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Addendum to Roadmap to QRET Report 2020: Pipeline Scenario B Queensland only

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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 Pipeline Scenario B 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 in 2030

a) Pipeline Scenario B (sB)

i. QLD Underlying assumptions

- N transmission network
- Direction of Flow loss method estimation
- Generation capacity at 2030 with ISP Central scenario demand assumptions
- Coal power in 2030 will decline to 4,839MW in QLD from 8,059MW currently (NSW 4,040MW from 10,210MW; VIC 3,144MW from 4,775MW)
- Coal unit closures:
    - QLD: Units 1-2 Callide B; Units 1-2 Stanwell; Units 1-2,5-6 Gladstone; Units 1-2 Tarong;
    - NSW: Units 1-4 Liddell; Units 1-4 Eraring; Units 5-6 Vales Point
    - VIC: Units 1-4 Yallourn
- Gas power in 2030 will decline to 2,691MW in QLD from 3,076MW currently with closure of Swanbank E (NSW 1,174MW from 2,155MW)
- Wind power in 2030 will reach 4,820MW in QLD (NSW 5,671MW; VIC 8,470MW; SA 3,652MW; TAS 2,302MW)
- Solar power in 2030 will reach 8,736MW in QLD (NSW 8,021MW; VIC 2,141MW; SA 4,213MW)
- Pump hydro (PHES) in 2030 includes notional Mt Byron (1020MW) and Urannah (1020MW) to reach 2,860MW in QLD (NSW 3,180MW; 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 sB

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.

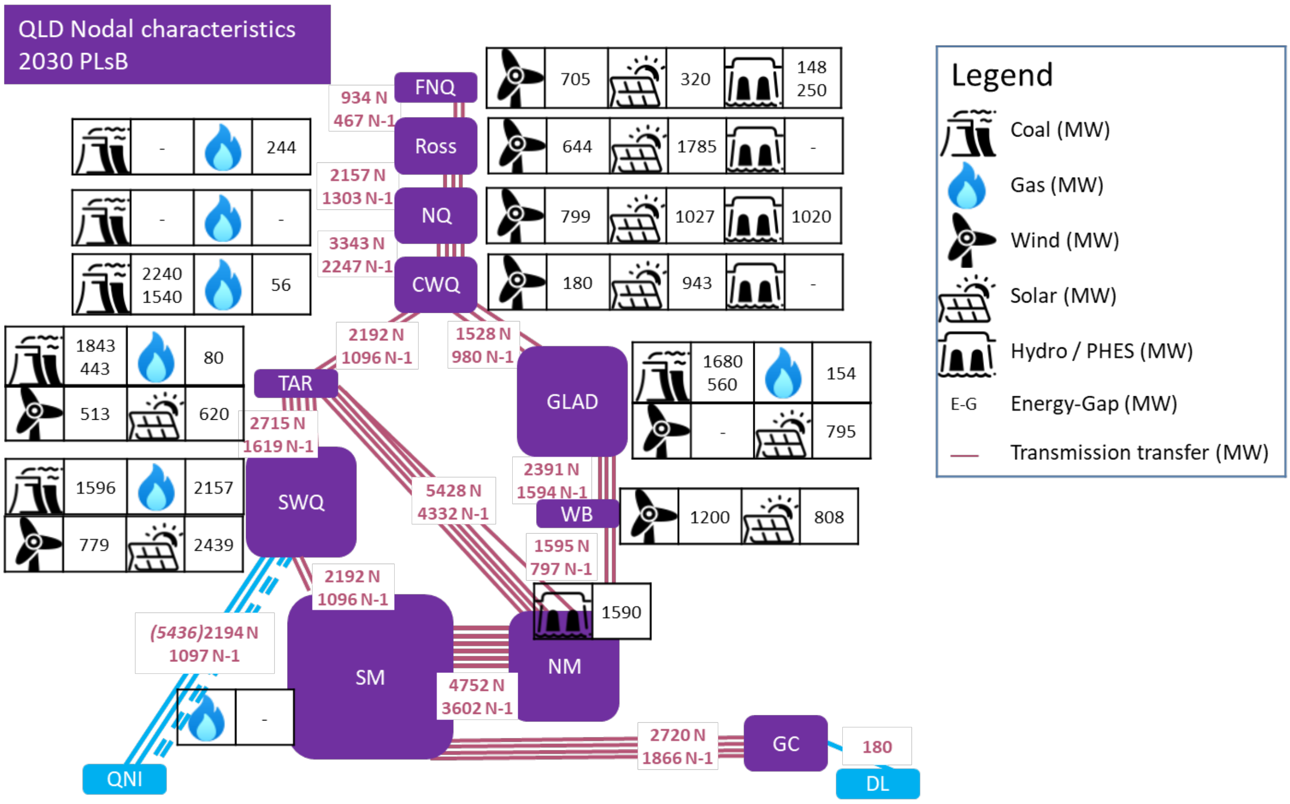

Figure 1: QLD ANEM nodal structure for sB

iii. QLD ANEM transmission corridors for sB

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 sB

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, and that transmission lines are always operational – provides ideal setting for dispatch
[3] Assumes removal of the largest line from the transmission corridor between nodes – matches transmission planning frameworks, and how AEMO manages the grid in practice.

iv. QLD ANEM generation capacity assumptions for sB

Table 2: Queensland capacity assumptions under sB

Queensland Capacity	Current [4] (MW)	2030 (MW)	Notes
Coal	8,059	4,839	Closures: Callide B 700MW, Gladstone 1,2,5,6 1120MW, Stanwell 1-2 730MW, Tarong 1-2 700MW Capacity factor: 75% (full year); 81% (SummWD)
Gas	3,076	2,622	Closures: Swanbank E 385MW Capacity factor: 31% (full year); 31% (SummWD)
Hydro	148	148	Closures: None Capacity factor: 16% (full year); 15% (SummWD)
Solar	1,784	8,736	Capacity factor: 25% (full year); 28% (SummWD) Curtailment SummWD: 16%, Max 5078MW
Wind	641	4,820	Capacity factor: 37% (full year); 36% (SummWD) Curtailment SummWD: 5%, Max 1646MW
PHES	570	2,860	Capacity factor: 14% (full year); 13% (SummWD)
Storage/Other	-	4034 (Summ) 4,573 (Year)	E-G Capacity factor; 17% (full year); 17% (SummWD)
TOTAL	14,242	28,598	

[4] Source: AEMO Generation Information July 2020

v. QLD modelling outcomes for Summer Weekdays (SummWD)

1. QLD Fuel share of electricity generated

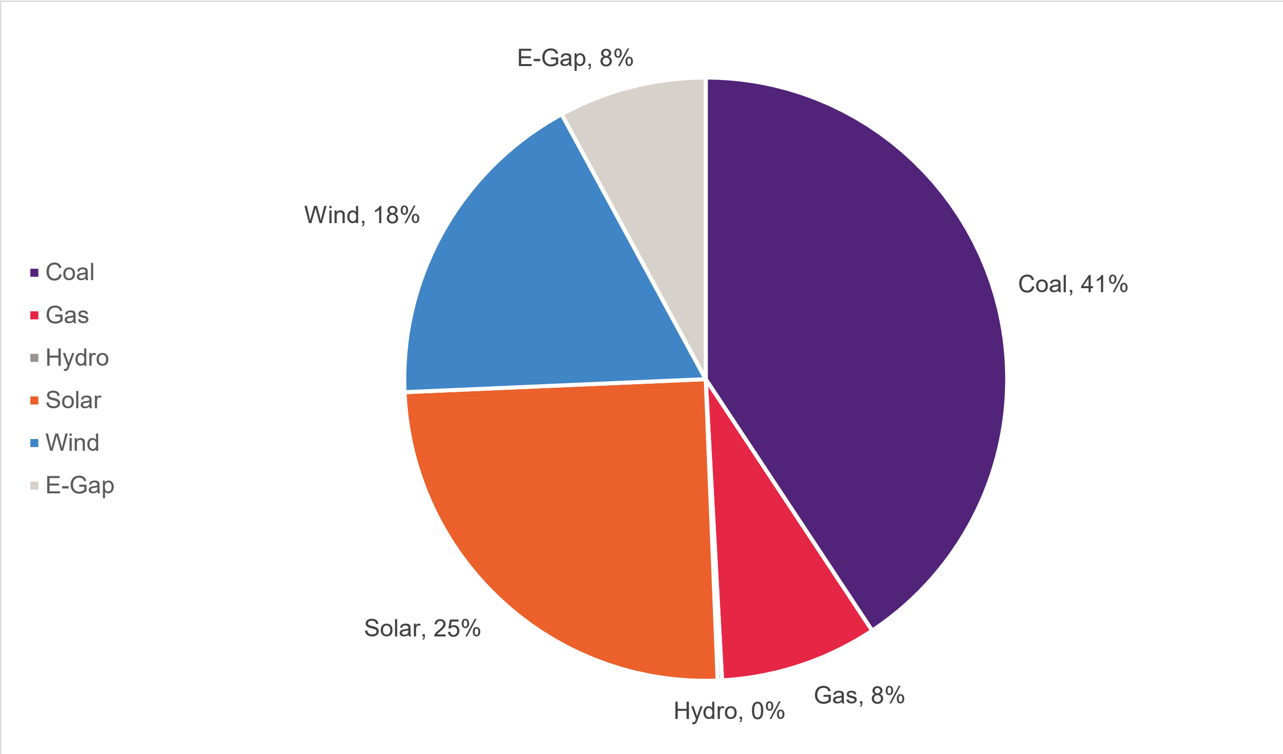

Figure 2: QLD Fuel share during summer weekdays under sB

Modelling outcomes predict that 41% of electricity generated in QLD in 2030 is sourced from coal, 25% from solar, 18% from wind, 8% from gas and 0% from hydro as shown in Figure 1. Under these assumptions it is possible to achieve the QRET of all energy supplied to the NEM. The Energy-Gap (E-G) that emerges is sizeable, at 1104GWh or 7.6% of energy generated, 67GWh of which occurs during the evening peak, 925GWh overnight and 112GWh during daylight.

2. QLD Energy Flows (SummWD)

Figure 2 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 7,106MW
- 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)

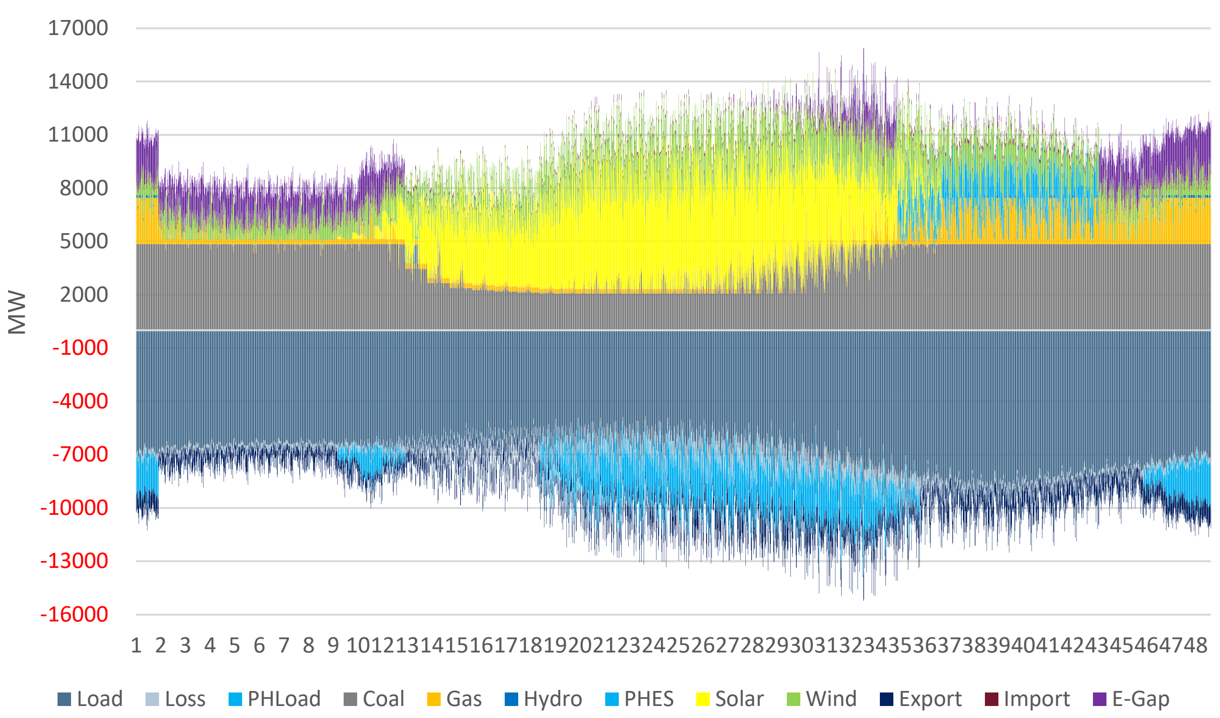

Figure 3: QLD energy flows for SummWD under sB

Table 2 provides totals and averages of SummWD energy flows. Coal generation across the state, with the removal of 3GW of capacity, achieves 81% capacity factor. Gas generation capacity factor reaches 31%. With 16% curtailment of solar energy from potential dispatch, solar generation achieves a capacity factor of 28%. Curtailment of wind energy from potential dispatch is lower than solar at 5%, ensuring that wind generation state-wide achieves 36% capacity factor. E-G is persistent overnight, pre-evening peak and evening peak at 1840-1930MW (periods 1-12, 31-33, 34-42 and 43-48) and, occasionally highly elevated to a maximum of 4034MW. QLD exports to NSW (1471GWh) with very low levels of imports from NSW to QLD (168GWh), which suggests the important role that imports from QLD play in supporting energy flows to Newcastle when Liddell and Eraring close.

