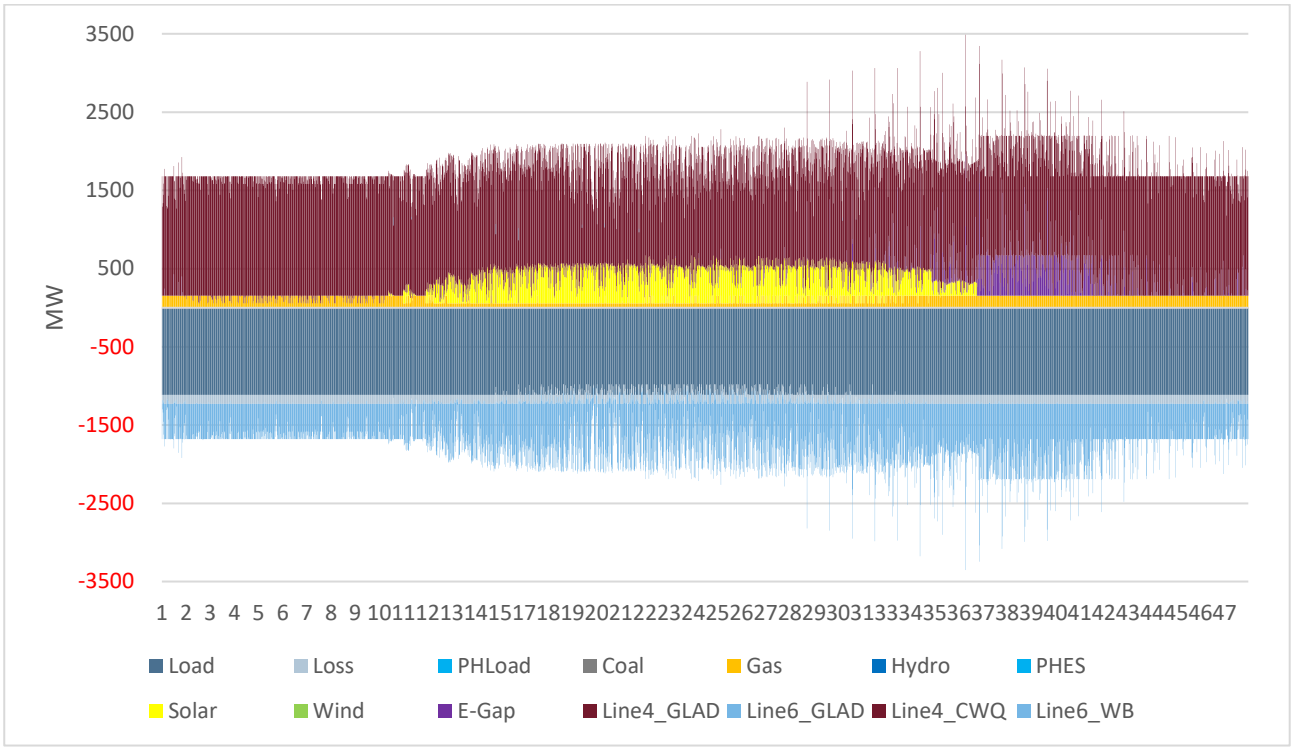

Figure 24: Gladstone energy flows for SummWD under 2040C

Figure 24 provides detail on the flow of energy through GLAD node by time-of-day period by type of supply and demand. Of note:

[12] Source: AEMO Generation Information July 2020

- the maroon coloured series indicates imports from CWQ and potentially the northern nodes of NQ, Ross and FNQ. The solid block of imports indicates maximum transfer capacity reached
- the light blue coloured series indicates exports to Wide Bay and probably North Moreton (Brisbane). Exports occur throughout the day but escalate during daylight to transfer solar from the northern nodes to southern nodes
- the steel blue coloured series indicates GLAD load which is fairly constant and averaging 1105MW. GLAD node hosts the Boyne Aluminium Smelter
- the light grey coloured series indicates generation from coal capacity of which there is none in GLAD with the closure of Gladstone Power station which is assumed to be closed in 2040C.
- the gold coloured series indicates generation from Yarwun combined cycle gas turbine (154MW) .
- the yellow coloured series indicates energy sourced from solar capacity of 515MW. Solar dispatch achieves a capacity factor of 35% after curtailment of 1% from potential dispatch. Figure 26 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity. In 2040C there is no wind capacity assumed in GLAD node.
- E-G is present at evening peak periods at levels of 200-500MW with occasional spikes to a maximum of 1673MW. Figure 25 provides detail

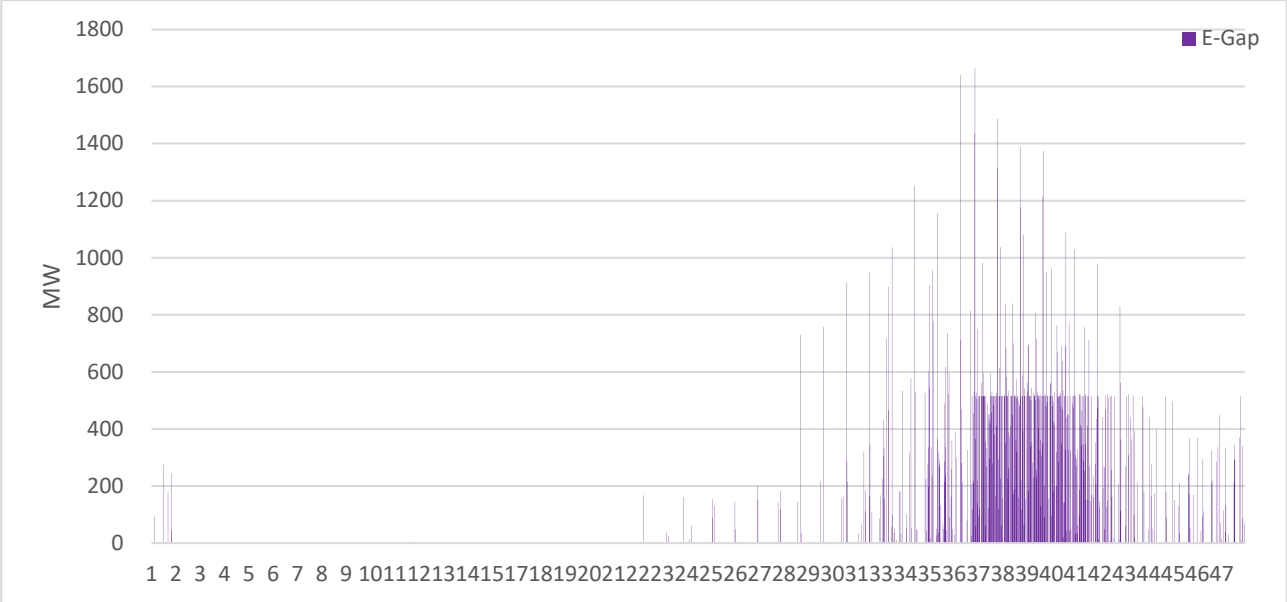

Figure 25: Gladstone energy-gap for SummWD under 2040C

Table 14 details statistics for GLAD energy flows

Table 14: Gladstone salient statistics under 2040C

GLAD Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(1,591)	(1,113)	(1,105)	(1,113)	99%	(1,113)
Coal	0	0	0	0	0%	0
Gas	167	152	116	154	75%	154
Solar	257	86	178	515	35%	51
Wind	0	0	0	0	0%	0
E-G	97	277	67	1,664	4%	0
Exports (node)	(877)	(789)	(609)	(2,127)	29%	(542)
Imports (node)	2,103	1,508	1,460	1,528	96%	1,528
Solar_spill	2	0	2	405	0%	0
Wind_spill	0	0	0	0	0%	0
Solar spill %	1%	0%	1%			
Wind spill %	0%	0%	0%			

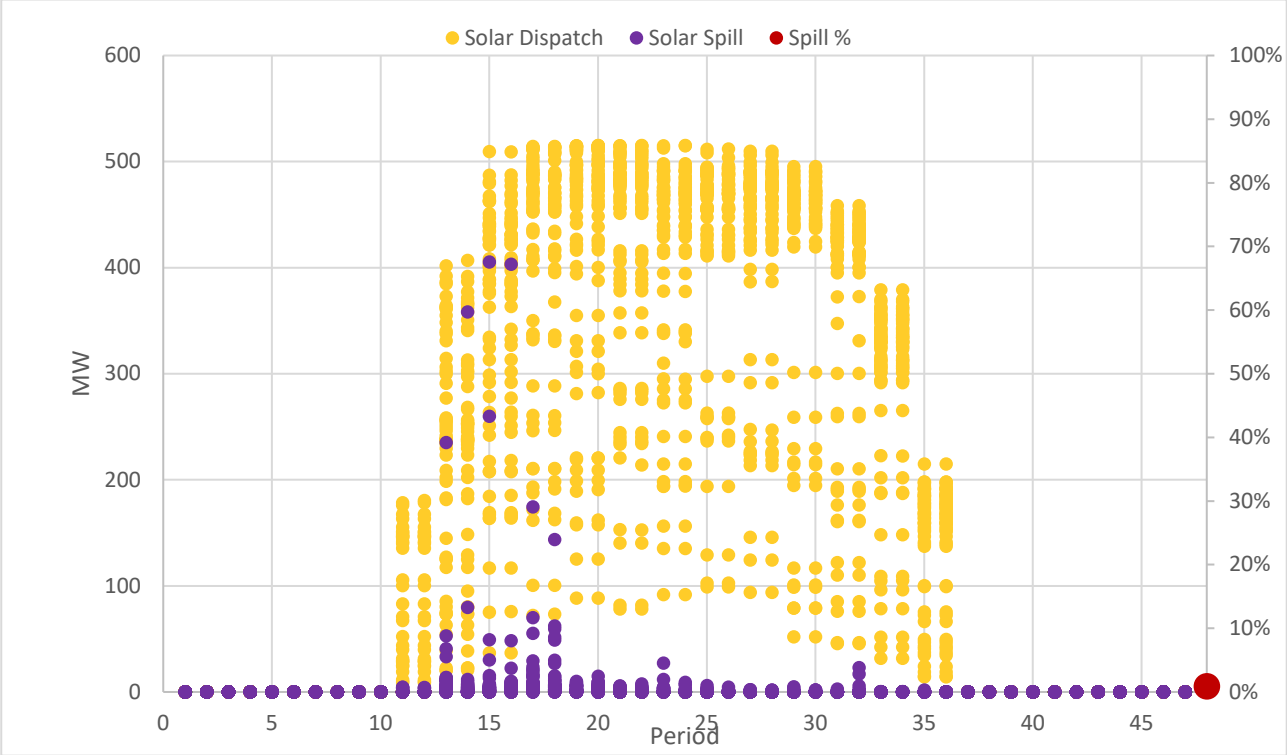

Figure 26: Gladstone solar dispatch and curtailment under 2040C

11. WIDE BAY details for summer weekdays

Table 15 provides detail on generating capacity assumptions for Wide Bay (WB) node

Table 15: Wide Bay capacity assumptions under 2040C

WB capacity assumptions	Current [13] (MW)	2030 (MW)	Notes
Wind	-	-	
Solar	141	500	CF AllYear 30%; CF SummWD 33% Curtail SummWD 1%; Max 449
Storage/Other/ E-G	-	855 (Summ) 1249 (Year)	CF AllYear 4%; CF SummWD 2% SummWD Incidences: EPeak 332 (55%); ONight 68 (6%); Daylight 61 (5%)
TOTAL	141	1749	

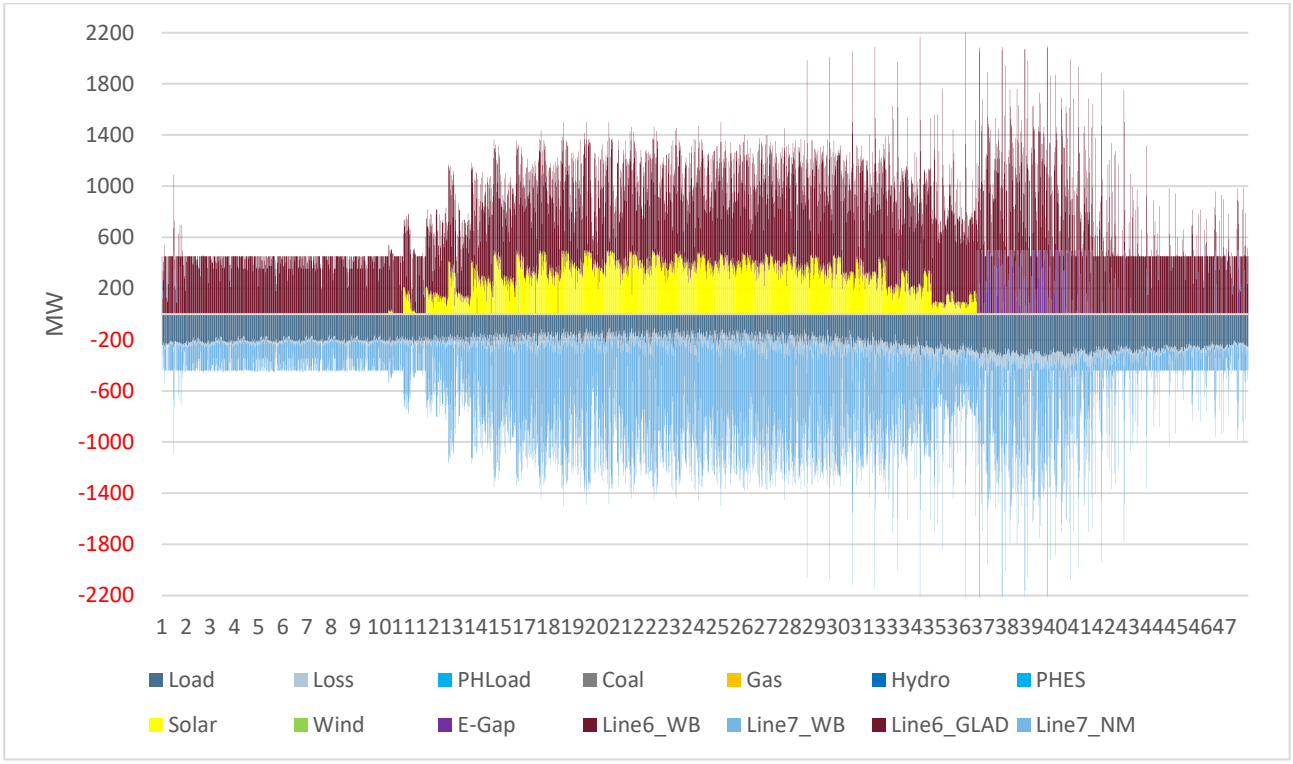

Figure 27: Wide Bay energy flows for SummWD under 2040C

Figure 27 provides detail on the flow of energy through WB node by time-of-day period by type of supply and demand. Of note:

[13] Source: AEMO Generation Information July 2020

- the maroon coloured series indicates imports from GLAD and ultimately CWQ
- the light blue coloured series indicates exports to North Moreton (North Brisbane)
- the steel-blue coloured series indicates WB load averaging 227MW
- the yellow coloured series indicates energy sourced from solar capacity of 500MW. Solar dispatch achieves a capacity factor of 33% after curtailment of 1% from potential dispatch. Figure 29 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind of which there is none in 2040C.
- E-Gs are evident in WB primarily during evening peak periods 37-43. Maximum capacity of E-G is 855MW, with a capacity factor of 3%. Figure 28 shows detail.

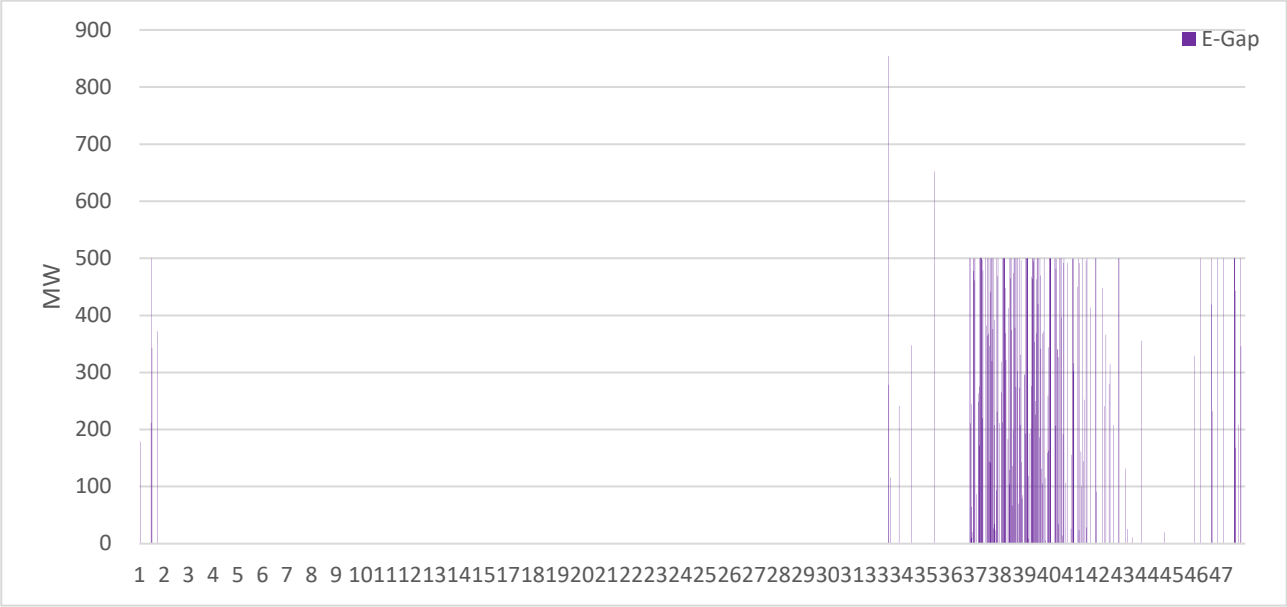

Figure 28: Wide Bay energy-gap for SummWD under 2040C

Table 16 details statistics for WB energy flows

Table 16: Wide Bay salient statistics under 2040C

WB Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(327)	(294)	(227)	(375)	60%	(218)
Solar	235	67	163	500	33%	78
Wind	0	0	0	0	0%	0
E-G	40	116	28	855	3%	0
Exports (node)	(767)	(624)	(533)	(1,595)	33%	(503)
Imports (node)	879	789	610	2,127	29%	542
Solar_spill	3	0	2	449	0%	0
Wind_spill	0	0	0	0	0%	0
Solar spill %	1%	0%	1%			
Wind spill %	0%	0%	0%			