Table 3: QLD Salient statistics under sB

QLD Energy Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(10,233)	(8,531)	(7,106)	(10,489)	68%	(6,834)
PH_Load	(1,570)	(564)	(1,090)	(2,760)	40%	(290)
Coal	5,665	4,781	3,934	4,839	81%	4,836
Gas	1,176	1,436	816	2,624	31%	292
Hydro	33	46	23	148	15%	0
PH_Disp	515	1,505	358	2,860	13%	0
Solar	3,472	948	2,411	8,115	28%	1,001
Wind	2,472	2,136	1,717	4,630	36%	1,682
E-G	1,104	385	767	4,034	19%	90
Exports	(1,471)	(1,213)	(1,022)	(2,737)	37%	(992)
Imports	168	123	117	180	65%	180
Solar_spill	662	2	460	5,078	9%	0
Wind_spill	119	15	83	1,646	5%	0
PH_Spill	858	783	596	2,860	21%	0
Solar spill %	16%	0%	16%	38%		0
Wind spill %	5%	1%	5%	26%		0

3. QLD Generation adequacy

The maximum for coincident E-G is 4.0GW, although the median E-G is 90MW, and a capacity factor of 19%, indicating persistent coincident E-G periods. 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 2 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 3 provides coincident detail of E-G. Figure 3 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 sB

Energy-Gap	Periods	>3000	>2500	>2000	>1000	>500	>100	>0	=0
Total		27	112	109	797	187	139	289	1220
% of periods		0.9%	4%	4%	28%	6%	5%	10%	42%
Overnight	43-48, 0-12	27	105	90	681	81	11	48	37
Evening Peak	34-42	-	7	19	47	30	34	205	215
Daylight	20-29	-	-	-	69	76	94	36	968

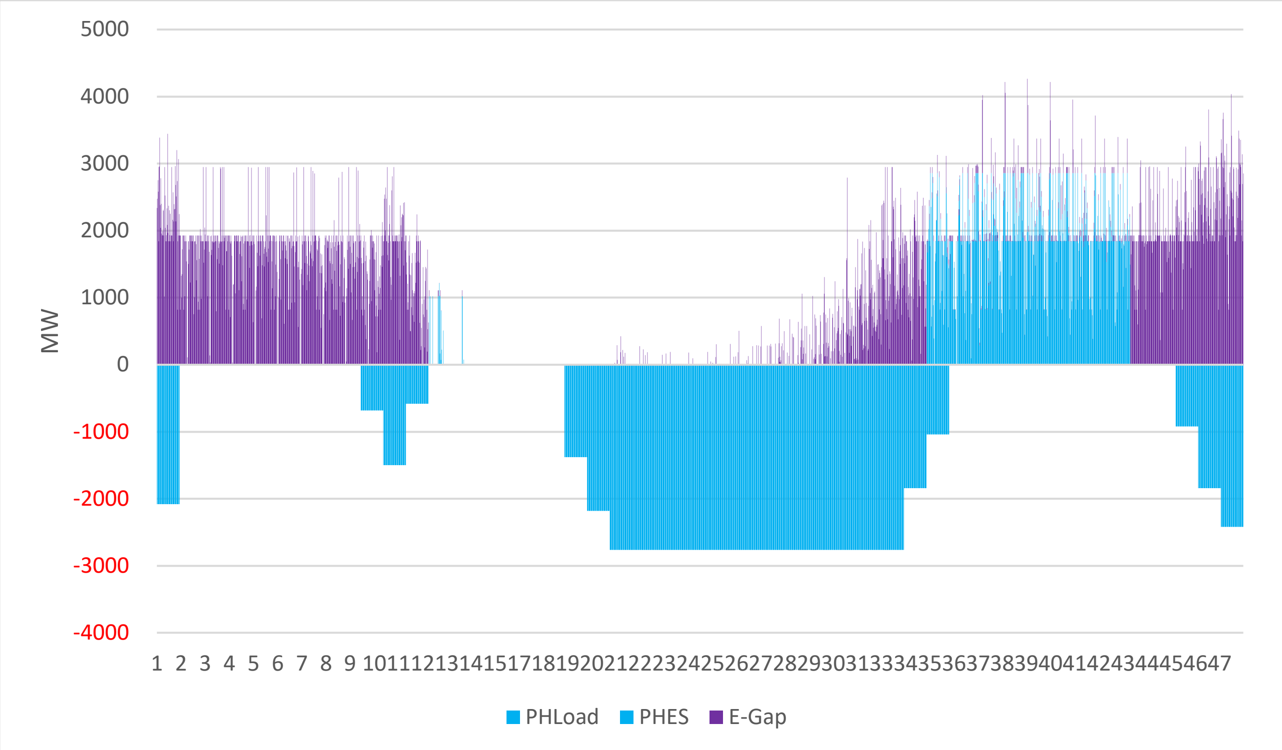

Figure 4: QLD Coincident Energy Gap under sB

4. QLD Variable Renewable Energy (VRE) Resource

Solar achieves 28% capacity factor because of 16% curtailment from potential resource due to excess wind and coal generation available during the day as detailed in Figure 4 below. Wind provides a less predictable resource as detailed in Figure 5 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.

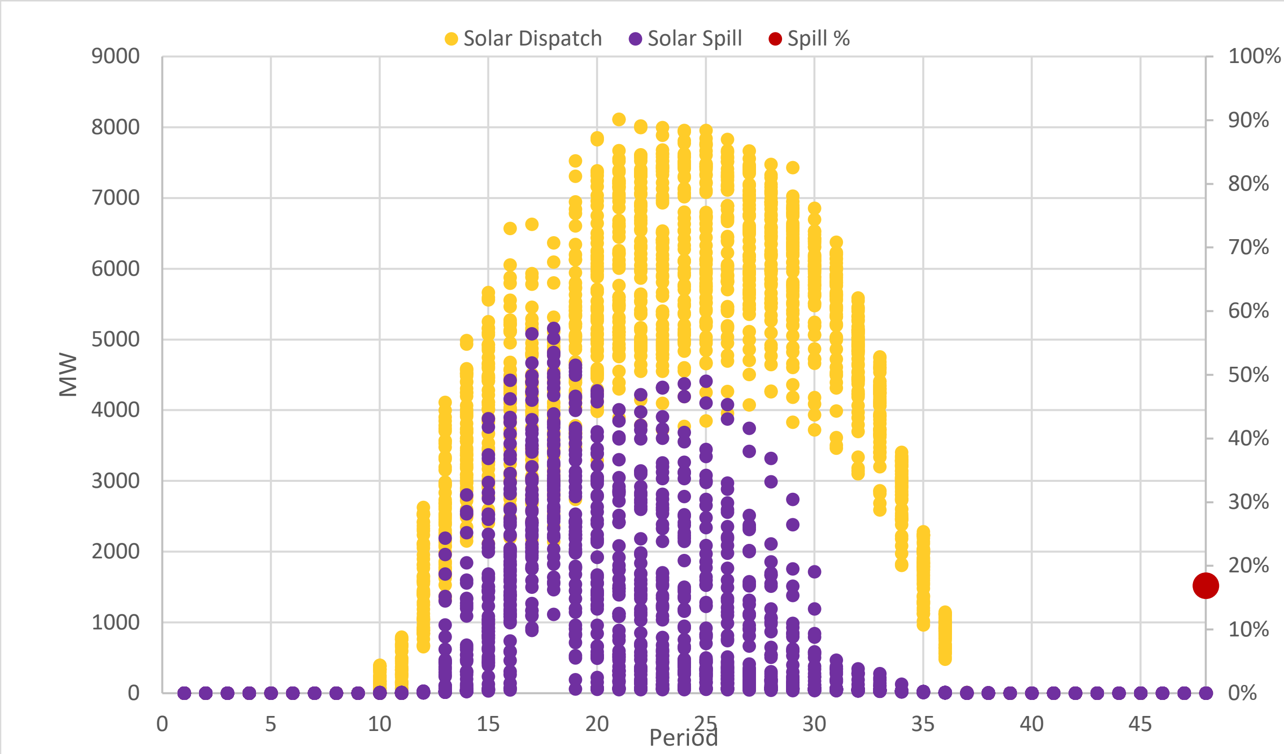

Figure 5: QLD Coincident solar dispatch and curtailment under sB

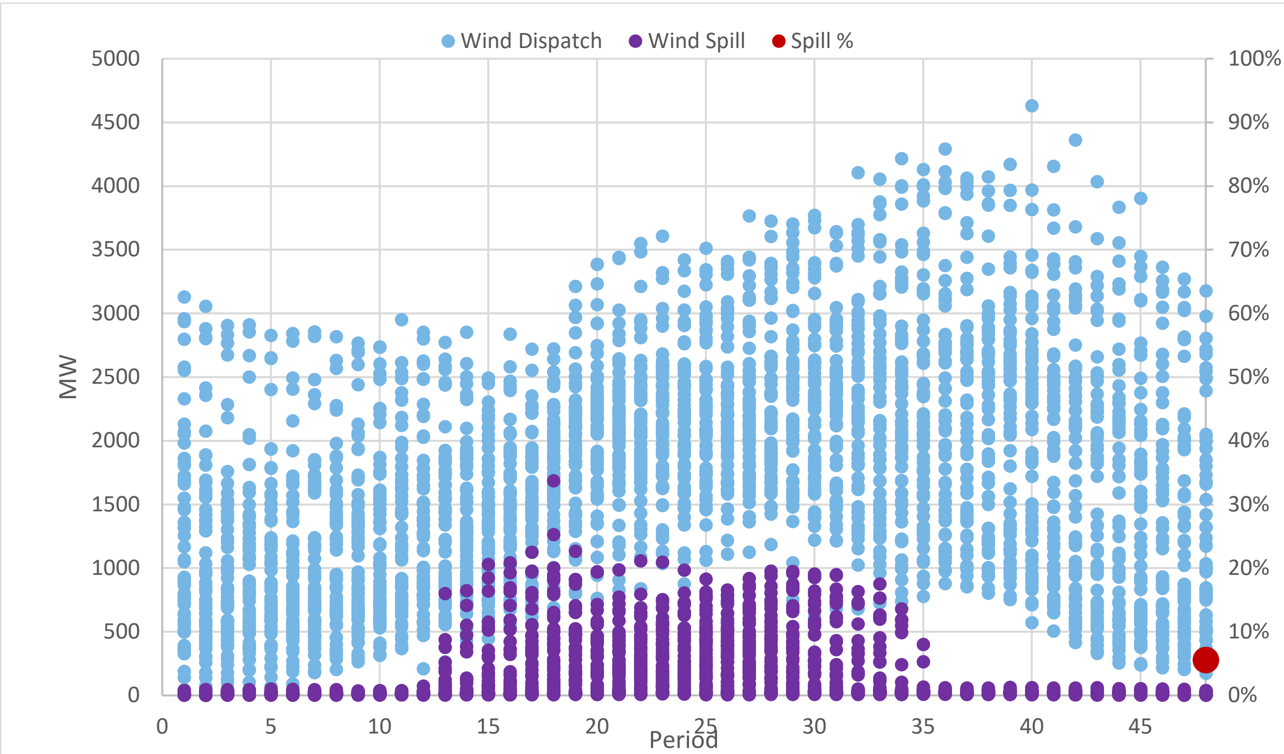

Figure 6: QLD Coincident wind dispatch and curtailment under sB

5. QLD exports/imports to NSW

There are no imports to QLD from NSW. Energy flows from QLD to NSW at an average of 989MW and a maximum of 2.5GW. Figure 6 gives detail.

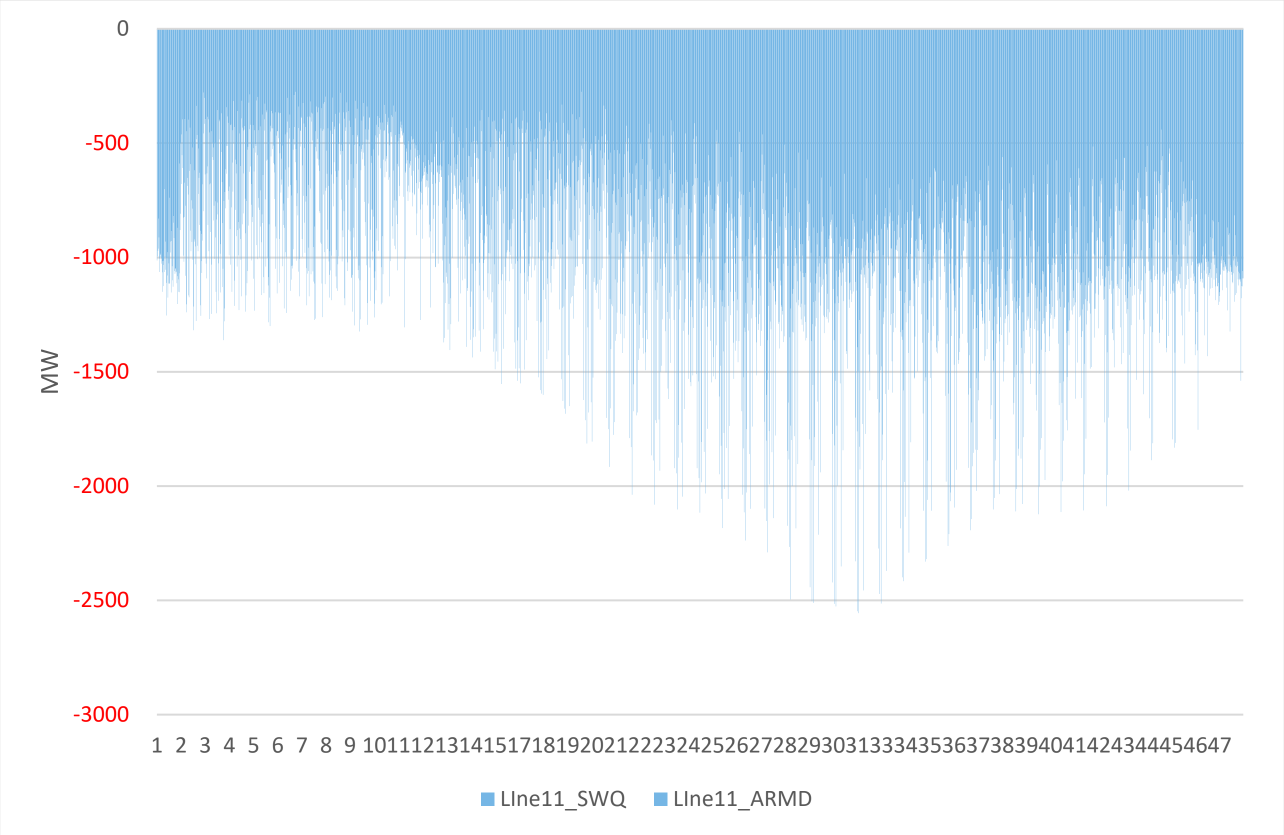

Figure 7: Energy flows to and from NSW on QNI for SummWD under sB

6. FNQ details for summer weekdays

Assumptions for Far North Queensland (FNQ) generation capacity are detailed in Table 4.

Table 5: Far North Queensland capacity assumptions under sB

FNQ Capacity	Current [5] (MW)	2030 (MW)	Notes
Hydro	148	148	Capacity factor (CF): 15%
Wind	192	705	CF AllYear 40%, CF SummWD 28% Curtail SummWD -%, Max curtail 148MW
Solar	50	320	CF AllYear 35%, CF SummWD 35% Curtail SummWD -%, Max curtail 56MW
PHES	-	250	CF AllYear 20%, CF SummWD 17%
Storage/E-G		250	CF AllYear 34%, CF SummWD 34%
TOTAL	390	1673	

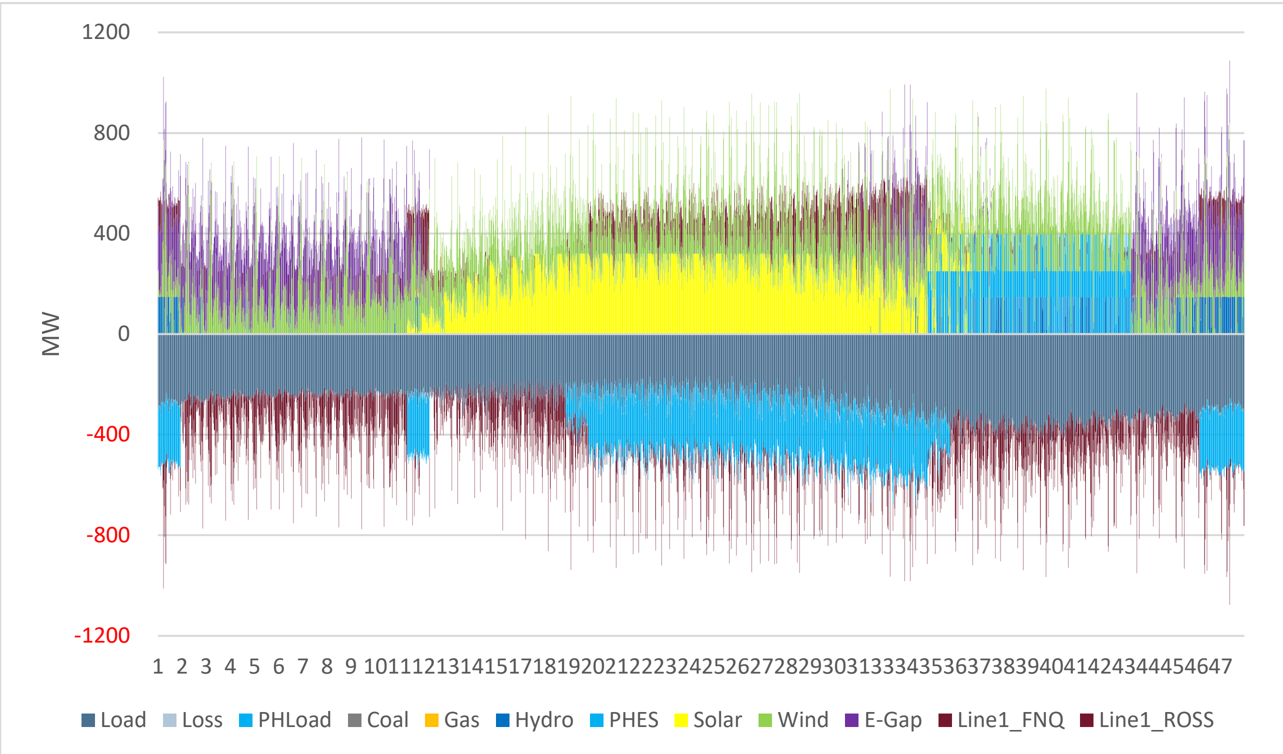

Figure 8: Far North Queensland energy flows for SummWD under sB

Figure 7 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:

[5] Source: AEMO Generation Information July 2020

- the steel grey coloured series indicates FNQ demand, an average of 279MW
- 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 wind resource overnight leads to sustained E-Gs. Solar reaches a capacity factor of 35% over SummWDs. Wind reaches a capacity factor of 28% suggesting low wind resource in FNQ.
- There is little solar curtailment in FNQ node, as shown in Figure 9
- There is little wind curtailment in FNQ node, as shown in Figure 10
- the purple coloured series indicates E-G. E-G occurs during periods 44-48 and 1-12, as is shown in Figure 8. E-G maximises at 250MW with an average of 84MW, but a relatively high capacity factor of 34% shows persistence
- Table 5 provides the salient statistics on FNQ energy flows

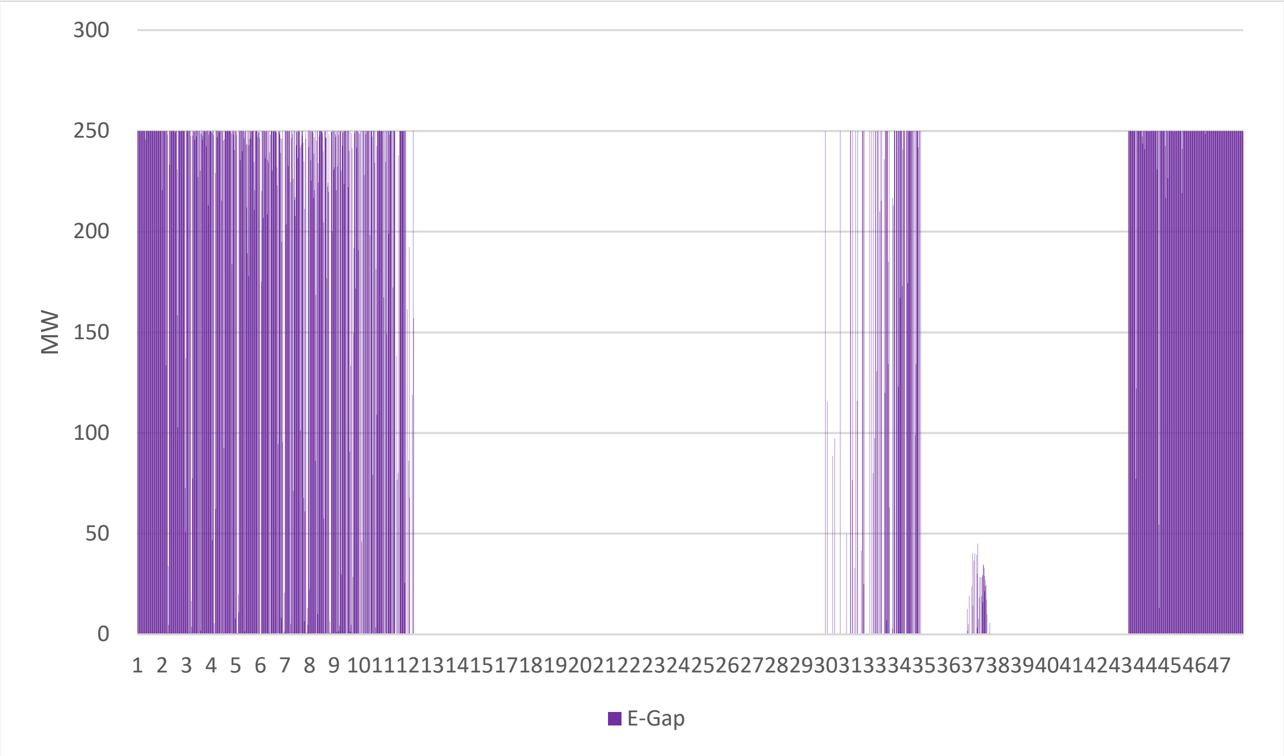

Figure 9: Far North Queensland Energy Gap during SummWD in SB

This clustering of E-G overnight from 10pm to 6am is evidence of a lack of wind resource to sustain demand both for consumption and for pumping. There is also evidence of insufficient generation to meet demand 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 9 where solar generation falls sharply from period 33 and Figure 10 where wind generation is 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 sB

FNQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(401)	(354)	(279)	(452)	62%	(265)
PH Load	(144)	(60)	(100)	(240)	42%	0
Hydro	33	46	23	148	15%	0
PHES	62	182	43	250	17%	0
Solar	163	49	113	320	35%	35
Wind	286	223	199	705	28%	165
E-G	122	31	84	250	34%	0
Exports (node)	(158)	(130)	(110)	(635)	17%	(77)
Imports (node)	46	19	32	447	7%	0
Solar_spill	0	0	0	56	1%	0
Wind_spill	0	0	0	148	-%	0
PH_spill	58	18	40	250	16%	0
Solar spill %	-%	-%	-%			
Wind spill %	-%	-%	-%			

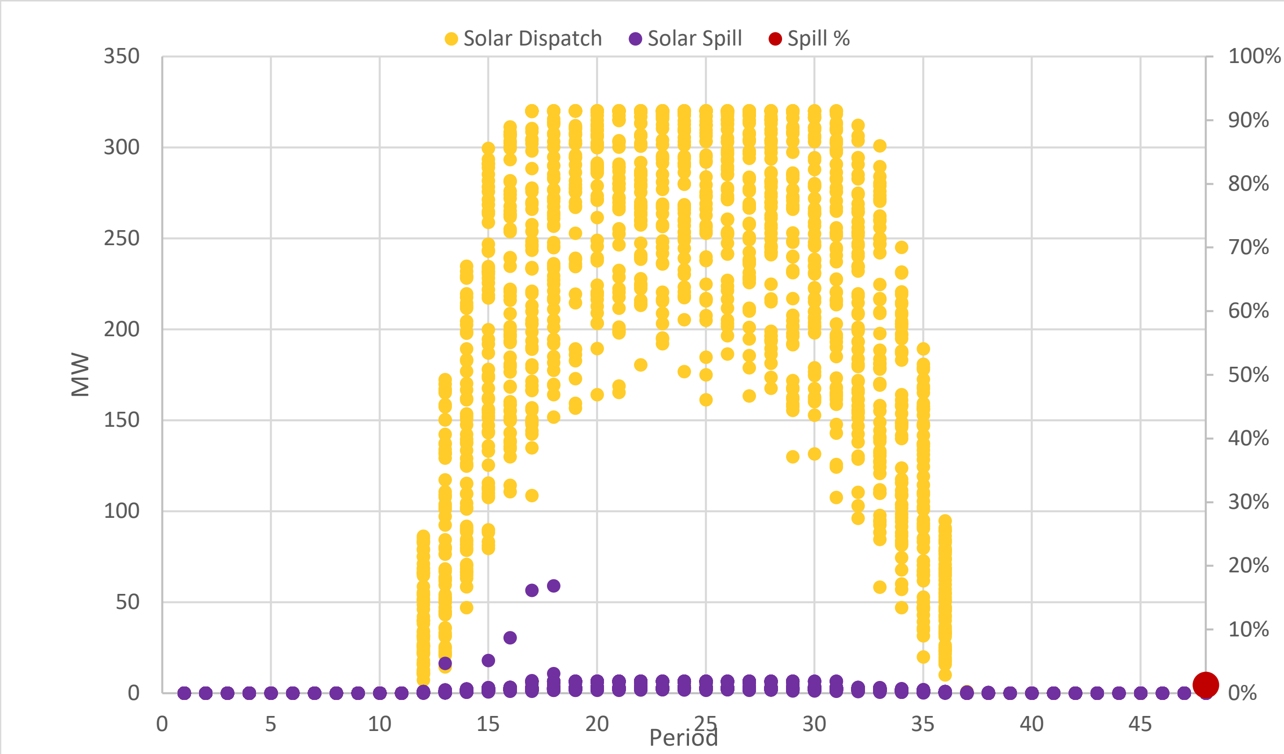

Figure 10: Far North Queensland solar dispatch and curtailment under sB

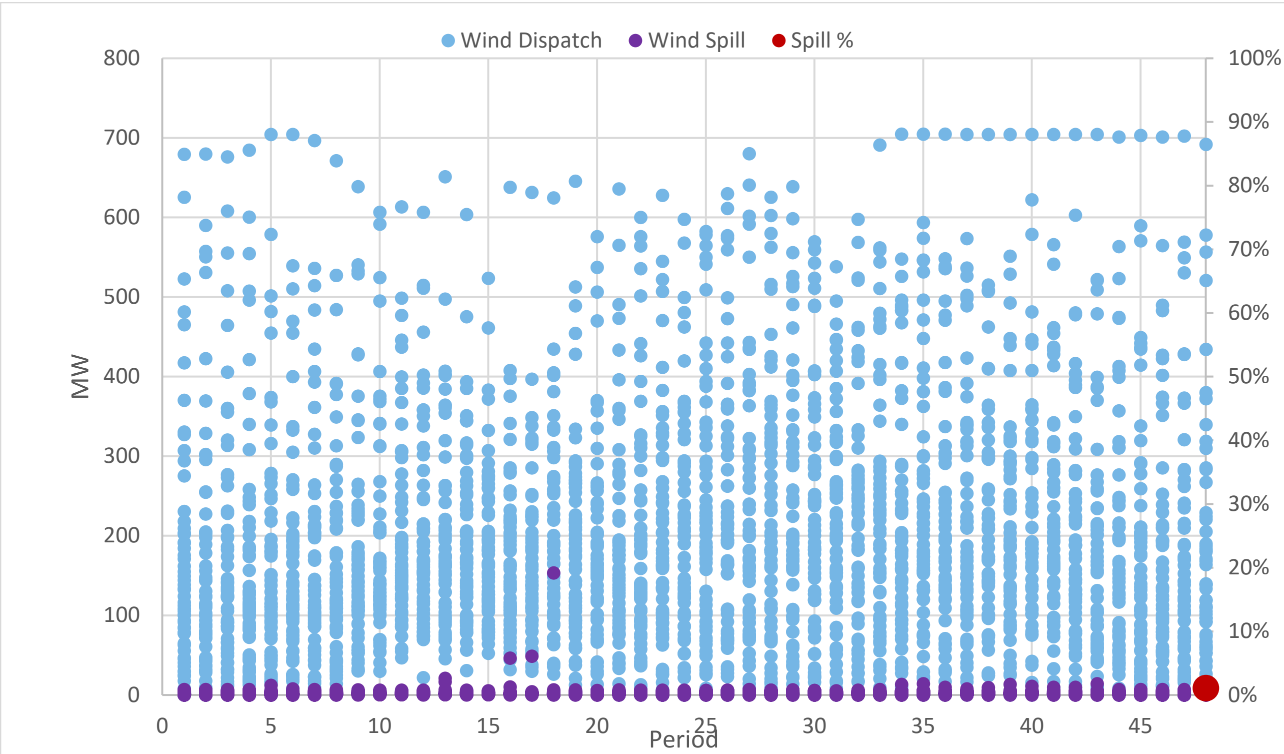

Figure 11: Far North Queensland wind dispatch and curtailment under sB

7. ROSS details for summer weekdays

Table 6 provides a summary of Ross generation capacity assumptions

Table 7: Ross capacity assumptions under sB

ROSS Capacity	Current [6] (MW)	2030 (MW)	Notes
Gas	244	244	CF AllYear 44%; CF SummWD 45%
Wind	-	644	CF AllYear 38%; CF SummWD 27% Curtail SummWD -%; Max 87MW
Solar	497	1785	CF AllYear 24%; CF SummWD 27% Curtail SummWD 24%; Max 1497MW
Storage/Other/ E-G	-	423	CF AllYear 1%; CF SummWD 2%
TOTAL	741	3096	

[6] Source: AEMO Generation Information July 2020

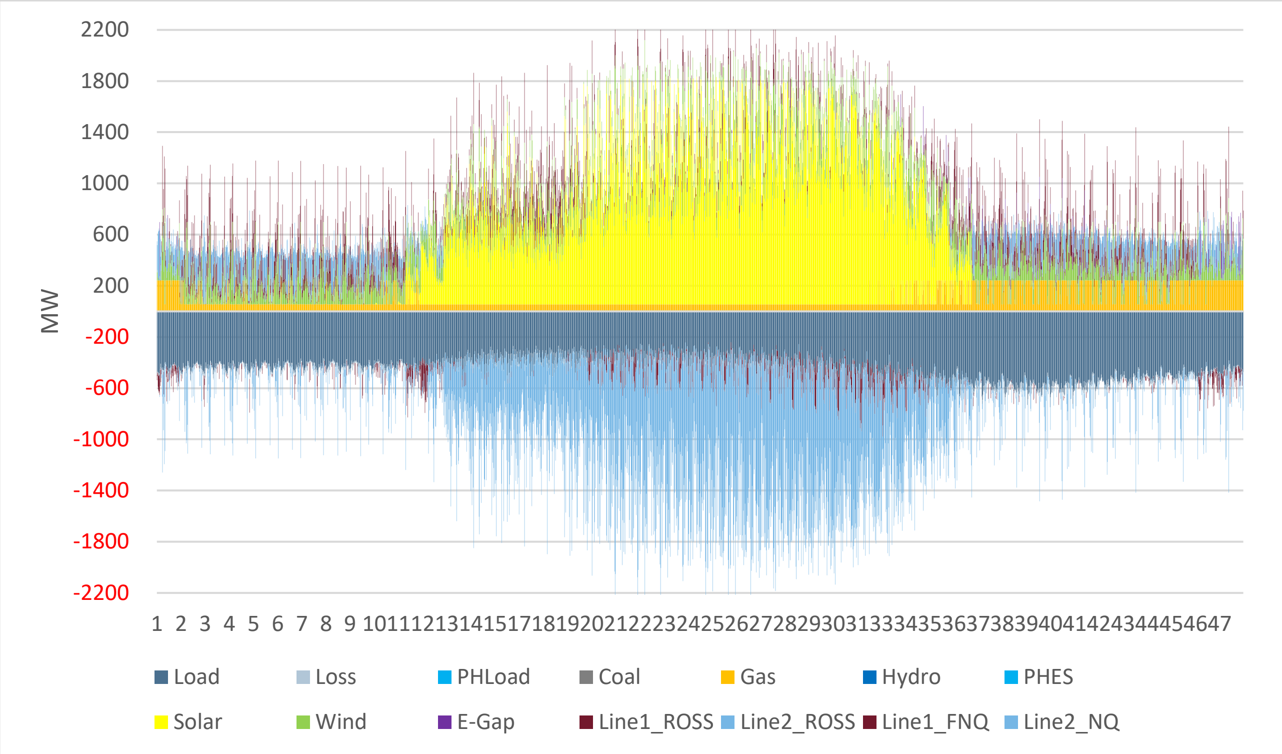

Figure 12: Ross energy flows for SummWD under sB

Figure 11 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 southwards towards North Queensland predominantly during daylight hours, and lesser transfers at other times
- the steel-blue coloured series indicates demand in Ross node which averages 445MW
- the gold coloured series indicates gas generation from 244MW. Gas generation achieves capacity factor of 45% which is persistently dispatched during evening peak and overnight.
- the yellow coloured series indicates solar generation from 1785MW. Solar generation achieves a capacity factor of 27% due to high levels of curtailment (24%) from potential dispatch. Figure 13 provides detail.
- the green coloured series indicates wind generation from 644MW. Wind generation achieves a capacity factor of 27% indicating a modest wind resource in ROSS. Figure 14 provides detail.
- the purple coloured series indicates Energy-Gap (E-G). E-G in ROSS occurs during evening peak and overnight at 400MW. Figure 12 provides detail

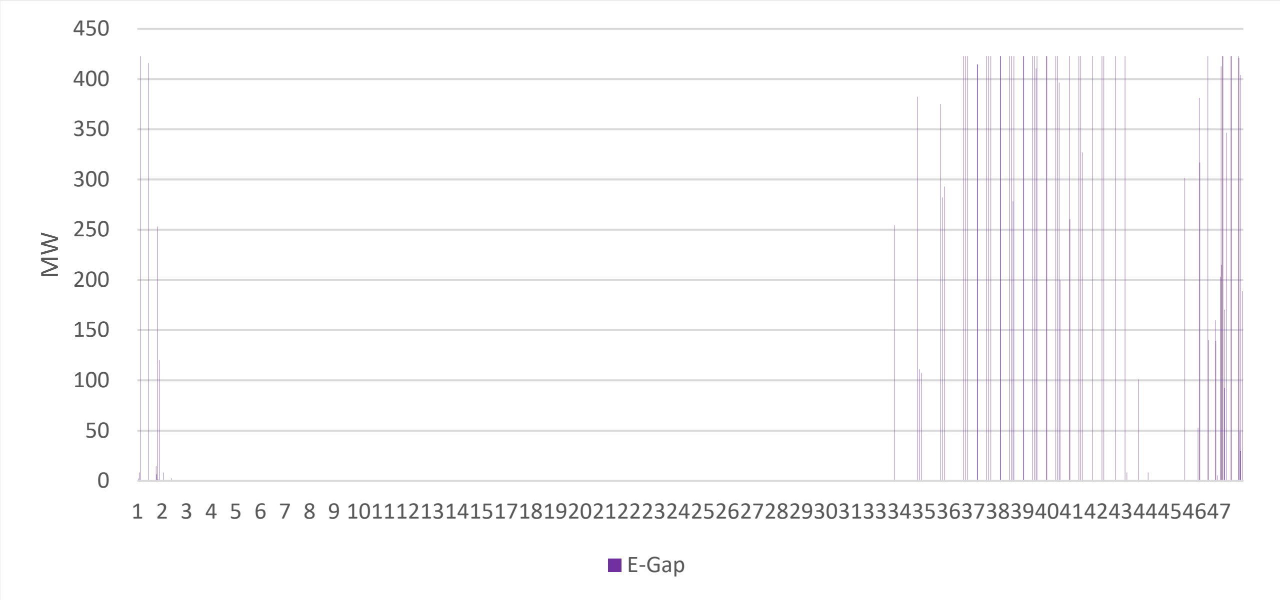

Figure 13: Ross energy gap for SummWD under sB

Table 7 details statistics for Ross energy flows

Table 8: ROSS salient statistics under sB

ROSS Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(641)	(554)	(445)	(748)	60%	(437)
Gas	157	169	109	242	45%	56
Solar	690	268	479	1,785	27%	224
Wind	248	192	172	644	27%	136
E-G	12	26	8	423	2%	0
Exports (node)	(675)	(267)	(468)	(1,925)	24%	(309)
Imports (node)	258	204	179	732	25%	182
Solar_spill	222	0	154	1,497	10%	0
Wind_spill	0	0	0	87	0%	0
Solar spill %	24%	-%	24%			
Wind spill %	-%	-%	-%			

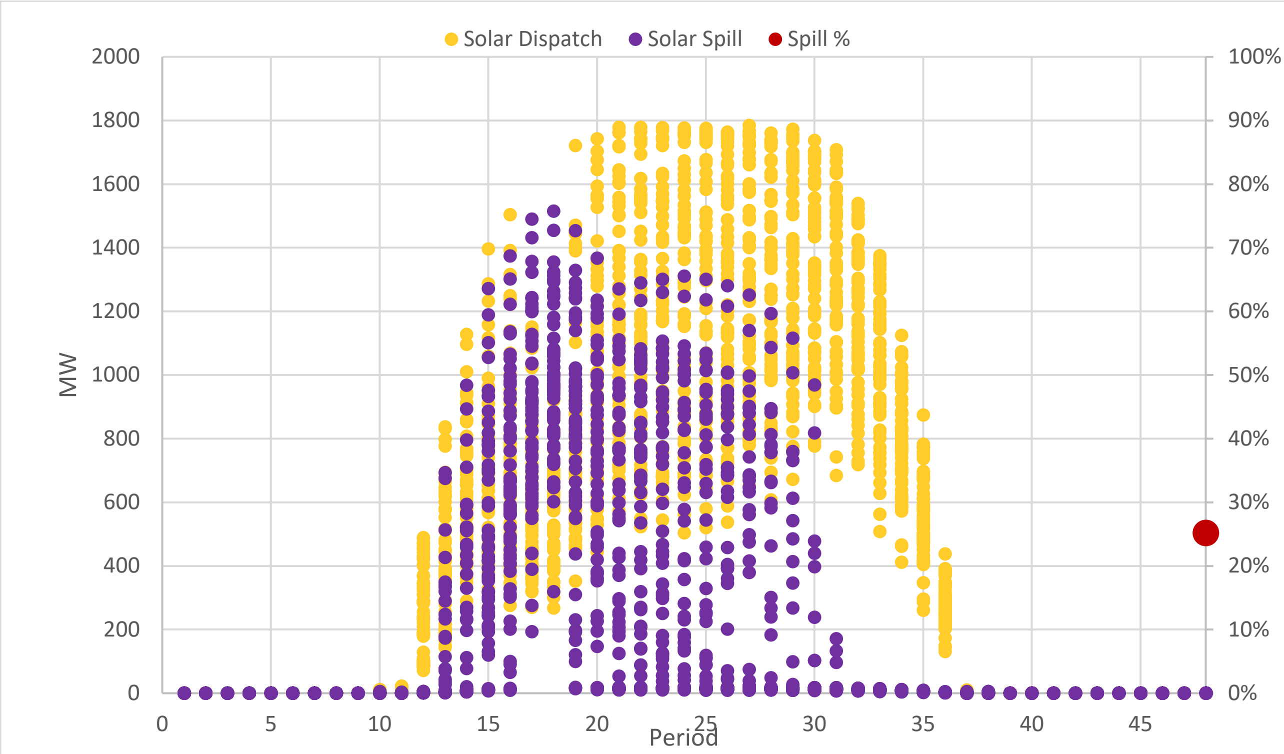

Figure 14: Ross solar dispatch and curtailment under sB

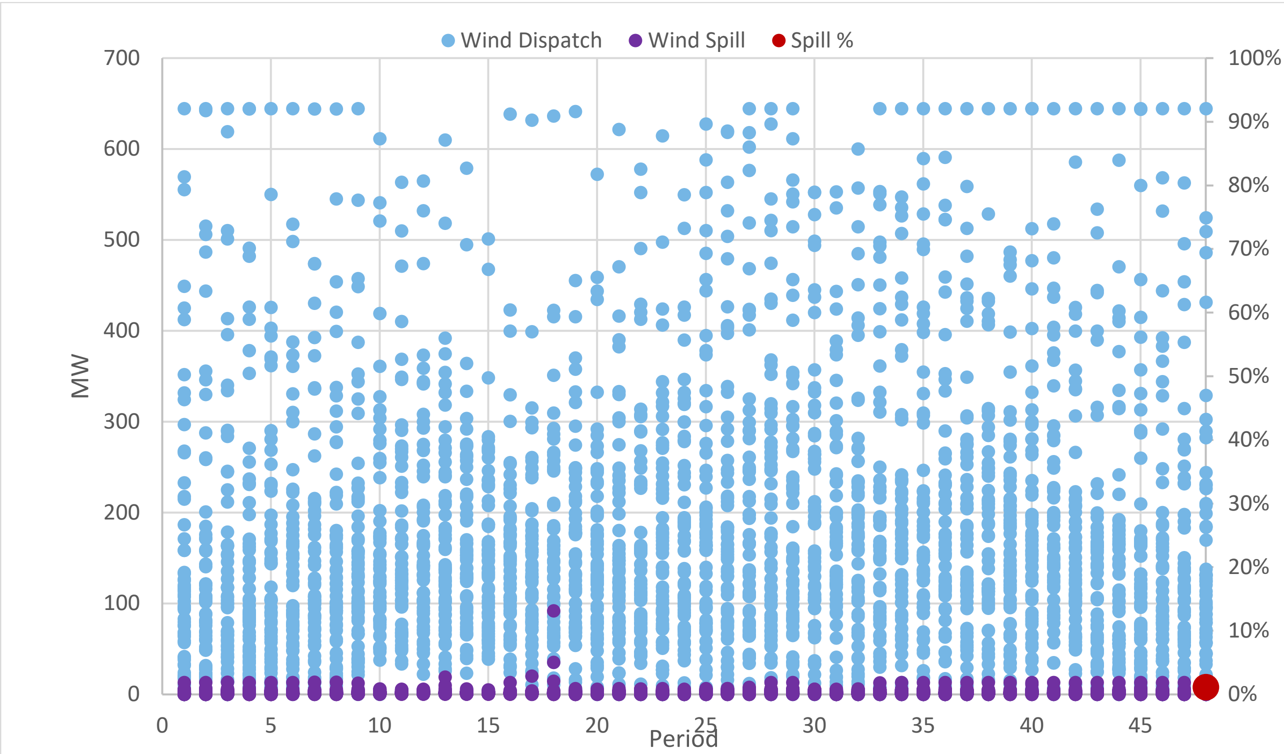

Figure 15: Ross wind dispatch and curtailment under sB

8. NORTH QUEENSLAND details for summer weekdays

Table 8 summarises the generating capacity assumptions for North Queensland (NQ)

Table 9: North Queensland capacity assumptions under sB

NQ Capacity assumptions	Current [7] (MW)	2030 (MW)	Notes
Wind	-	799	CF AllYear 38%; CF SummWD 37% Curtail SummWD 1%; Max 306MW
Solar	382	1027	CF AllYear 29%; CF SummWD 31% Curtail SummWD 10%; Max 753MW
PHES	-	1110	CF AllYear 11%; CF SummWD 10%
Storage/E-G	-	533	CF AllYear 20%; CF SummWD 20%
TOTAL	382	3469	

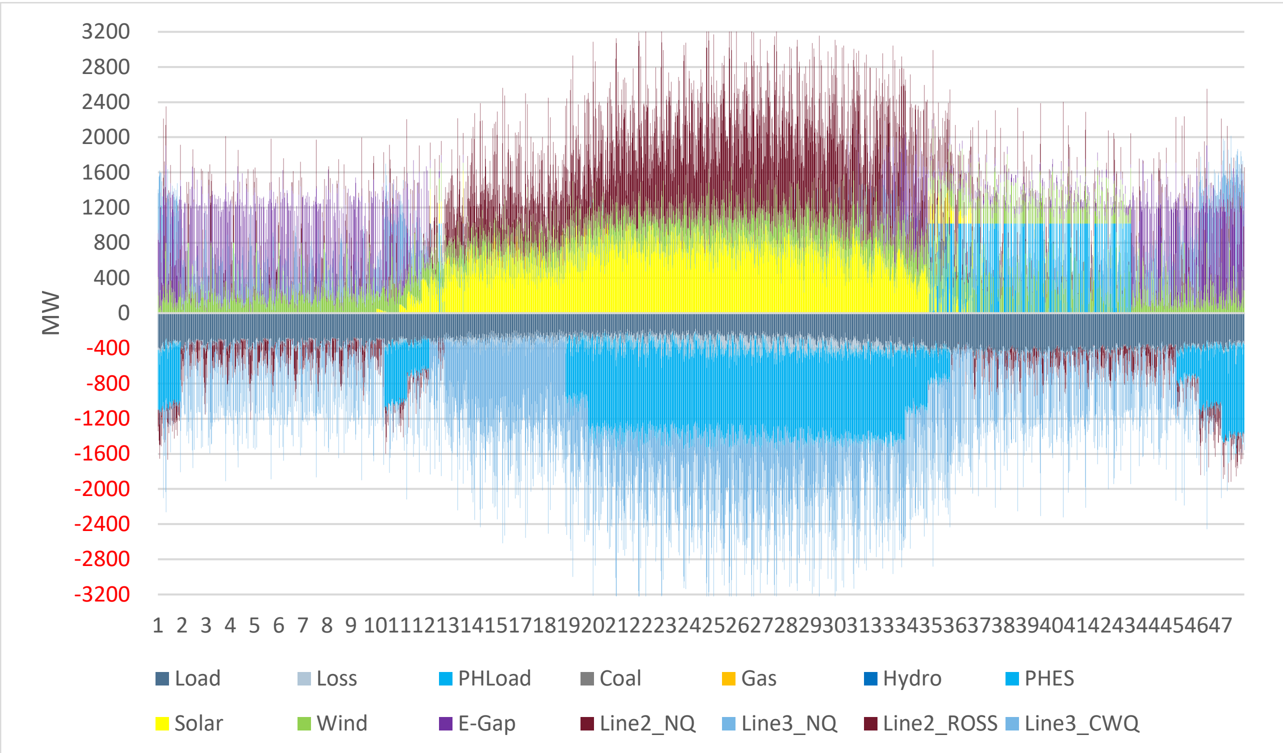

Figure 16: North Queensland energy flows for SummWD under sB

[7] Source: AEMO Generation Information July 2020

Figure 15 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. Imports are predominantly during daylight.
- the light blue coloured series indicates exports to CWQ, primarily during daylight, with regular imports for evening peak and overnight.
- the steel-blue coloured series indicates demand in NQ which averages 337MW
- the yellow coloured series indicates solar generation from 1027MW. Solar generation achieves a capacity factor of 31% with 10% curtailment from potential dispatch. Figure 17 provides detail.
- the green coloured series indicates wind generation from 799MW. Wind generation achieves a capacity factor of 37% with modest curtailment (1%) from potential dispatch. Figure 18 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 16 provides detail.