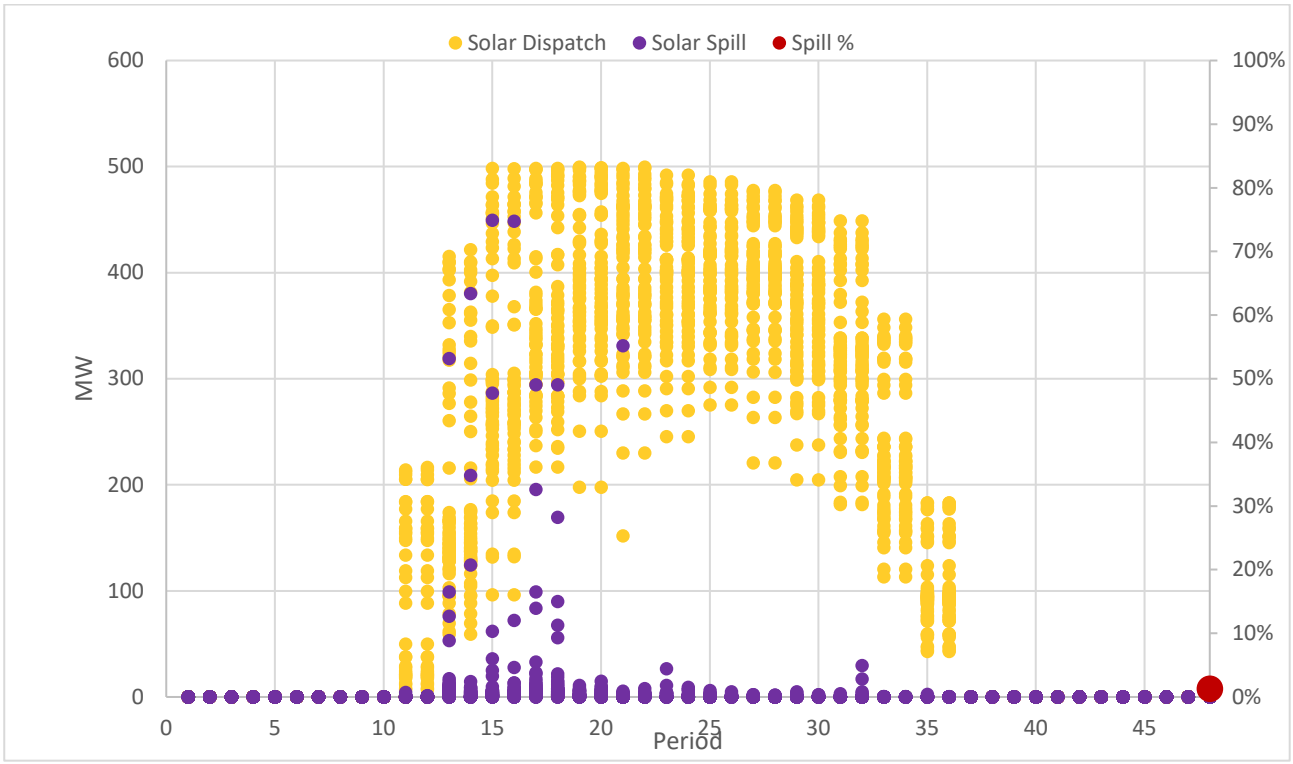

Figure 29: Wide Bay solar dispatch and curtailment under 2040C

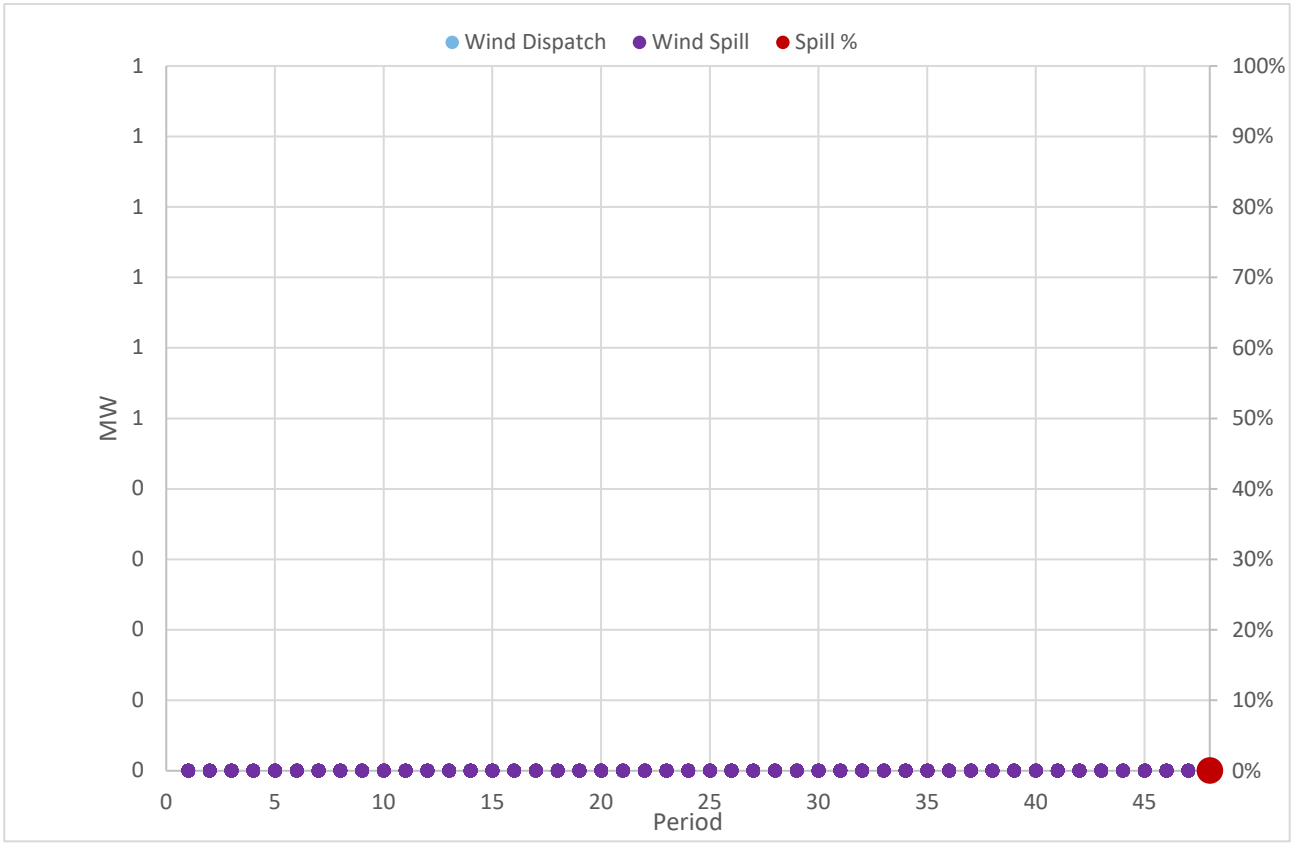

Figure 30: Wide Bay wind dispatch and curtailment under 2040C

12. TARONG details for summer weekdays

Table 17 provides a summary of generating capacity assumptions for Tarong (TAR) node

Table 17: Tarong capacity assumptions under 2040C

TAR capacity assumptions	Current [14] (MW)	2030 (MW)	Notes
Coal	1843	-	
Gas	80	-	
Wind	449	728	CF: AllYear 40%; SummWD 49% Curtail SummWD -%; Max 223MW
Solar	15	20	CF: AllYear 29%; SummWD 34% Curtail SummWD 10%; Max 10
Storage/E-G		391 (Summ) 746 (Year)	CF: AllYear -%; SummWD -% SummWD Incidences: EPeak 317 (53%); ONight 159 (15%); Daylight 64 (5%)
TOTAL	2387	1494	

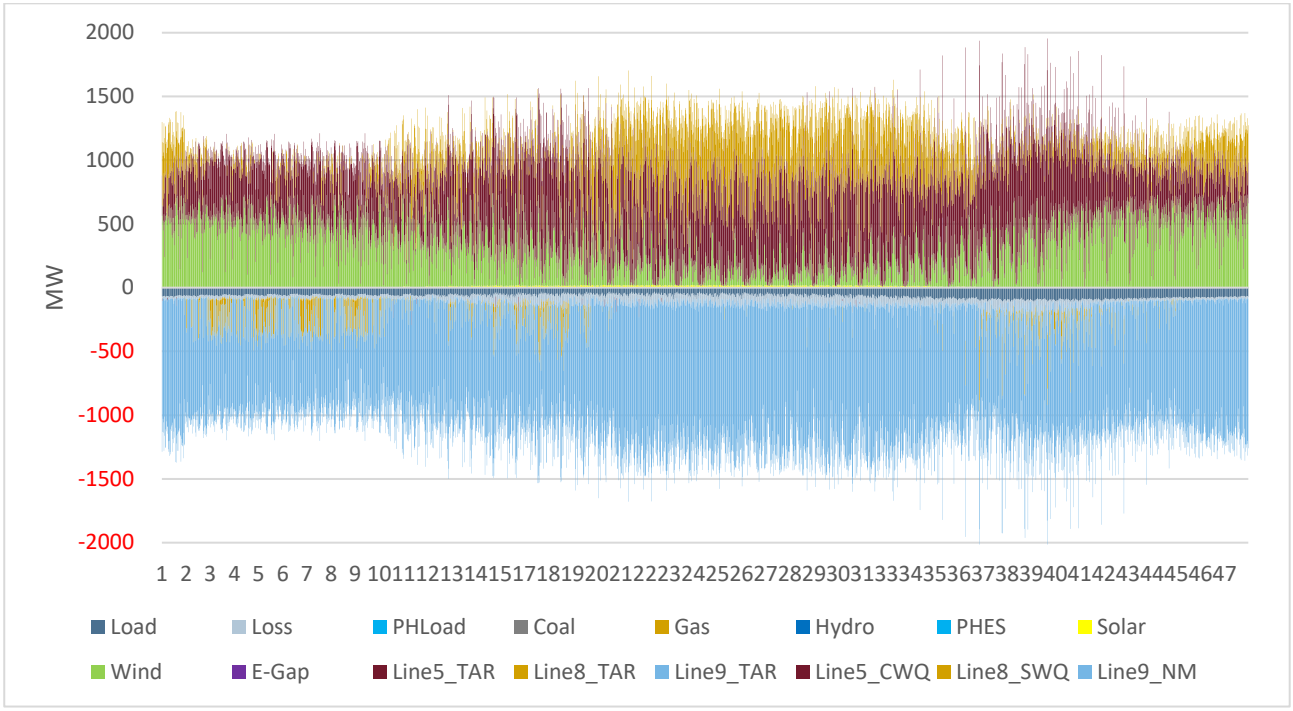

Figure 31: Tarong energy flows for SummWD under 2040C

[14] Source: AEMO Generation Information July 2020

Figure 31 provides detail on the flow of energy through TAR node by time-of-day period by type of supply and demand. Of note:

- the maroon coloured series indicates imports (primarily) from CWQ
- The light-blue coloured series indicates exports (primarily) to NM (North Brisbane)
- the light brown coloured series indicates imports (primarily) from SWQ
- the light-grey coloured series indicates generation from Tarong power stations which are assumed to close in 2040C
- The gold coloured series indicates generation from Roma GT which is assumed to close in 2040C
- the yellow coloured series indicates energy sourced from solar capacity of 20MW. Solar dispatch achieves a capacity factor of 34% after curtailment of 10% from potential dispatch. Figure 33 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity of 728MW. Wind dispatch achieves a capacity factor of 49% after curtailment of -% from potential dispatch. Figure 34 details wind dispatch and curtailment
- the steel-blue coloured series indicates TAR load, an average of 69MW
- E-G in TAR is negligible except for a single period where it escalates to 391MW. Figure 32 shows detail

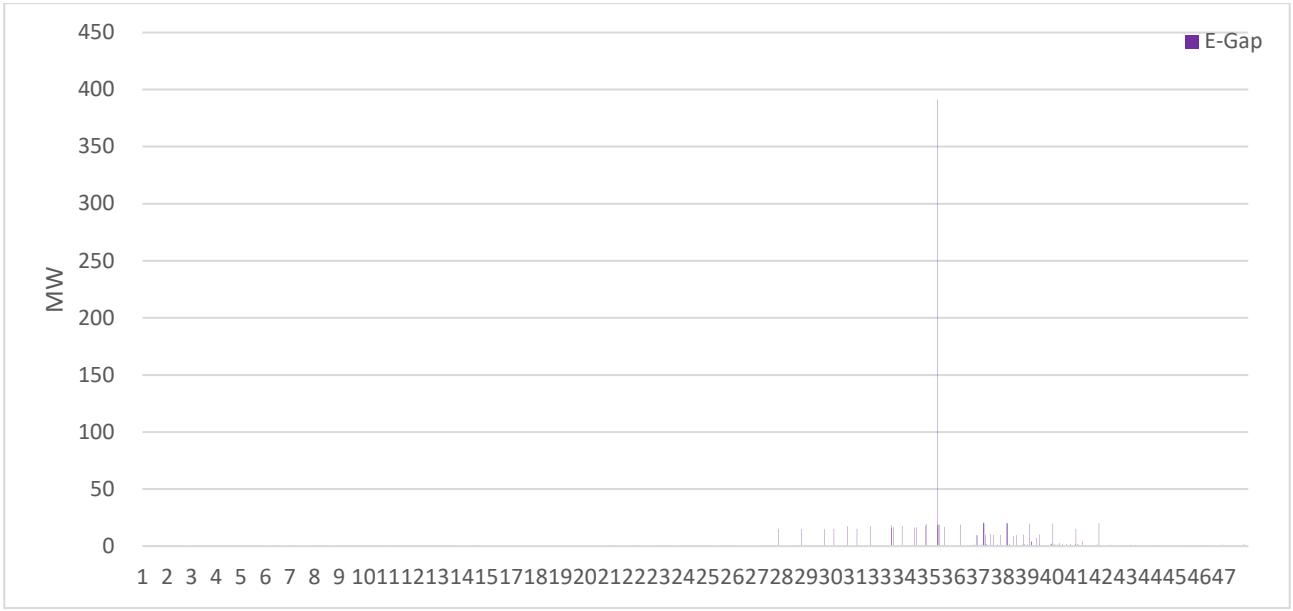

Figure 32: Tarong energy-gap for SummWD under 2040C

Table 18 details statistics for TAR energy flows

Table 18: Tarong Salient statistics under 2040C

TAR Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(100)	(92)	(69)	(120)	57%	(66)
Coal	0	0	0	0	0%	0
Gas	0	0	0	12	0%	0
Solar	10	3	7	20	34%	0
Wind	511	331	355	728	49%	365
E-G	1	2	0	391	0%	0
Exports (node)	(1,511)	(1,073)	(1,049)	(1,677)	63%	(1,040)
Imports (node)	1,167	886	811	1,677	48%	777
Solar_spill	1	0	1	10	8%	0
Wind_spill	2	0	1	223	0%	0
Solar spill %	10%	4%	10%	32%		
Wind spill %	0%	0%	0%	23%		