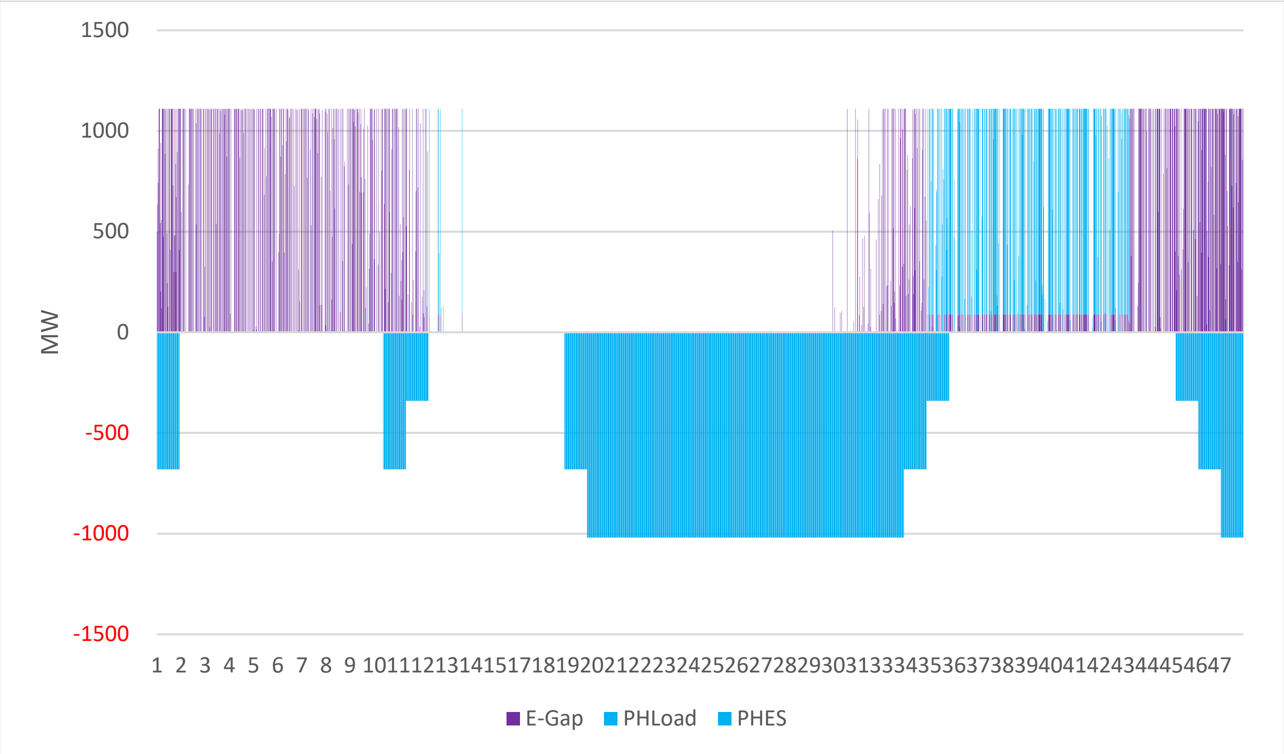

Figure 17: North Queensland energy-gap for SummWD under sB

Table 9 details statistics for NQ energy flows

Table 10: North Queensland salient statistics under sB

NQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(485)	(415)	(337)	(548)	61%	(333)
PH Load	(592)	(204)	(411)	(1,020)	40%	0
PHES	150	434	104	1,020	10%	0
Solar	460	139	319	1,027	31%	150
Wind	426	345	296	799	37%	269
E-G	316	116	219	1,110	20%	0
Exports (node)	(944)	(661)	(655)	(2,129)	31%	(667)
Imports (node)	762	314	529	1,925	27%	475
Solar_spill	52	0	36	753	5%	0
Wind_spill	2	0	2	306	0%	0
Solar spill %	10%	0%	10%			
Wind spill %	1%	0%	1%			

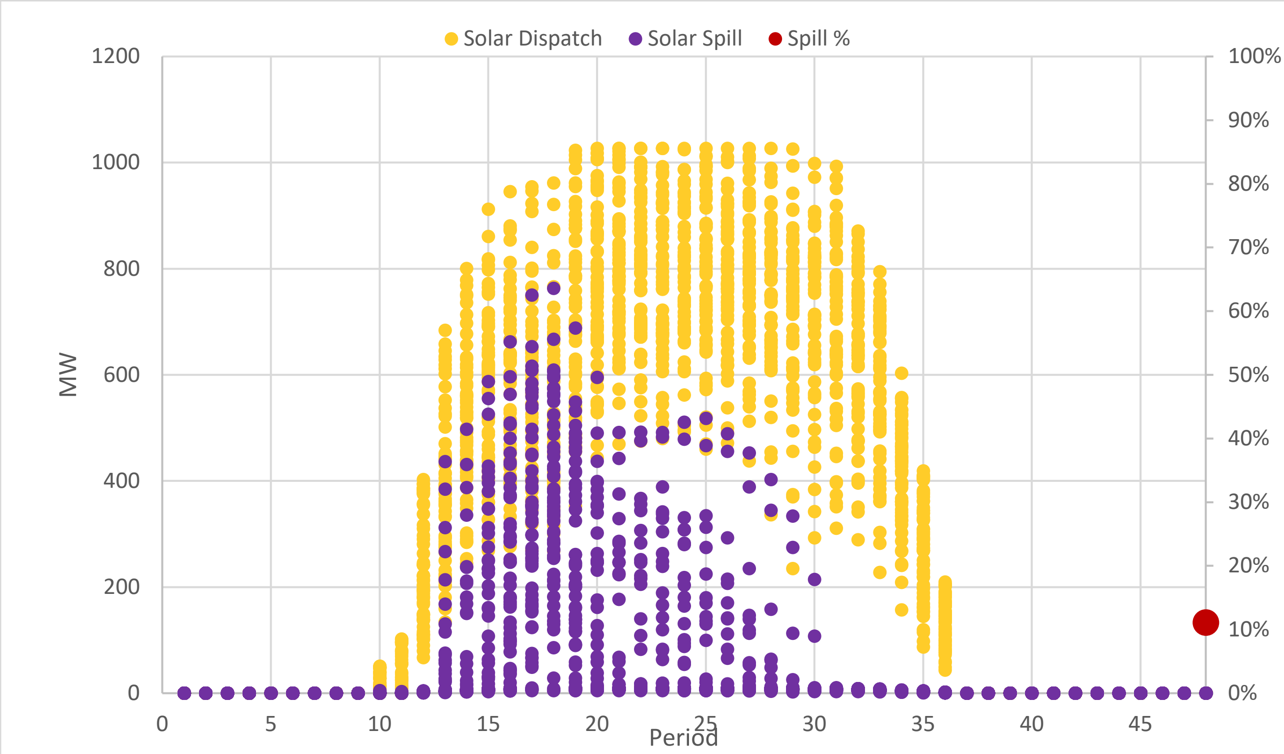

Figure 18: North Queensland solar dispatch and curtailment under sB

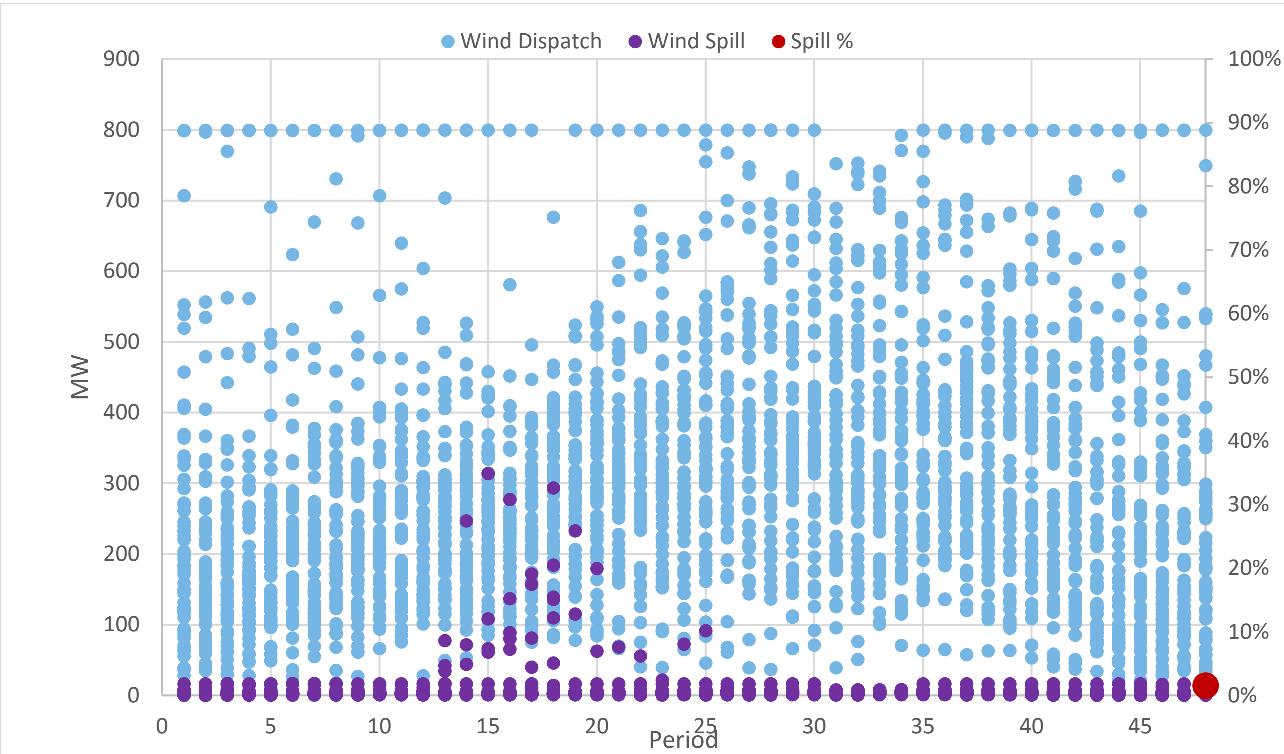

Figure 19: North Queensland wind dispatch and curtailment under sB

9. CENTRAL WEST QUEENSLAND details for summer weekdays

Table 10 summarises generating capacity assumptions for Central West Queensland (CWQ)

Table 11: CWQ capacity assumptions under sB

CWQ Capacity assumptions	Current [8] (MW)	2030 (MW)	Notes
Coal	2940	1540	CF AllYear 74%; CF SummWD 79%
Gas	56	55	CF AllYear 22%; CF SummWD 21%
Wind	-	180	CF AllYear 37%; CF SummWD 38% Curtail SummWD -%; Max 19MW
Solar	382	943	CF AllYear 30%; CF SummWD 34% Curtail SummWD 9%; Max 632MW
Storage/E-G	-	-	CF AllYear -%: CF SummWD -%
TOTAL	3378	2718	

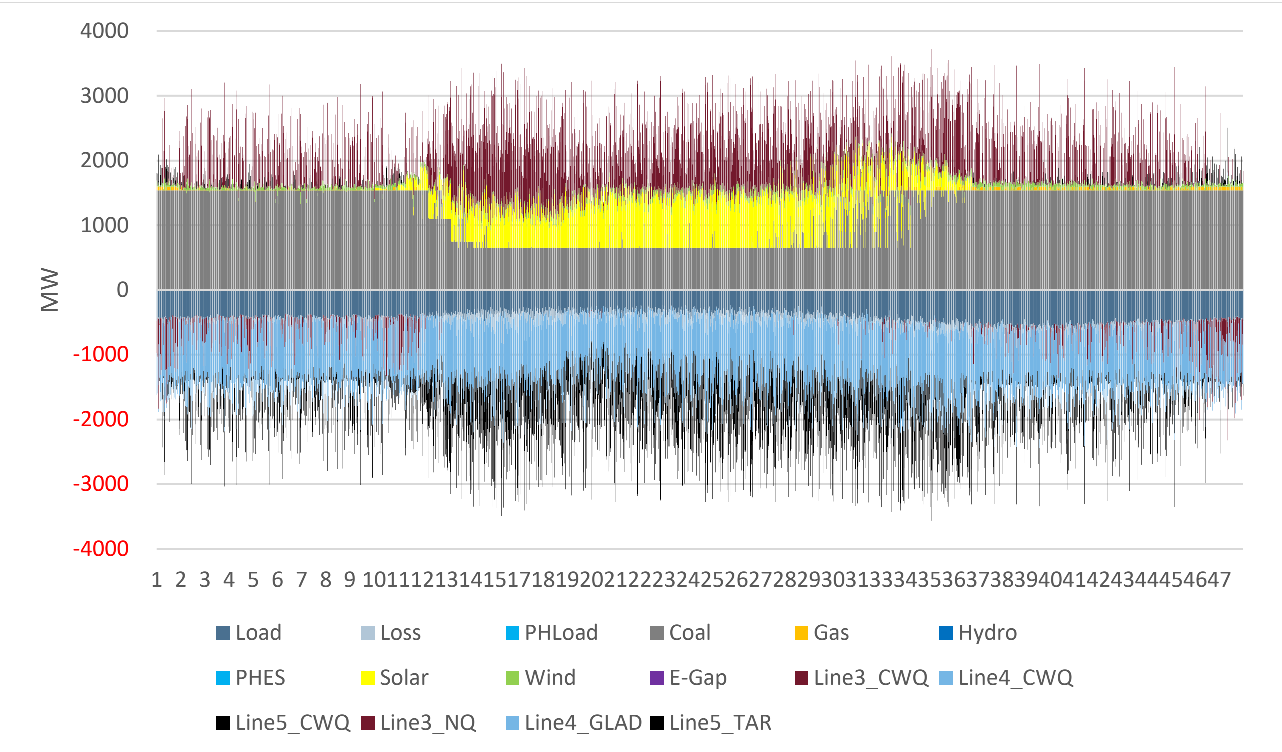

Figure 20: Central West Queensland energy flows for SummWD under sB

[8] Source: AEMO Generation Information July 2020

Figure 19 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, throughout the day but a higher levels during daylight
- 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 428MW
- The light grey coloured series indicates generation from coal capacity of 1540MW. Note the decrease in generation during daylight.
- The gold coloured series indicates generation from gas capacity of 56MW
- The yellow coloured series indicates dispatch from solar capacity of 943MW. Solar dispatch achieves a capacity factor of 34% after curtailment of 9% from potential dispatch. Recall that solar capacity is high during summer, with potential dispatch of 37% capacity factor compared to 28% during winter. Figure 21 shows dispatch and curtailment of solar
- The light green coloured series indicates dispatch from wind capacity of 180MW. Wind dispatch achieves a capacity factor of 38% after curtailment of 0% from potential dispatch. Figure 22 shows dispatch and curtailment of wind
- there are a handful of negligible E-Gs during evening peak in CWQ node. Figure 20 shows detail

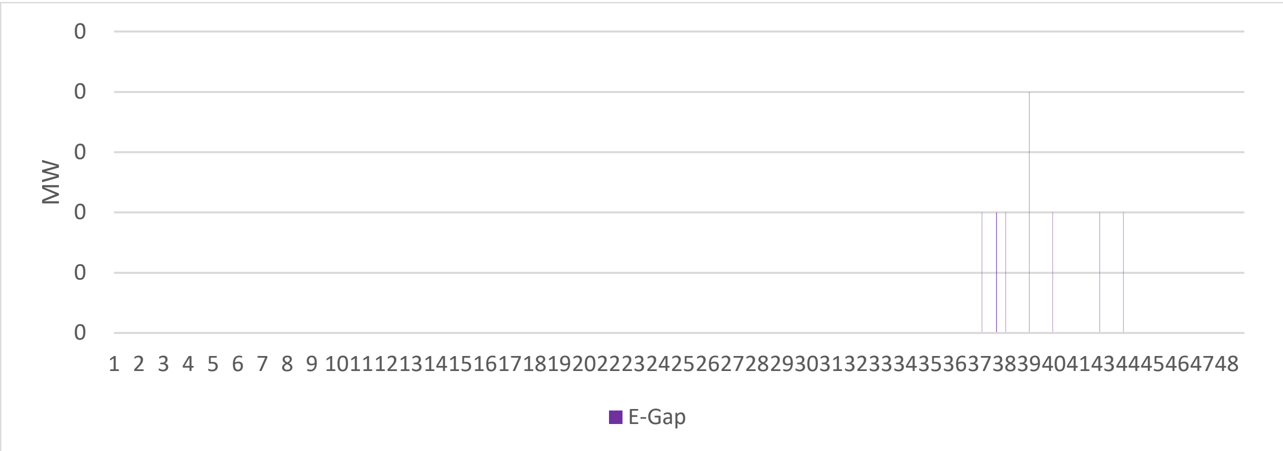

Figure 21: Central West Queensland energy gap for SummWD under sB

Table 11 details statistics for CWQ energy flows

Table 12: Central West Queensland salient statistics under sB

CWQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(617)	(531)	(428)	(692)	62%	(423)
Coal	1,741	1,509	1,209	1,540	79%	1,539
Gas	17	24	12	57	20%	0
Solar	459	141	319	943	34%	156
Wind	98	79	68	180	38%	61
E-G	0	0	0	0	0%	0
Exports (node)	(2,252)	(1,579)	(1,564)	(2,760)	57%	(1,529)
Imports (node)	866	595	602	2,129	28%	580
Solar_spill	44	0	30	632	5%	0
Wind_spill	0	0	0	19	0%	0
Solar spill %	9%	0%	9%			
Wind spill %	0%	0%	0%			

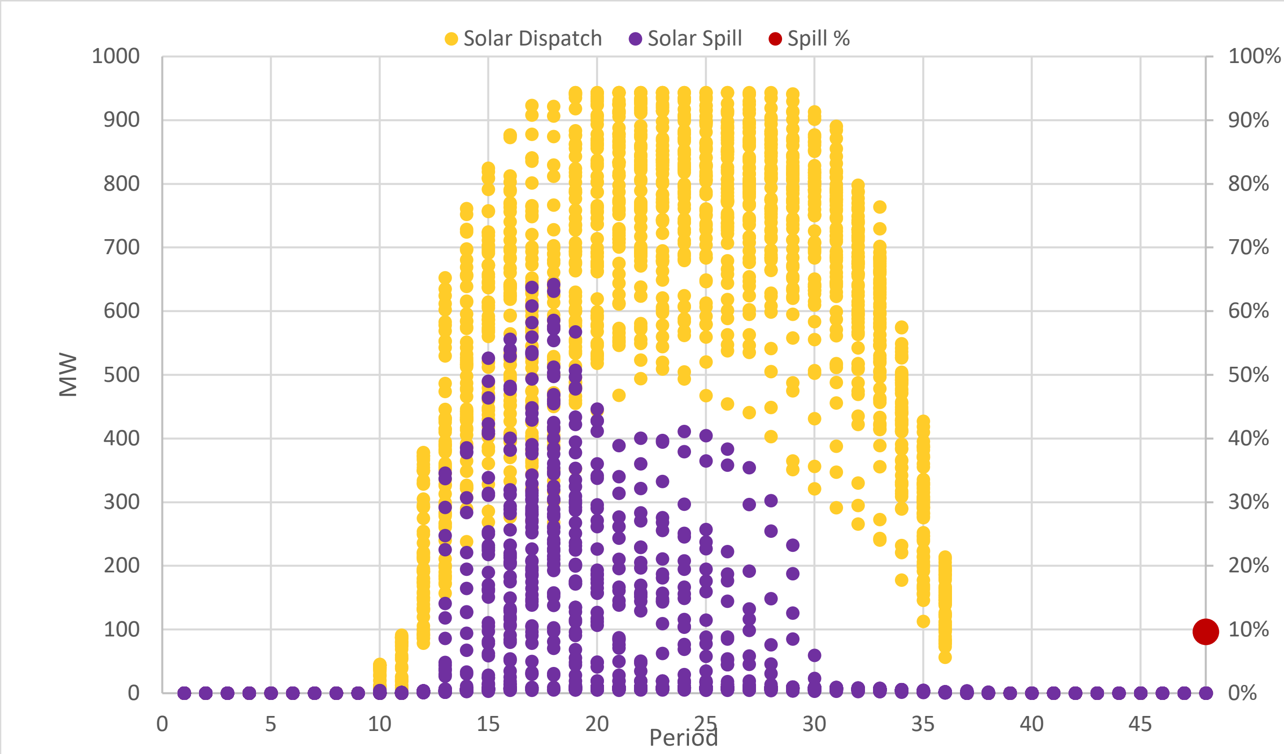

Figure 22: Central West Queensland solar dispatch and curtailment under sB

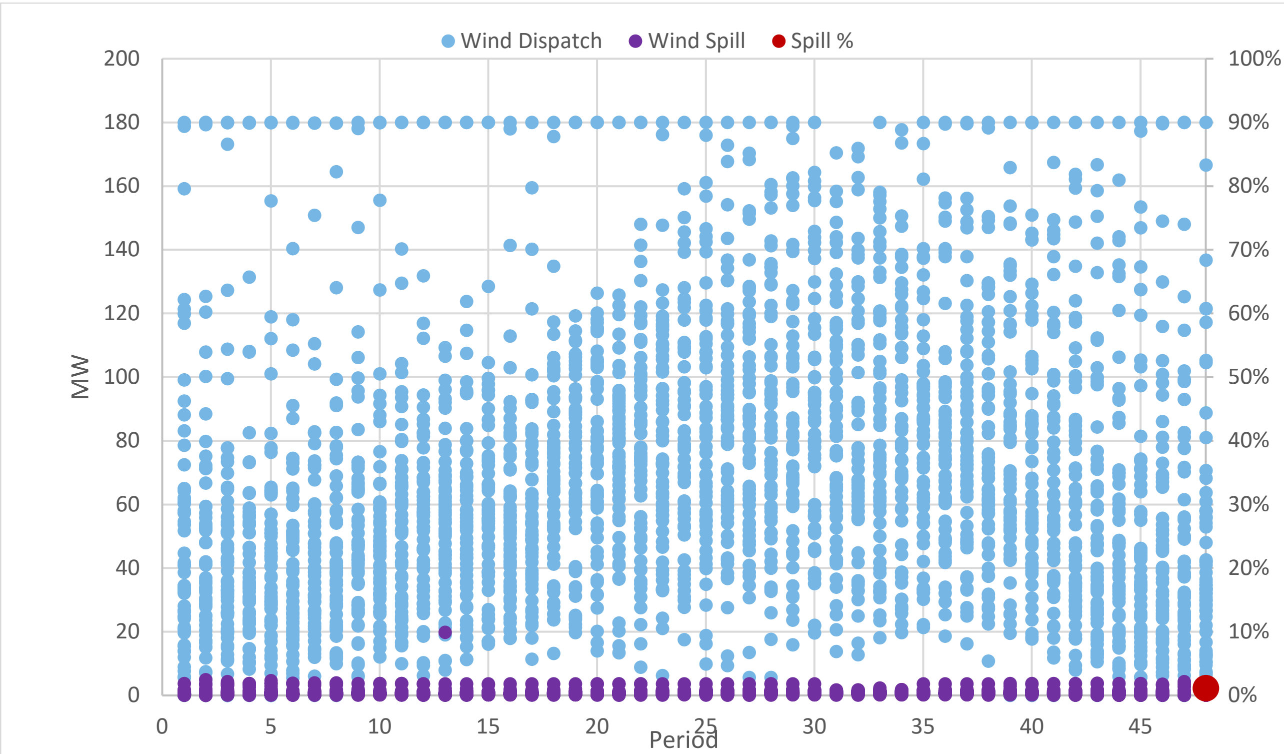

Figure 23: Central West Queensland wind dispatch and curtailment under sB

10. GLADSTONE details for summer weekdays

Table 12 summarises generating capacity assumptions for Gladstone (GLAD) node

Table 13: Gladstone capacity assumptions under sB

GLAD Capacity assumptions	Current [9] (MW)	2030 (MW)	Notes
Coal	1680	560	CF AllYear 74%; CF SummWD 78%
Gas	154	154	CF AllYear 54%; CF SummWD 57%
Solar	-	795	CF AllYear 30%; CF SummWD 33% Curtail SummWD 5%; Max 530MW
Storage/E-G		235	CF AllYear -%; CF SummWD -%
TOTAL	1834	1744	

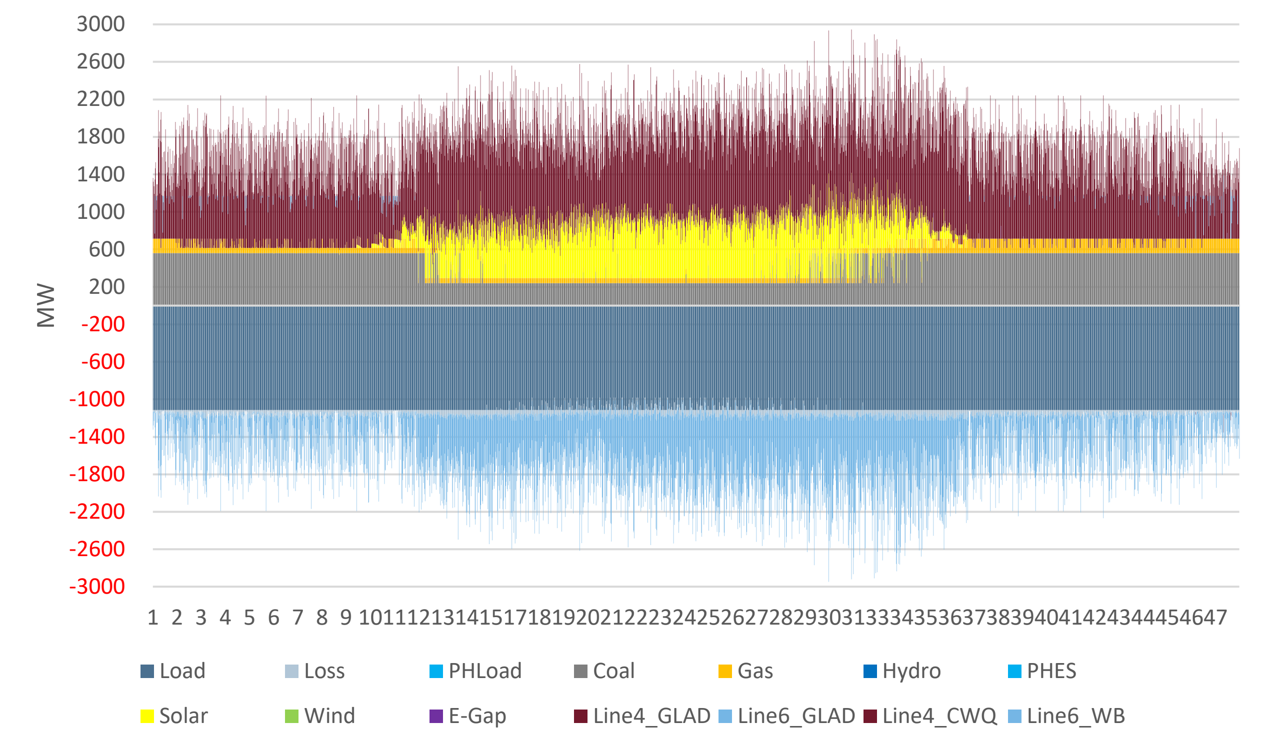

Figure 24: Gladstone energy flows for SummWD under sB

Figure 23 provides detail on the flow of energy through GLAD node by time-of-day period by type of supply and demand. Of note:

[9] Source: AEMO Generation Information July 2020

- the maroon coloured series indicates imports from CWQ and potentially the northern nodes of NQ, Ross and FNQ. Imports occur throughout the day but are higher during daylight
- 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 1109MW. GLAD node hosts the Boyne Aluminium Smelter
- the light grey coloured series indicates generation from coal capacity of 560MW. GLAD node hosts 1.68GW Gladstone Power station, of which units 1-2 and 5-6 are assumed to be closed by 2030.
- the gold coloured series indicates generation from Yarwun combined cycle gas turbine (154MW) which dispatches primarily outside of daylight hours.
- the yellow coloured series indicates energy sourced from solar capacity of 795MW. Solar dispatch achieves a capacity factor of 33% after curtailment of 5% from potential dispatch. Figure 25 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity. In sB there is no wind capacity assumed in GLAD node.
- there are a handful of E-G periods of 60-180MW in the GLAD node, primarily periods 34-39. Figure 24 provides detail

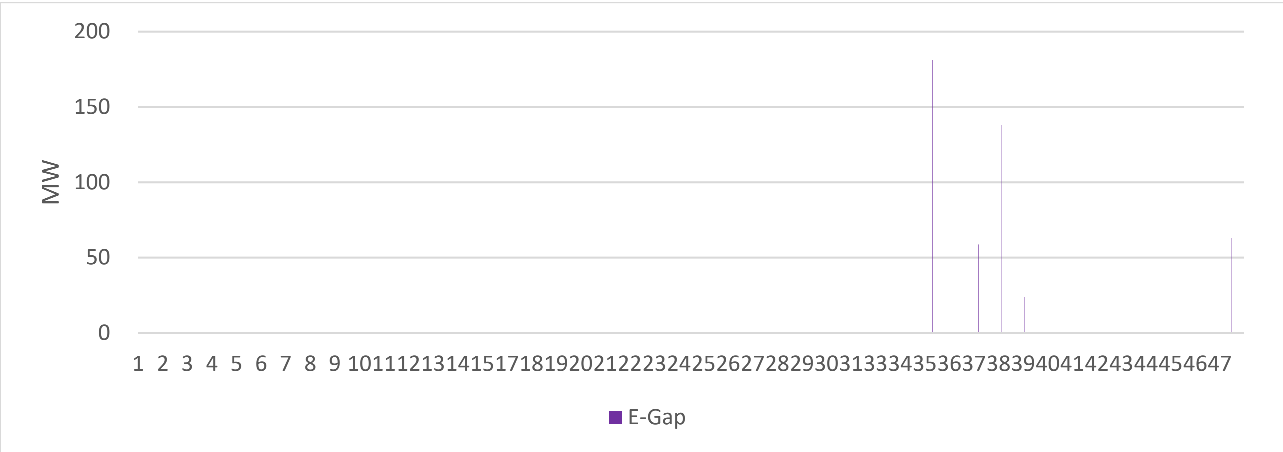

Figure 25: Gladstone energy-gap for SummWD under sB

Table 13 details statistics for GLAD energy flows

Table 14: Gladstone salient statistics under sB

GLAD Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(1,597)	(1,114)	(1,109)	(1,114)	100%	(1,114)
Coal	633	553	440	560	78%	560
Gas	126	122	87	154	57%	55
Solar	375	100	260	795	33%	93
Wind	0	0	0	0	0%	0
E-G	0	1	0	181	0%	0
Exports (node)	(812)	(579)	(564)	(1,719)	33%	(567)
Imports (node)	1,393	1,013	967	1,528	63%	977
Solar_spill	21	0	15	530	3%	0
Wind_spill	0	0	0	0	0%	0
Solar spill %	5%	0%	5%			
Wind spill %	0%	0%	0%			

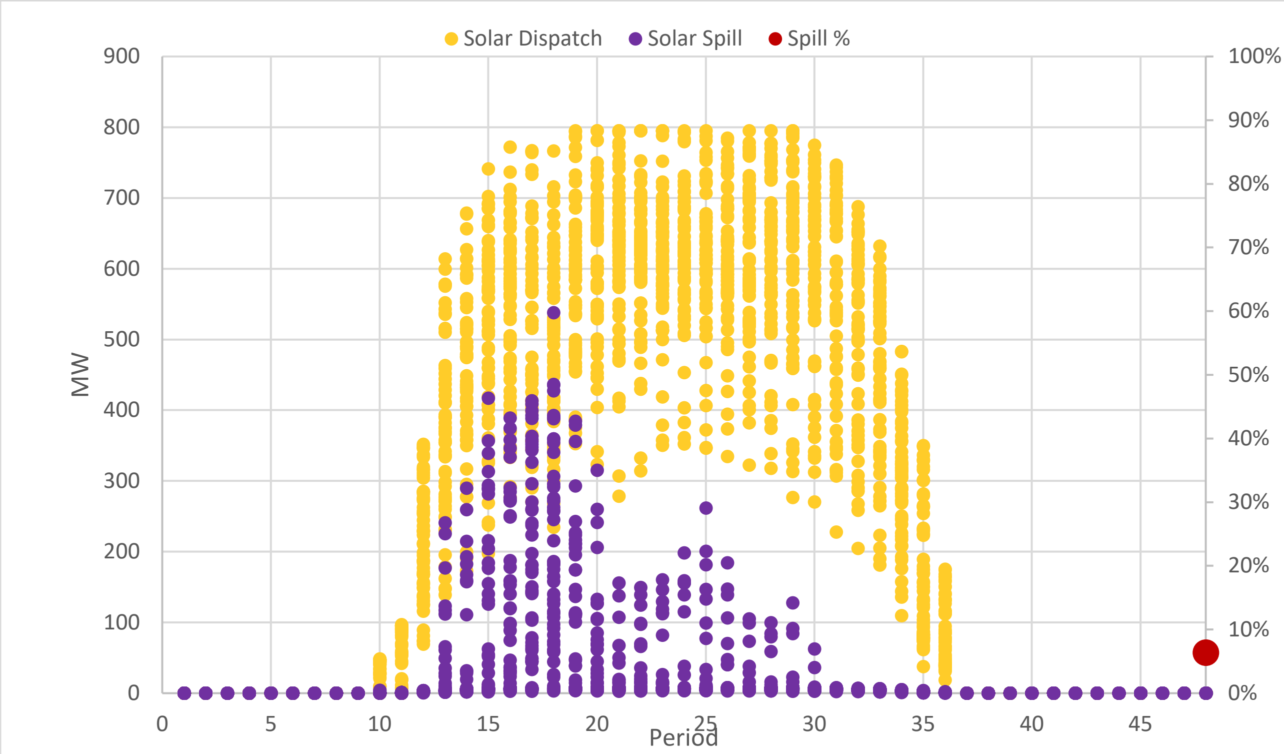

Figure 26: Gladstone solar dispatch and curtailment under sB

11. WIDE BAY details for summer weekdays

Table 14 provides detail on generating capacity assumptions for Wide Bay (WB) node