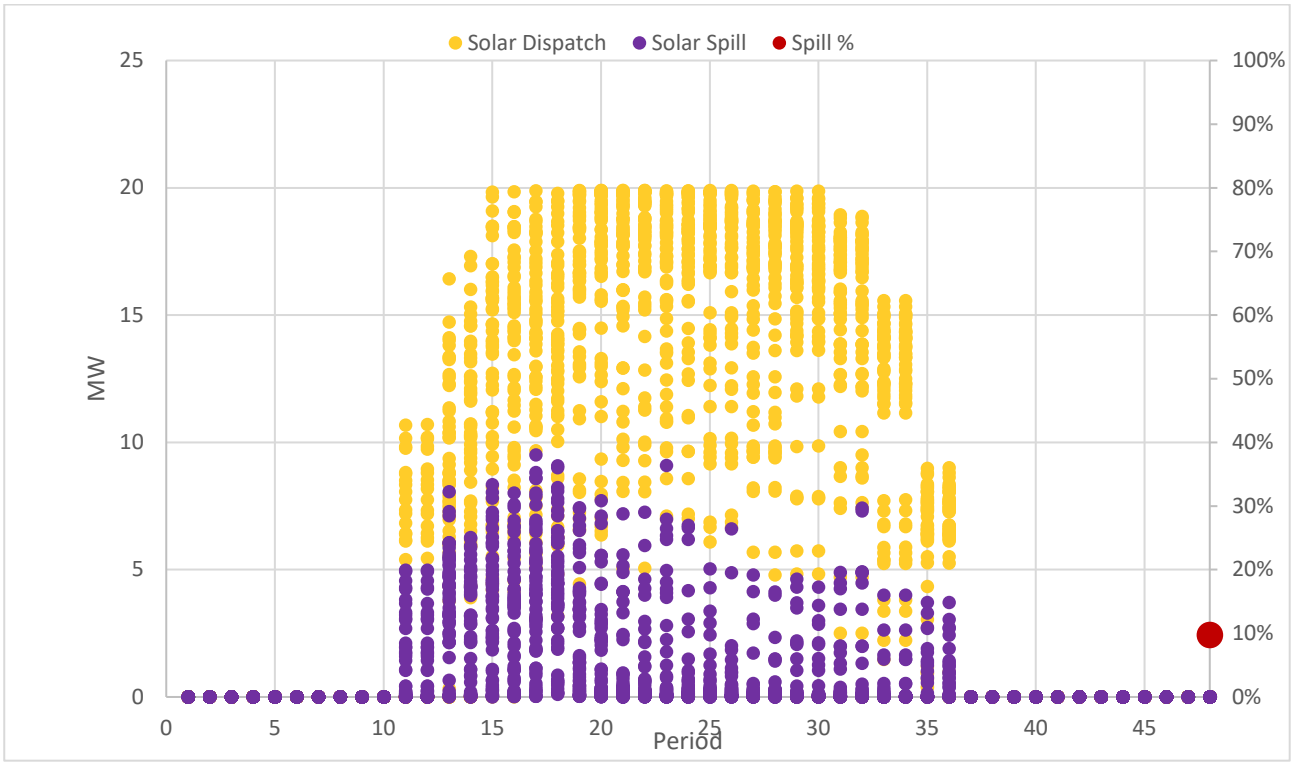

Figure 33: Tarong solar dispatch and curtailment under 2040C

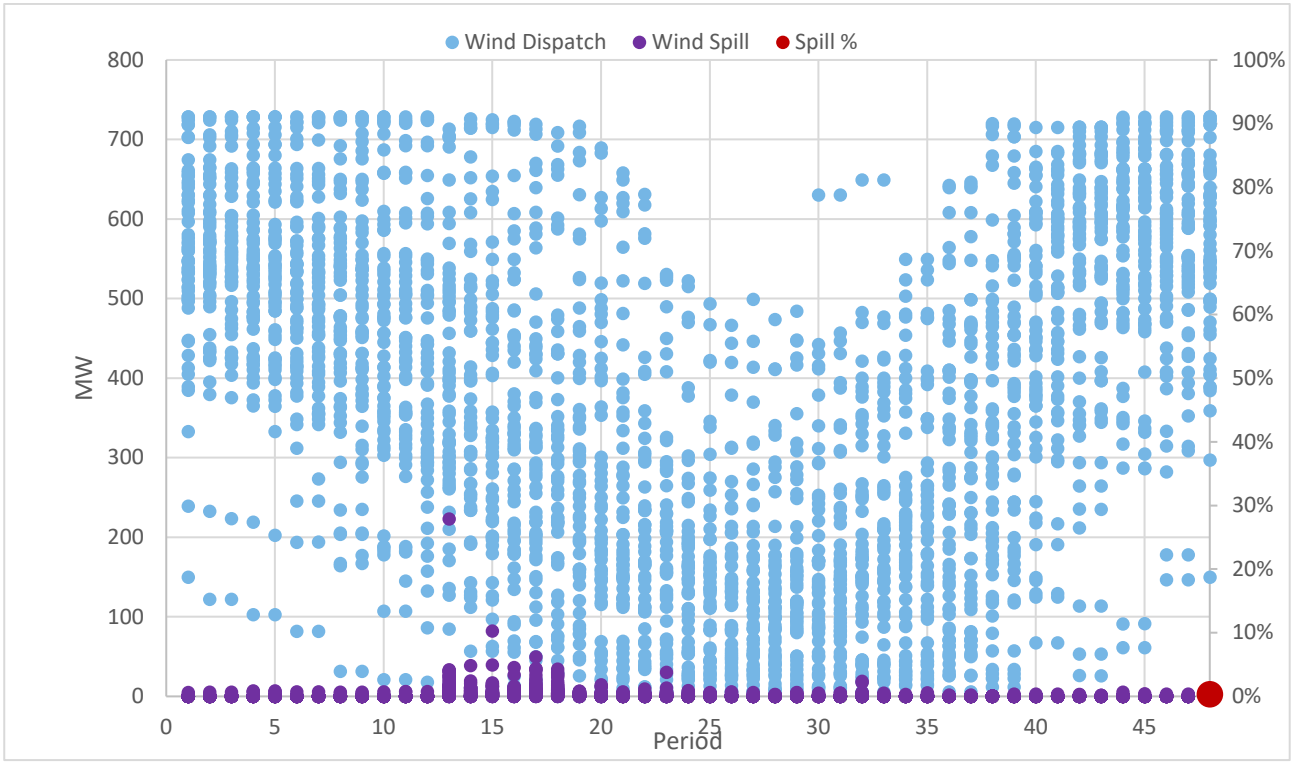

Figure 34: Tarong wind dispatch and curtailment under 2040C

13. SOUTH WEST QUEENSLAND details for summer weekdays

Table 19 provides a summary of generating capacity assumptions for South West Queensland (SWQ) node

Table 19: South West Queensland capacity assumptions under 2040C

SWQ Capacity assumptions	Current [15] (MW)	2030 (MW)	Notes
Coal	1596	1596	CF: AllYear 83%; SummWD 90%
Gas	2157	2157	CF: AllYear 50%; SummWD 49%
Wind	-	1305	CF: AllYear 38%; SummWD 51% Curtail SummWD 1%; Max 448MW
Solar	317	3831	CF: AllYear 28%; SummWD 32% Curtail SummWD 14%; Max 3079MW
Storage/Other/ E-G	-	1769 (Summ) 2822 (Year)	CF: AllYear 1%; SummWD -% SummWD Incidences: EPeak 310 (52%); ONight 181 (17%); Daylight 50 (4%)
TOTAL	4070	11711	

Figure 35 provides detail on the flow of energy through SWQ node by time-of-day period by type of supply and demand. Of note:

- the maroon coloured series indicates imports from or exports to TAR
- the light-blue coloured series indicates exports (primarily) to NSW via QNI which occur throughout the day
- the aqua-marine coloured series indicates exports to South Moreton (South Brisbane & Ipswich) and ultimately on to the Gold Coast
- the light-grey coloured series indicates generation from Kogan Creek and Millmerran coal plant, a total capacity of 1596MW.
- the gold coloured series indicates gas sourced from Oakey and Braemar open cycle gas turbines, and Darling Downs and Condamine combined cycle turbines, a total capacity of 2157MW.
- the yellow coloured series indicates energy sourced from solar capacity of 3831MW. Solar dispatch achieves a capacity factor of 32% after curtailment of 14% from potential dispatch. Figure 37 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity of 1305MW. Wind dispatch achieves a capacity factor of 51% after curtailment of 1% from potential dispatch. Figure 38 details wind dispatch and curtailment
- the steel-blue coloured series indicates SWQ load, an average of 951MW. SWQ demand includes consumption for CSG extraction, compression and transportation.

[15] Source: AEMO Generation Information July 2020

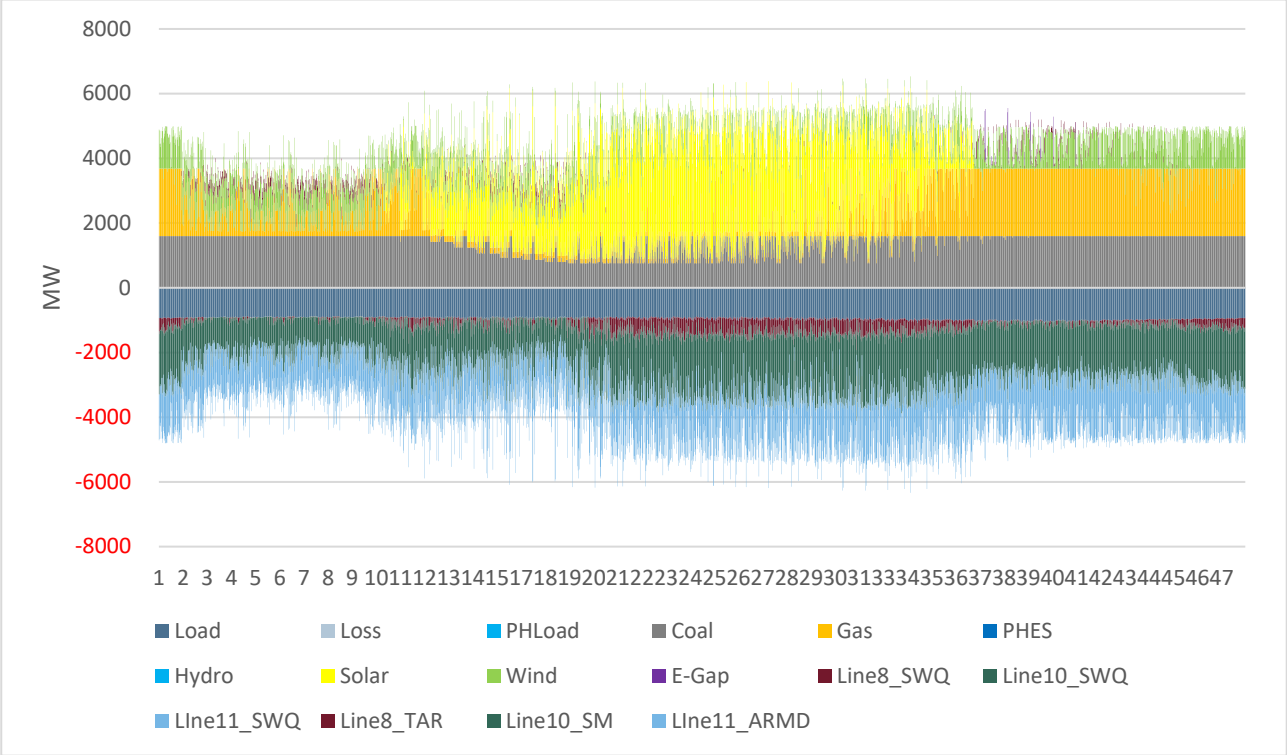

Figure 35: South West Queensland energy flows for SummWD under 2040C

There is evidence of E-G in SWQ, in some periods highly elevated to 1.8GW, although the periods of elevated E-G are few. Figure 36 shows detail