Table 15: Wide Bay capacity assumptions under sB

WB capacity assumptions	Current [10] (MW)	2030 (MW)	Notes
Wind	-	1200	CF AllYear 33%; CF SummWD 36% Curtail SummWD 15%; Max 1019MW
Solar	141	808	CF AllYear 23%; CF SummWD 26% Curtail SummWD 13%; Max 733MW
Storage/Other/ E-G	-	516	CF AllYear -%; CF SummWD -%
TOTAL	141	2524	

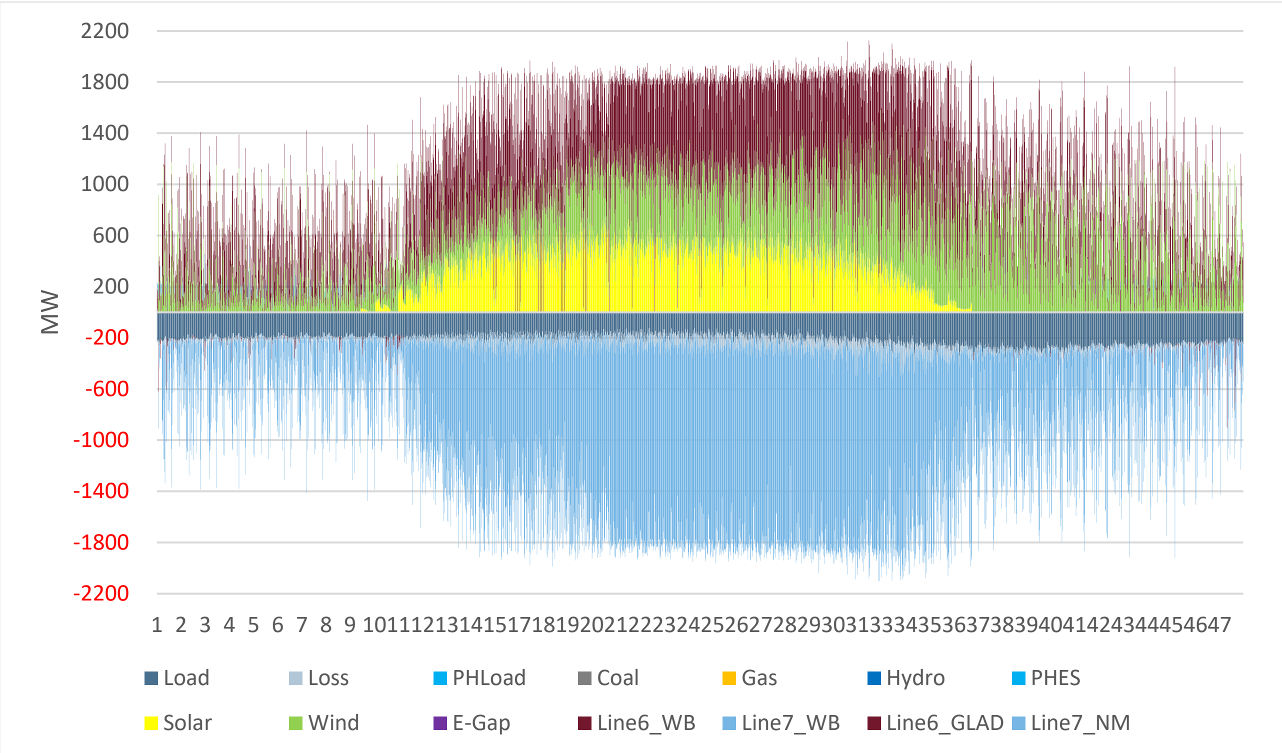

Figure 27: Wide Bay energy flows for SummWD under sB

Figure 26 provides detail on the flow of energy through WB node by time-of-day period by type of supply and demand. Of note:

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[10] Source: AEMO Generation Information July 2020

- the maroon coloured series indicates imports from GLAD and ultimately CWQ and the northern QLD nodes throughout the day, but at elevated levels during daylight
- the light blue coloured series indicates exports to North Moreton (North Brisbane) throughout the day but also at elevated levels during daylight
- the steel-blue coloured series indicates WB load averaging 217MW
- the yellow coloured series indicates energy sourced from solar capacity of 808MW. Solar dispatch achieves a capacity factor of 26% after curtailment of 13% from potential dispatch. Figure 28 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity of 1200MW. Wind dispatch achieves a capacity factor of 36% after curtailment of 15% from potential dispatch. Figure 29 details wind dispatch and curtailment
- a handful of E-Gs emerge in WB primarily during evening peak periods 37-47. Maximum capacity of E-G is 516MW, with a capacity factor of -%. This is despite 1.2GW of wind capacity in WB node, which is insufficient to meet NM evening peak consistently. Figure 27 shows detail.

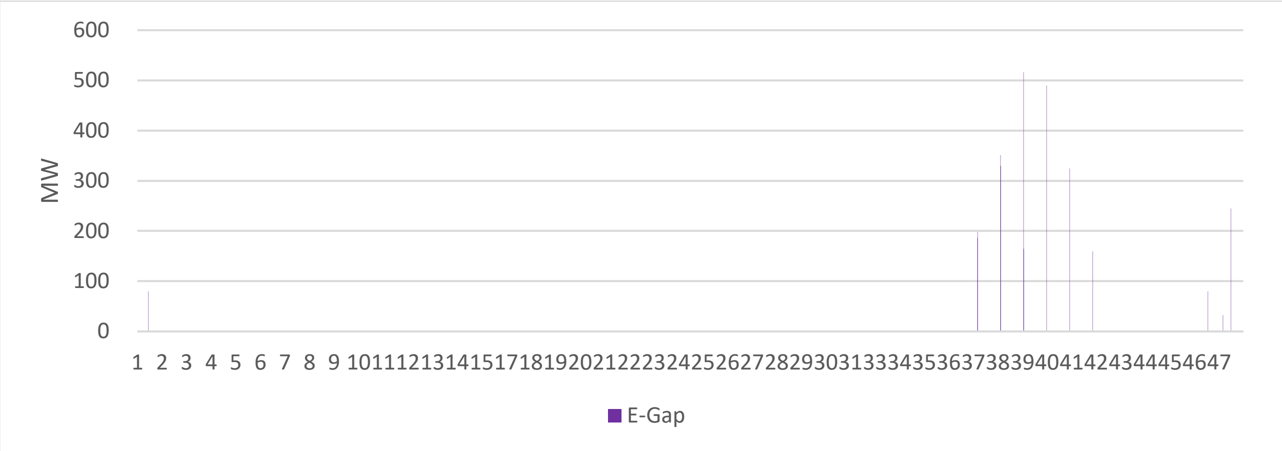

Figure 28: Wide Bay energy-gap for SummWD under sB

Table 15 details statistics for WB energy flows

Table 16: Wide Bay salient statistics under sB

WB Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(313)	(274)	(217)	(361)	60%	(207)
Solar	299	64	208	749	26%	60
Wind	630	630	437	1,200	36%	411
E-G	2	5	1	516	0%	0
Exports (node)	(1,382)	(964)	(960)	(1,595)	60%	(999)
Imports (node)	818	580	568	1,719	33%	567
Solar_spill	46	1	32	733	4%	0
Wind_spill	110	15	76	1,019	7%	0
Solar spill %	13%	2%	13%			
Wind spill %	15%	2%	15%			

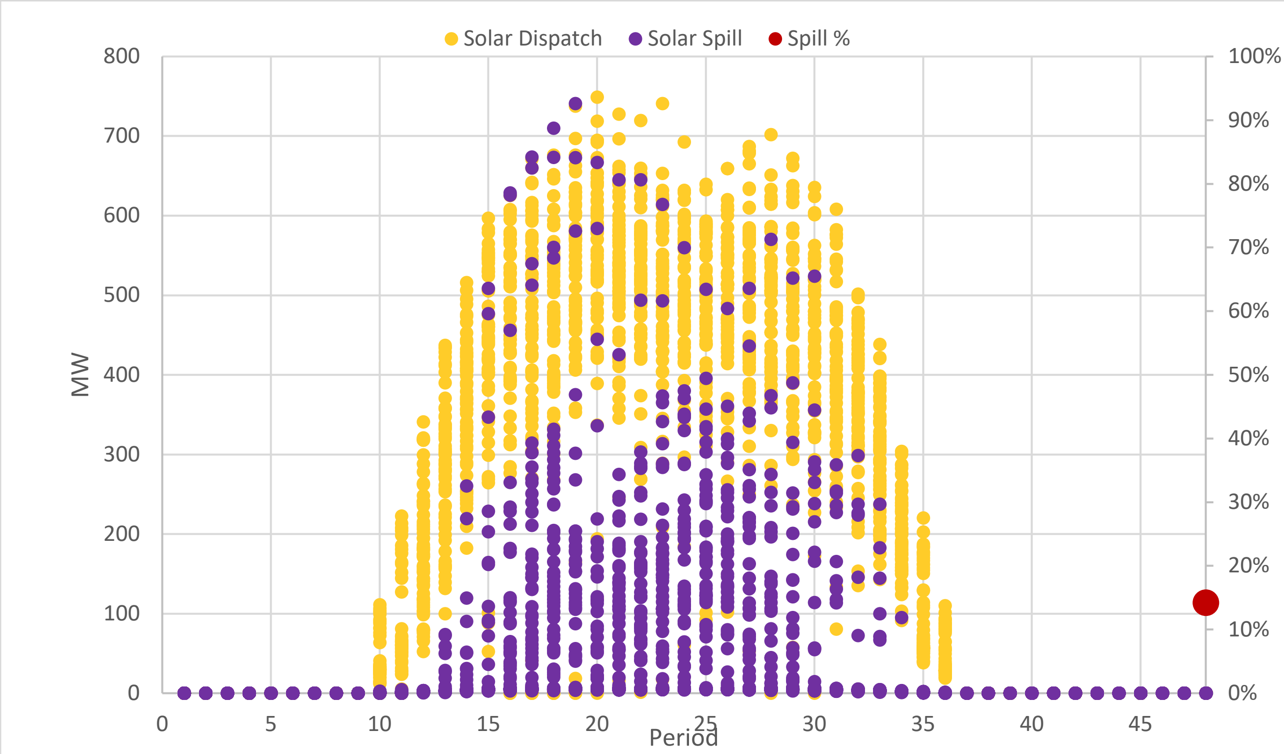

Figure 29: Wide Bay solar dispatch and curtailment under sB

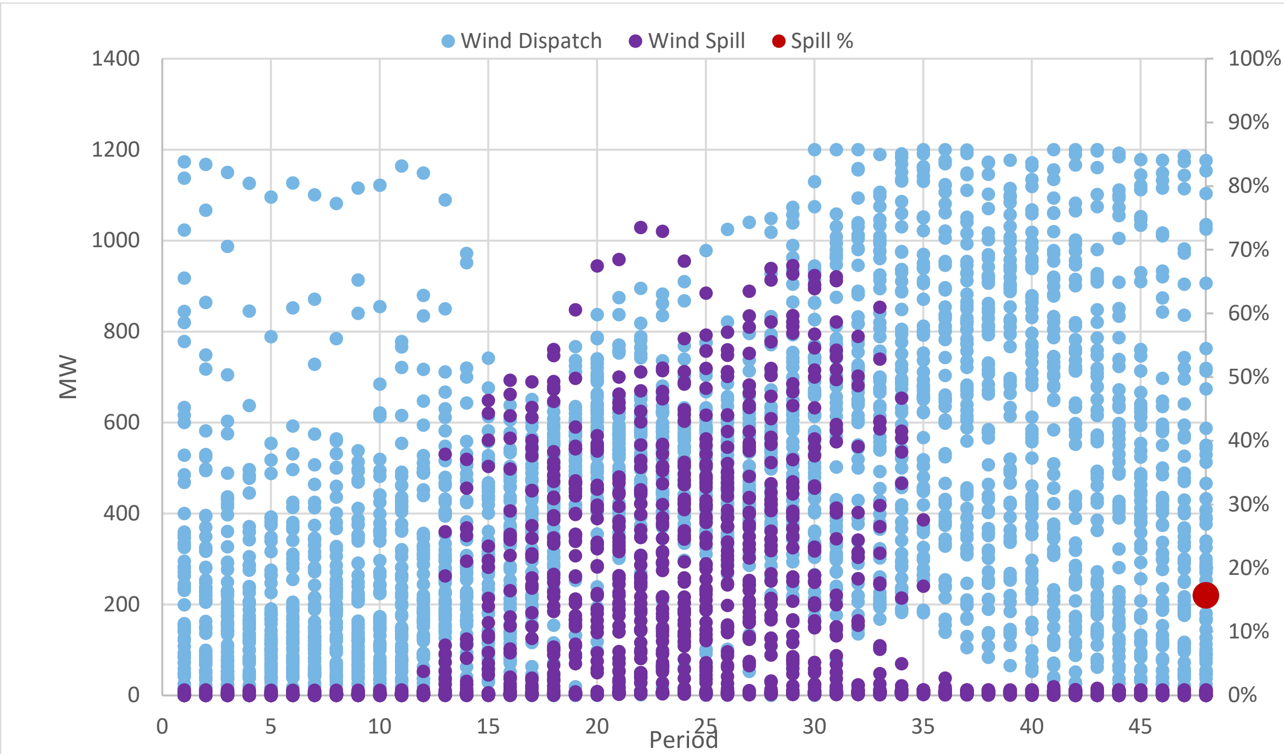

Figure 30: Wide Bay wind dispatch and curtailment under sB

12. TARONG details for summer weekdays

Table 16 provides a summary of generating capacity assumptions for Tarong (TAR) node

Table 17: Tarong capacity assumptions under sB

TAR capacity assumptions	Current [11] (MW)	2030 (MW)	Notes
Coal	1843	1143	CF: AllYear 73%; SummWD 79%
Gas	80	80	CF: AllYear 22%; SummWD 21%
Wind	449	513	CF: AllYear 37%; SummWD 42% Curtail SummWD -%; Max 129MW
Solar	15	620	CF: AllYear 27%; SummWD 27% Curtail SummWD -%; Max 196MW
Storage/E-G		94	CF: AllYear 1%; SummWD -%
TOTAL	2387	2450	