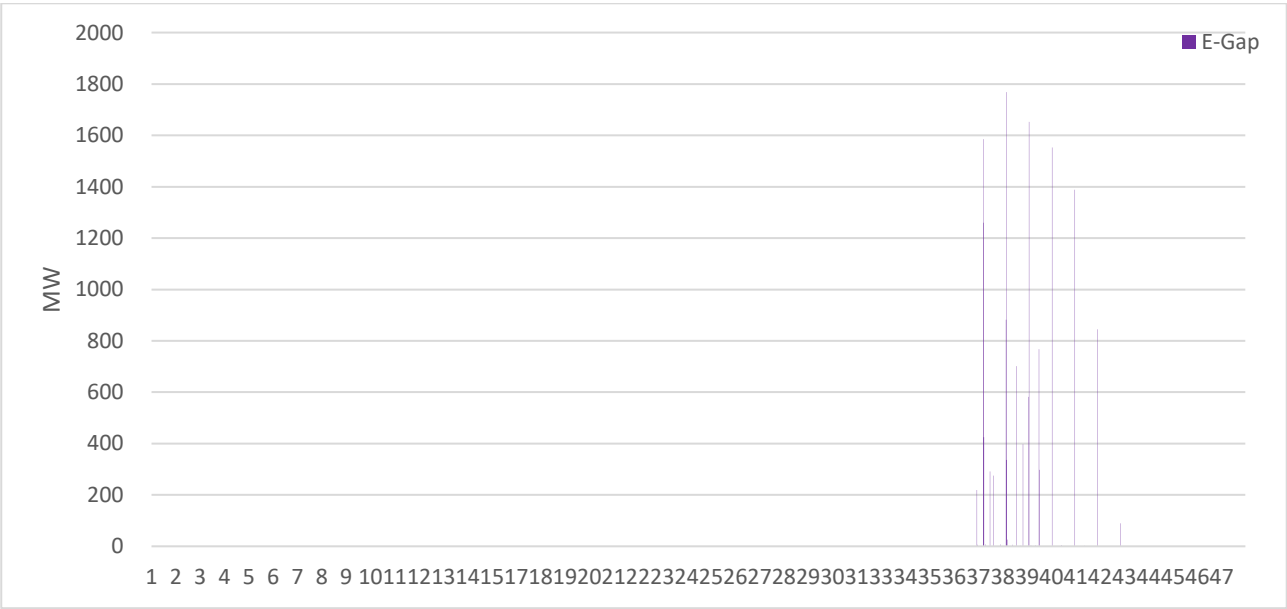

Figure 36: South West Queensland energy-gap for SummWD under 2040C

Table 20 details statistics for SWQ energy flows

Table 20: South West Queensland salient statistics under 2040C

SWQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(1,369)	(1,010)	(951)	(1,098)	87%	(941)
Coal	2,076	1,577	1,442	1,596	90%	1,596
Gas	1,482	1,846	1,029	2,091	49%	786
Solar	1,776	628	1,233	3,830	32%	564
Wind	958	644	665	1,305	51%	686
E-G	8	26	5	1,769	0%	0
Exports (node)	(4,765)	(3,573)	(3,309)	(5,333)	62%	(3,380)
Imports (node)	65	45	45	560	8%	0
Solar_spill	285	0	198	3,079	6%	0
Wind_spill	5	0	4	448	1%	0
Solar spill %	14%	0%	14%			
Wind spill %	1%	0%	1%			

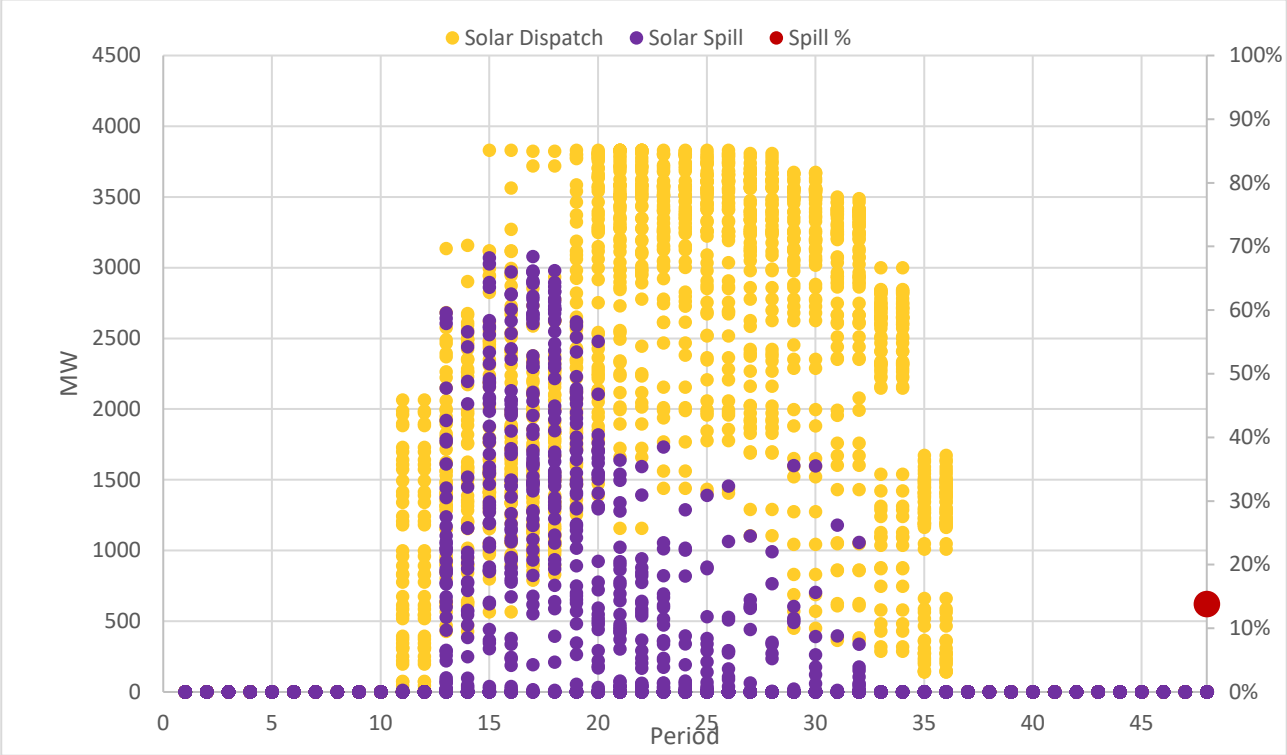

Figure 37: South West Queensland solar dispatch and curtailment under 2040C

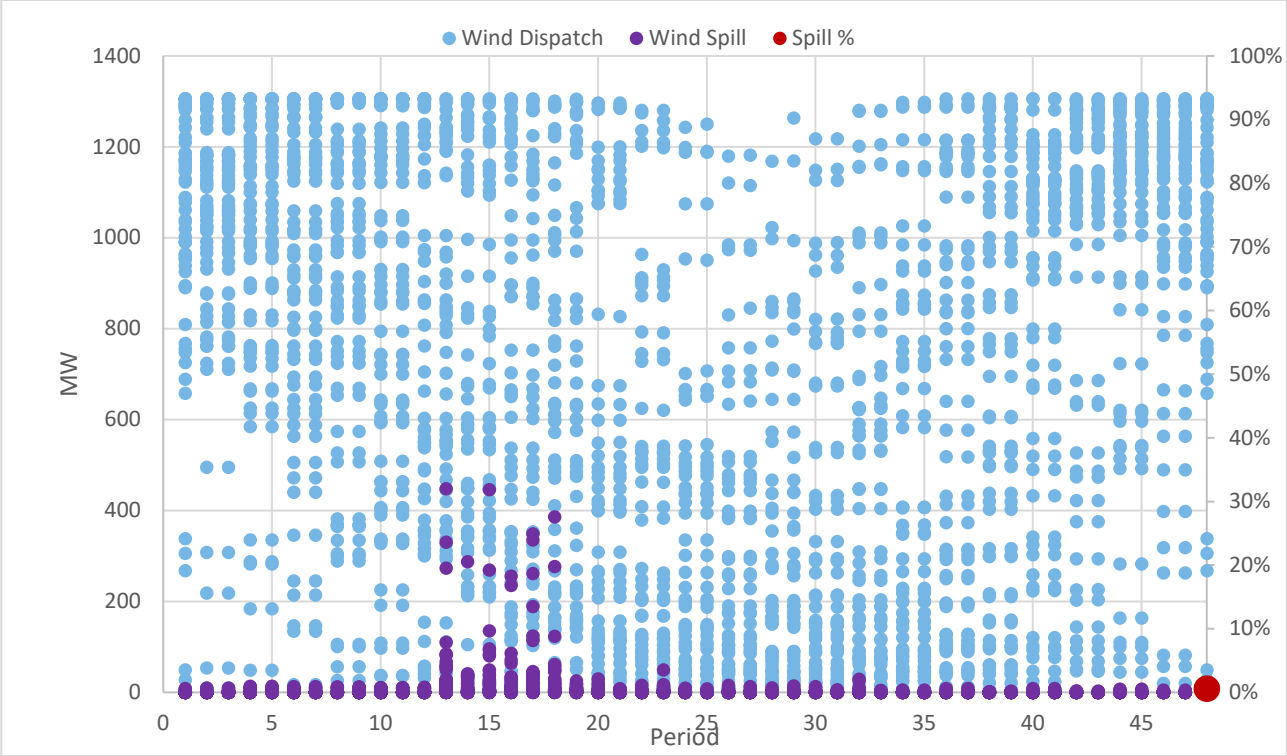

Figure 38: South West Queensland wind dispatch and curtailment under 2040C

14. SOUTH MORETON details for summer weekdays

Table 21 provides a summary of generating capacity assumptions for South Moreton (SM) node

Table 21: South Moreton capacity assumptions under 2040C

SM capacity assumptions	Current [16] (MW)	2030 (MW)	Notes
Gas	385	-	
Storage/Other/ E-G		885	CF: AllYear 1%; SummWD 1% SummWD Incidences: EPeak 124 (21%); ONight 23 (2%); Daylight 21 (2%)
TOTAL	700	885	

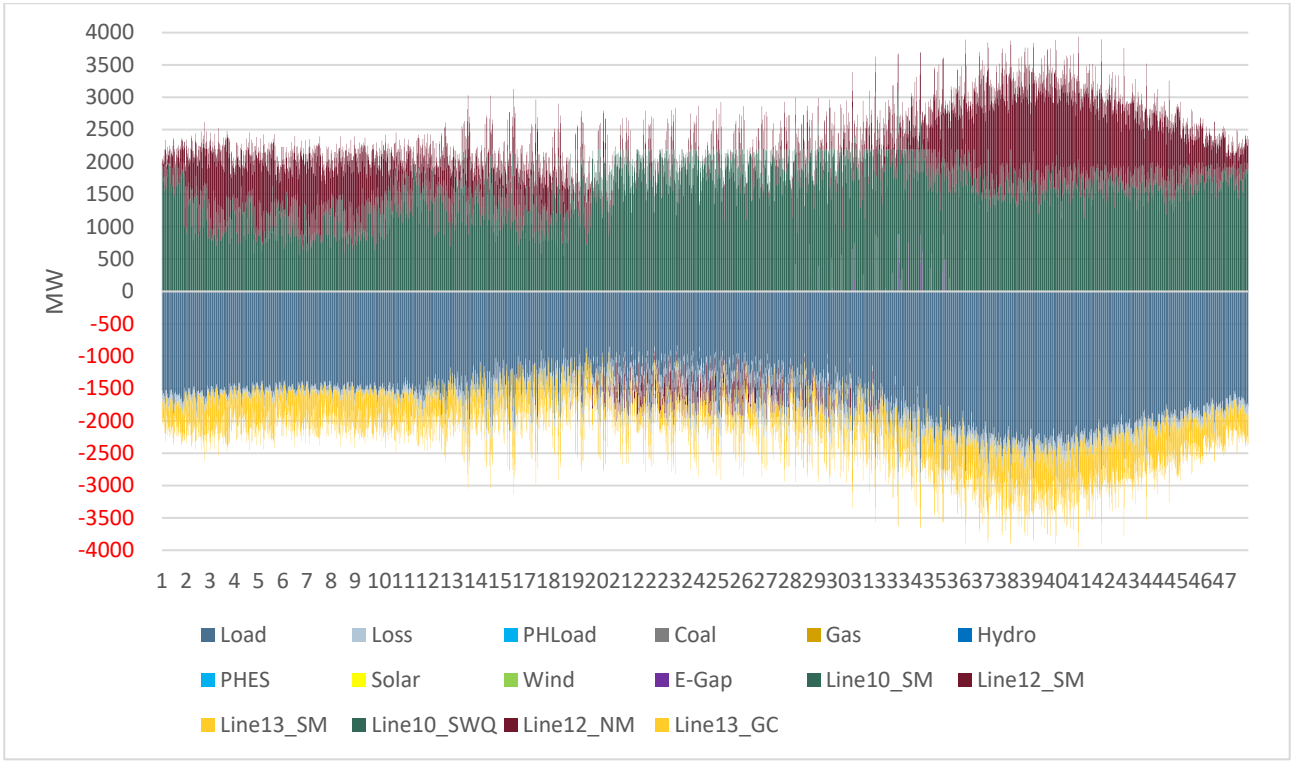

Figure 39: South Moreton energy flows for SummWD under 2040C

Figure 39 provides detail on the flow of energy through South Moreton node by time-of-day period by type of supply and demand. Of note:

- the maroon coloured series indicates imports (primarily) from North Moreton node
- the green coloured series indicates imports from SWQ node
- the gold coloured series indicates exports to Gold Coast

[16] Source: AEMO Generation Information July 2020

- the steel-blue coloured series indicates SM load, averaging 1711MW
- the purple coloured series indicates evidence of E-G in SM node during evening peak, although it is incidental. Figure 40 shows detail.

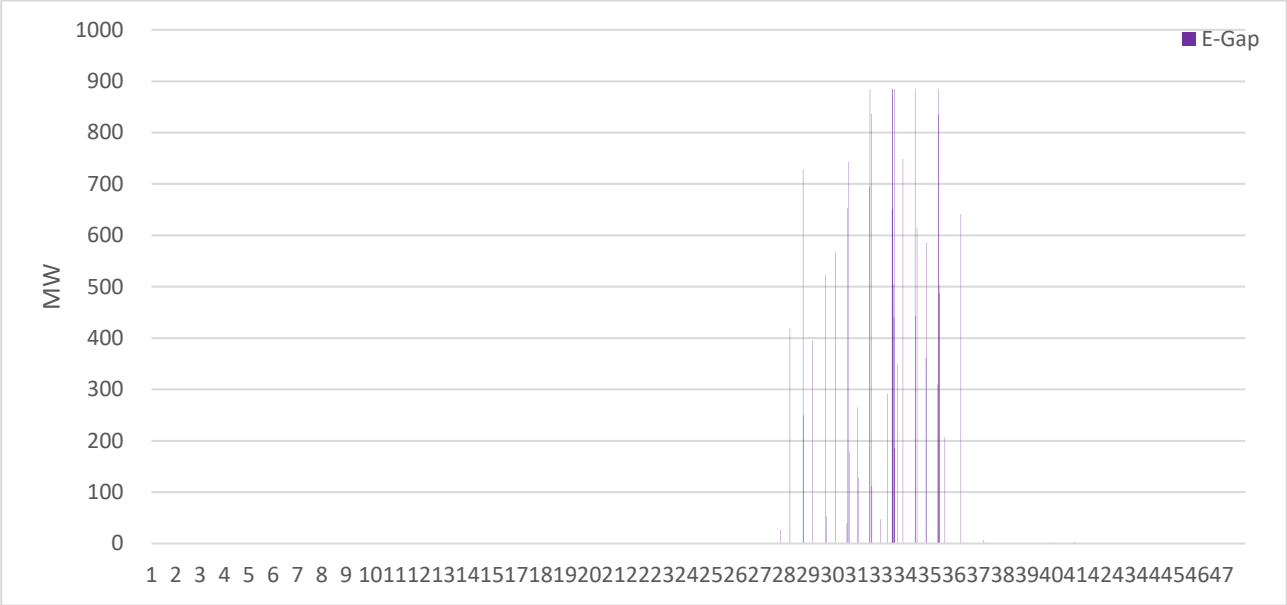

Figure 40: South Moreton energy-gap for SummWD under 2040C

Table 22 details statistics for SM energy flows

Table 22: South Moreton salient statistics under 2040C

SM Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(2,464)	(2,243)	(1,711)	(2,938)	58%	(1,620)
Gas	0	0	0	0	0%	0
E-G	10	21	7	885	1%	0
Exports (node)	(748)	(641)	(519)	(1,102)	47%	(512)
Imports (node)	3,356	3,002	2,331	3,933	59%	2,207

15. NORTH MORETON details for summer weekdays

Table 23 summarises generating capacity assumptions for North Moreton (NM) node

Table 23: North Moreton capacity assumptions under 2040C

NM Capacity assumptions	Current [17] (MW)	2030 (MW)	Notes
PHES	570	1590	CF: AllYear 22%; SummWD 20% Curtail SummWD 41%; Max 1590MW
Storage/Other/ E-G		1993	CF: AllYear 32%; SummWD 33% Incidences: EvPeak 598 (100%), ONight 1080 (100%), Daylight 789 (66%)
TOTAL	570	3583	

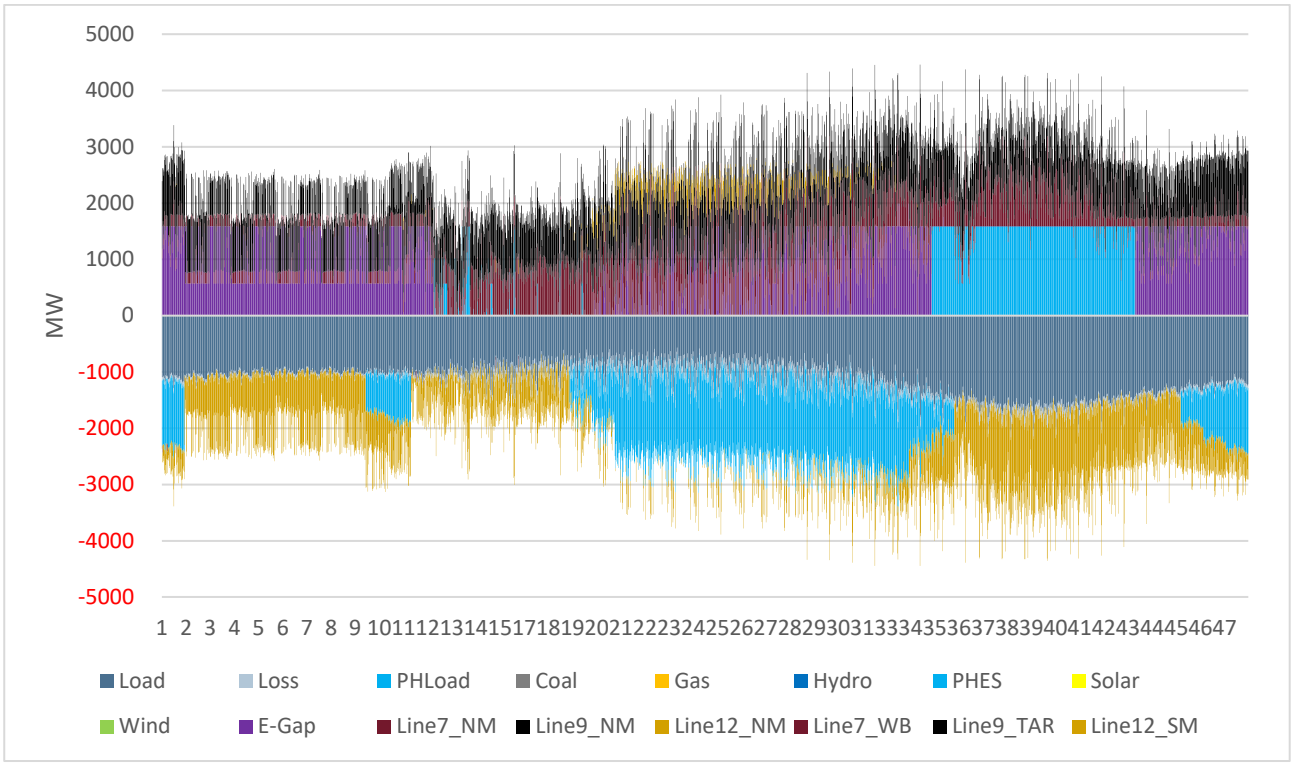

Figure 41: North Moreton energy flows for SummWD under 2040C

Figure 41 provides detail on the flow of energy through NM (North Brisbane) node by time-of-day period by type of supply and demand. Of note:

- The maroon coloured series indicates imports from WB
- the black coloured series indicates imports from TAR node
- gold coloured series indicates exports to or imports from SM (South Brisbane)

[17] Source: AEMO Generation Information July 2020

- the cyan coloured series indicates Wivenhoe (570MW) and Mt Byron (1020MW) pump hydro load (if negative) and dispatch (if positive). Note dispatch occurs during evening peak, and load is targeted at solar generation during daylight and a few periods overnight to charge for adequate capacity at peaks
- a persistent E-G is apparent in NM node after evening peak, before morning peak, and during the day. The E-G reflects dispatch from Wivenhoe (570MW) and Mt Byron (1020MW), which is outside of the dispatch strategy, and assumed to be E-G (because dispatch is only possible at high spot price). The associated reason for classifying this dispatch as E-G, is because all-night dispatch would deplete potential for dispatch during morning and evening peak. However, it is apparent that there is a significantly large requirement for supply overnight (due to the lack of solar energy, and unreliable generation from wind) and sporadically during the day in addition to evening peak. This implies a greater requirement for storage and/ or generation to meet demand. (New version of ANEM, which pumps based on VRE resource and dispatches based on storage, will provide greater clarity with respect to real E-G). Figure 42 shows detail.

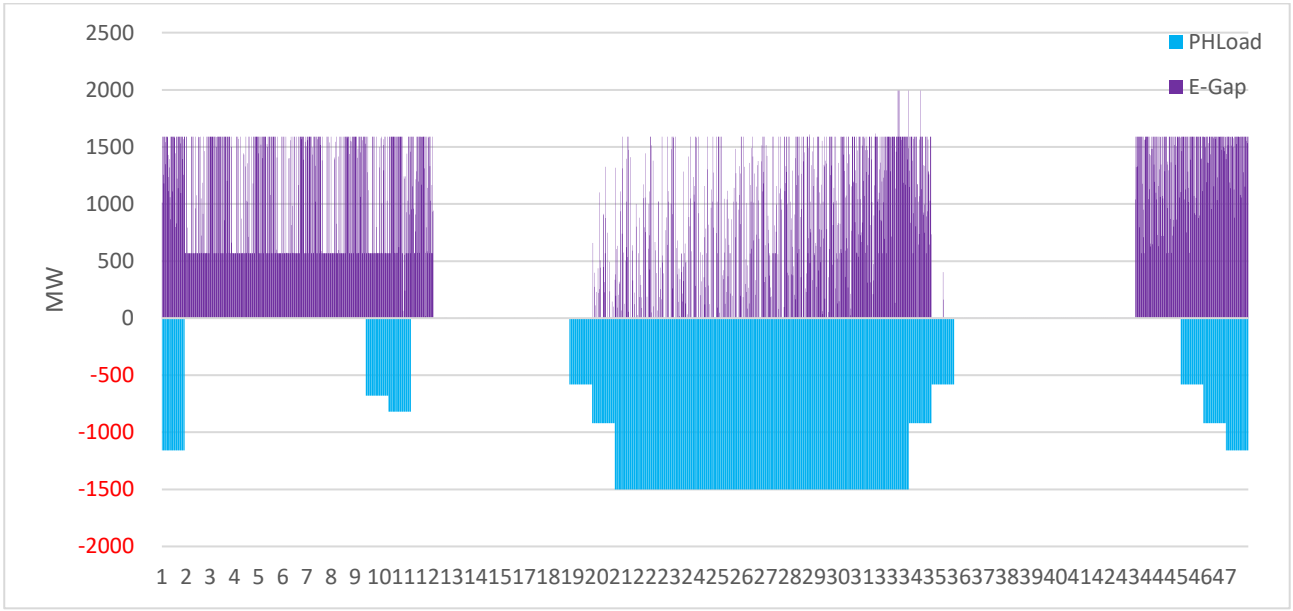

Figure 42: North Moreton energy-gap for SummWD under 2040C

Table 24 details statistics for NM energy flows

Table 24: North Moreton salient statistics under 2040C

NM Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(1,685)	(1,548)	(1,170)	(2,055)	57%	(1,101)
PH Load	(835)	(300)	(580)	(1,500)	39%	0
PHES	447	1,235	310	1,590	20%	0
E-G	949	282	659	1,993	33%	570
Exports (node)	(1,026)	(1,234)	(713)	(2,371)	30%	(644)
Imports (node)	2,275	1,652	1,580	2,867	55%	1,523

16. GOLD COAST details for summer weekdays

Table 25 summarises generating capacity assumptions for Gold Coast (GC) node

Table 25: Gold Coast capacity assumptions under 2040C

GC capacity assumptions	Current [18] (MW)	2030 (MW)		
Solar	-	-		
Wind	-	-		
Storage/Other/ E-G	-	-		
TOTAL	-	-		

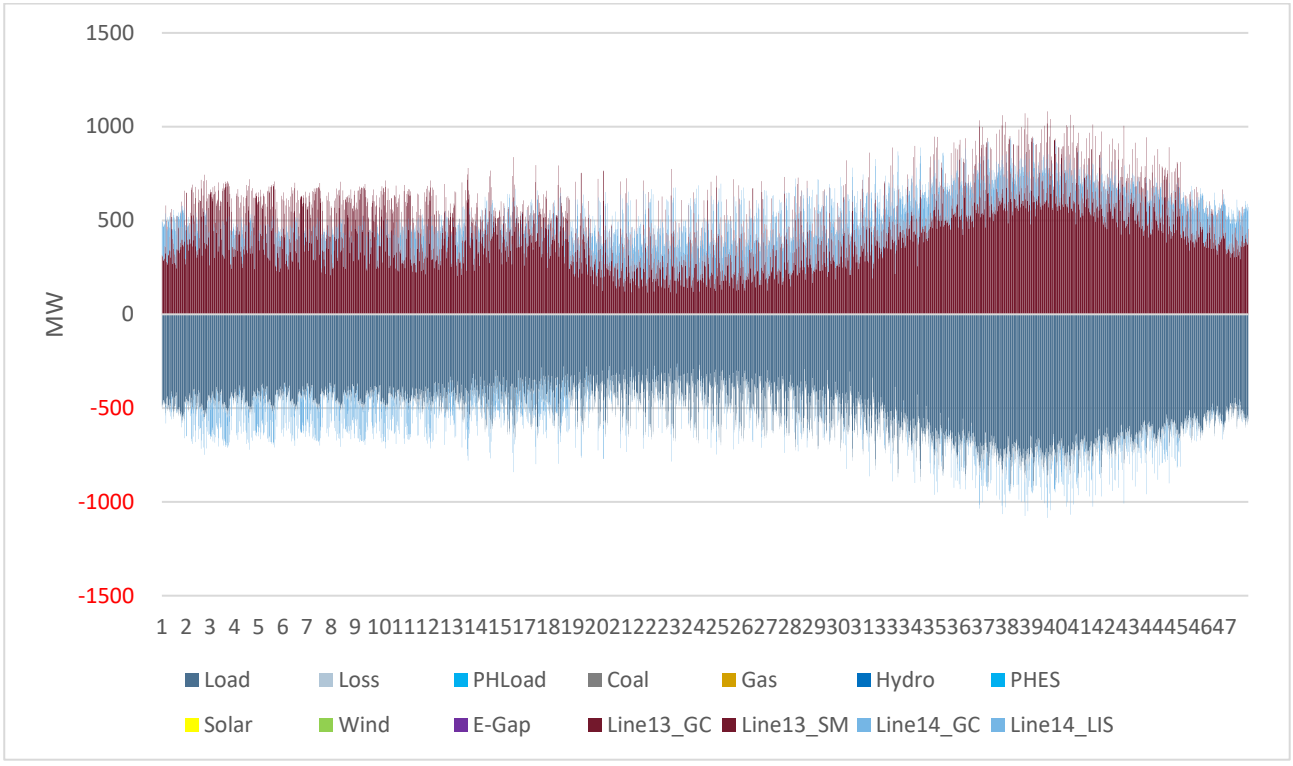

Figure 43: Gold Coast energy flows for Summer WD under 2040C

Figure 43 provides detail on the flow of energy through GC node by time-of-day period by type of supply and demand. Of note:

- the maroon coloured series indicates imports from SM (South Brisbane)
- the light-blue coloured series indicates imports from and exports to Lismore in NSW via DirectLink. GC appears heavily reliant on imports from NSW

[18] Source: AEMO Generation Information July 2020

- the steel-blue coloured series indicates load in GC, averaging 522MW
- There is no E-G in GC
- Table 26 details statistics for GC energy flows

Table 26: Gold Coast salient statistics under 2040C

GC Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(752)	(700)	(522)	(915)	57%	(489)
E-G	0	0	0	0	0%	0
Exports (node)	(63)	(36)	(44)	(180)	24%	0
Imports (node)	832	753	578	1,082	53%	568

17. CONCLUDING OBSERVATIONS on QLD nodal supply-demand balance

Under the assumptions for the modelling of this scenario, 49% of energy dispatched is from coal and gas which is adequate to reach QRET. The modelling outcomes imply, however, that introducing Pump Hydro, or any form of storage that requires charging, can lead to sizable E-Gs because of the increase in load. There is also evidence of insufficient wind resource overnight to meet demand constantly.

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

Contact details

Dr Lynette Molyneaux and Dr Phillip Wild
T +61 7 **33461003**
M +61 **415 054 064**
E l.molyneaux@uq.edu.au
W uq.edu.au

CRICOS Provider Number 00025B