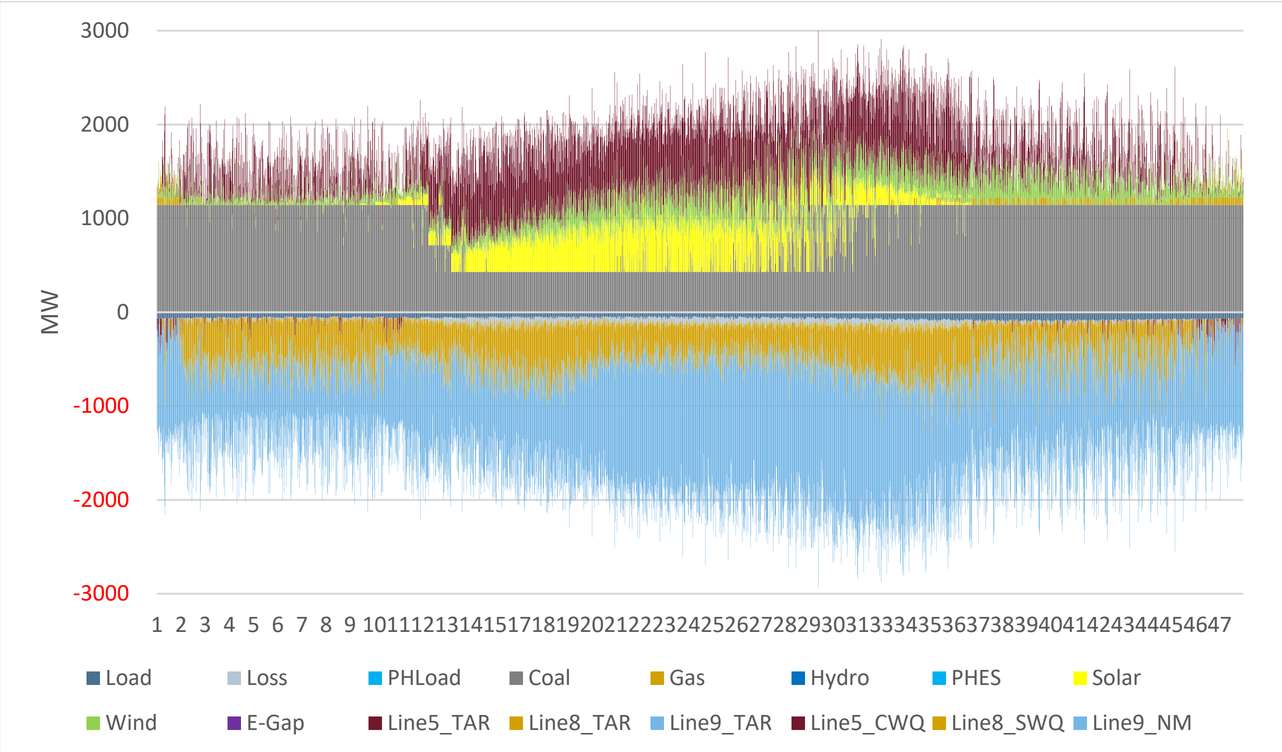

Figure 31: Tarong energy flows for SummWD under sB

[11] Source: AEMO Generation Information July 2020

Figure 30 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 from CWQ which occur throughout the day but are elevated during daylight
- The light-blue coloured series indicates exports to NM (North Brisbane) which occur throughout the day but are elevated during evening peak
- the light brown coloured series indicates exports to SWQ, are modest and occur throughout the day
- the light-grey coloured series indicates generation from Tarong and Tarong North coal power stations. Units 1-2 of Tarong are assumed to be shut by 2030 in sB, leaving generation from coal of 1143MW
- The gold coloured series indicates generation from Roma GT with capacity of 80MW
- the yellow coloured series indicates energy sourced from solar capacity of 620MW. Solar dispatch achieves a capacity factor of 27% after curtailment of 0% from potential dispatch. Figure 32 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity of 513MW. Wind dispatch achieves a capacity factor of 42% after curtailment of 0% from potential dispatch. Figure 33 details wind dispatch and curtailment
- the steel-blue coloured series indicates TAR load, an average of 66MW
- there is a small E-G in TAR with a maximum of 22MW. Figure 31 shows detail

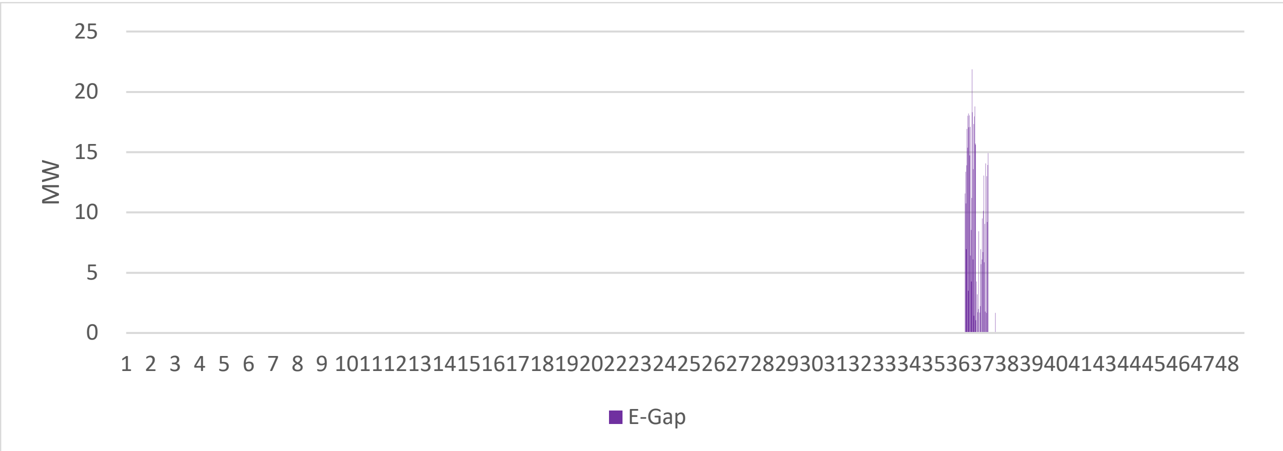

Figure 32: Tarong energy-gap for SummWD under sB

Table 17 details statistics for TAR energy flows

Table 18: Tarong Salient statistics under sB

TAR Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(96)	(86)	(66)	(119)	56%	(64)
Coal	1,306	1,137	907	1,143	79%	1,143
Gas	25	36	17	80	21%	0
Solar	244	38	169	620	27%	46
Wind	310	271	215	513	42%	194
E-G	0	1	0	22	1%	0
Exports (node)	(2,377)	(1,780)	(1,650)	(2,735)	60%	(1,652)
Imports (node)	738	503	512	1,236	41%	555
Solar_spill	1	0	1	196	0%	0
Wind_spill	0	0	0	129	0%	0
Solar spill %	0%	0%	0%			
Wind spill %	0%	0%	0%			

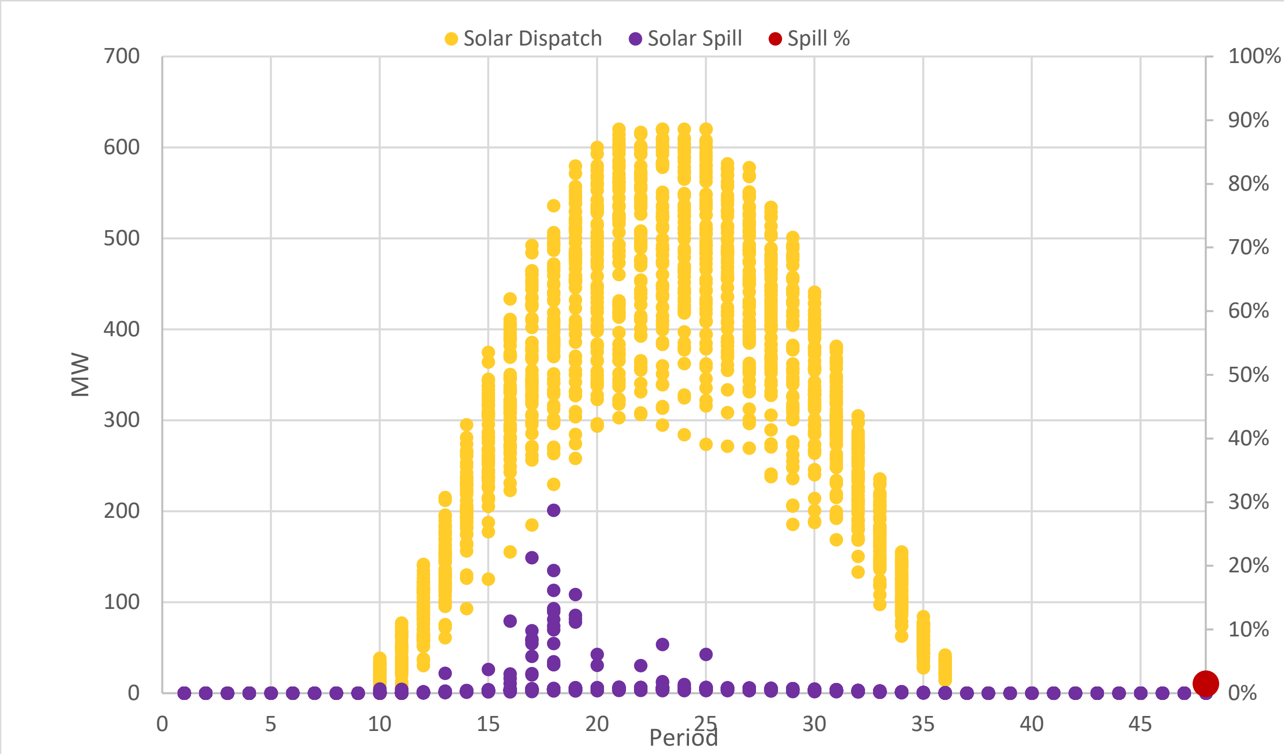

Figure 33: Tarong solar dispatch and curtailment under sB

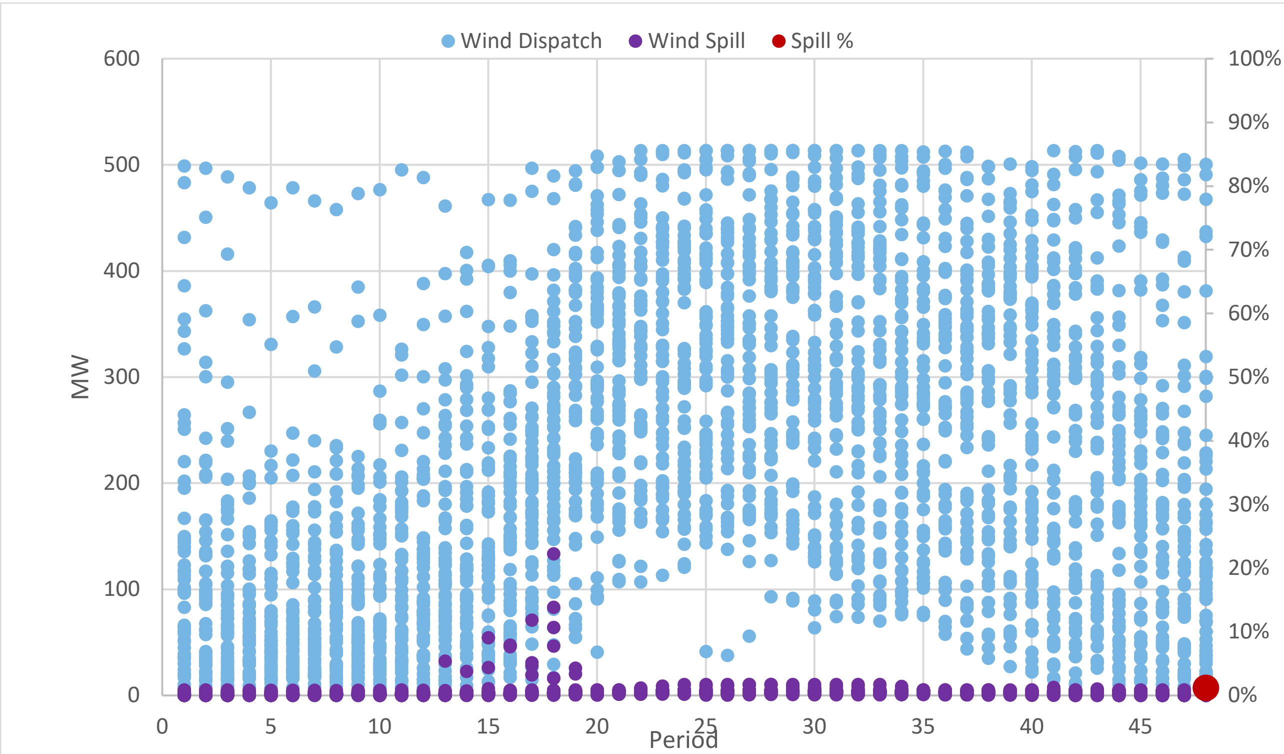

Figure 34: Tarong wind dispatch and curtailment under sB

13. SOUTH WEST QUEENSLAND details for summer weekdays

Table 18 provides a summary of generating capacity assumptions for South West Queensland (SWQ) node

Table 19: South West Queensland capacity assumptions under sB

SWQ Capacity assumptions	Current [12] (MW)	2030 (MW)	Notes
Coal	1596	1596	CF: AllYear 78%; SummWD 86%
Gas	2157	2157	CF: AllYear 29%; SummWD 28%
Wind	-	779	CF: AllYear 39%; SummWD 42% Curtail SummWD 1%; Max 384MW
Solar	317	2439	CF: AllYear 20%; SummWD 22% Curtail SummWD 26%; Max 1916MW
Storage/Other/ E-G	-	-	CF: AllYear -%; SummWD -%
TOTAL	4070	6971	

Figure 34 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 TAR which occur persistently between midnight and daylight and then interspersed throughout the day with generation from wind, solar and gas
- the light-blue coloured series indicates exports to NSW via QNI which occur throughout the day but are occasionally elevated during pre-and early-evening peak periods 29-36
- the aqua-marine coloured series indicates exports to South Moreton (South Brisbane & Ipswich) and ultimately on to the Gold Coast which occur throughout the day but elevate for evening peak
- 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 2439MW. Solar dispatch achieves a capacity factor of 22% after curtailment of 26% from potential dispatch. Figure 36 details solar dispatch and curtailment
- the light green coloured series indicates energy sourced from wind capacity of 779MW. Wind dispatch achieves a capacity factor of 42% after curtailment of 1% from potential dispatch. Figure 37 details wind dispatch and curtailment
- the steel-blue coloured series indicates SWQ load, an average of 967MW. SWQ demand includes consumption for CSG extraction, compression and transportation.

[12] Source: AEMO Generation Information July 2020

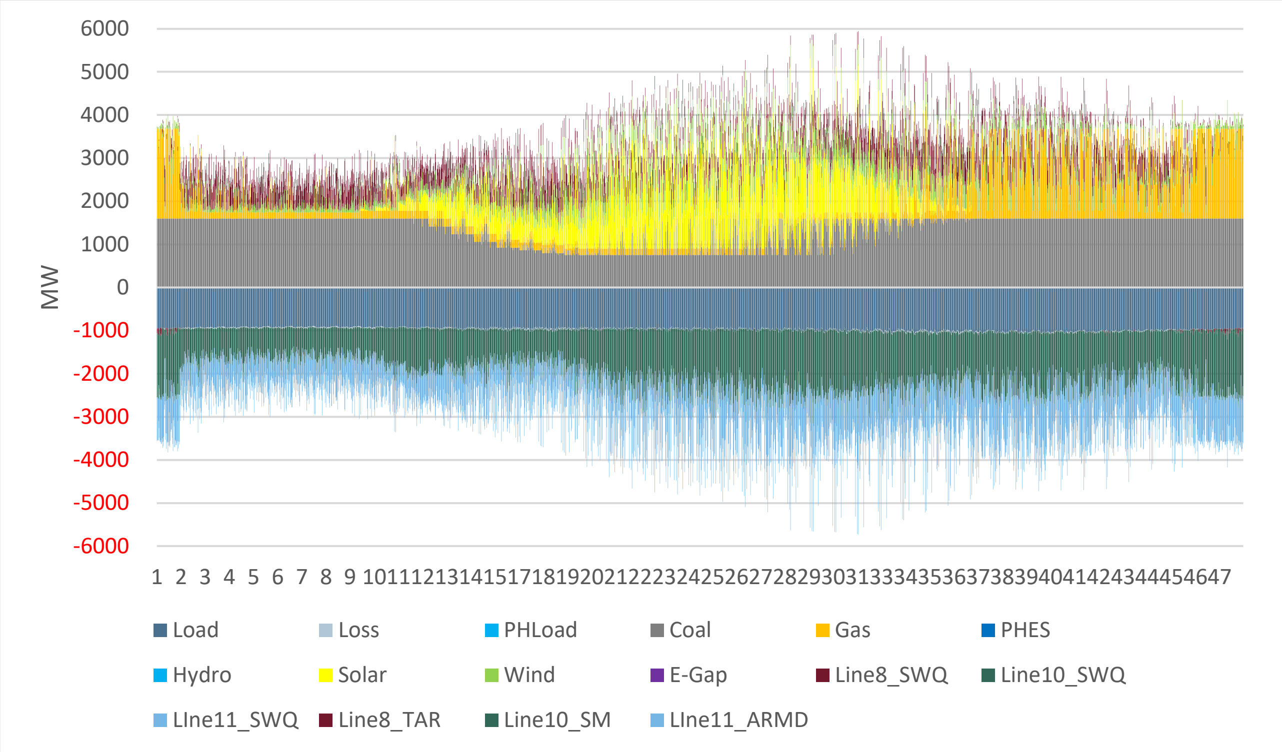

Figure 35: South West Queensland energy flows for SummWD under sB

There is a negligible E-G in SWQ. Figure 35 shows detail

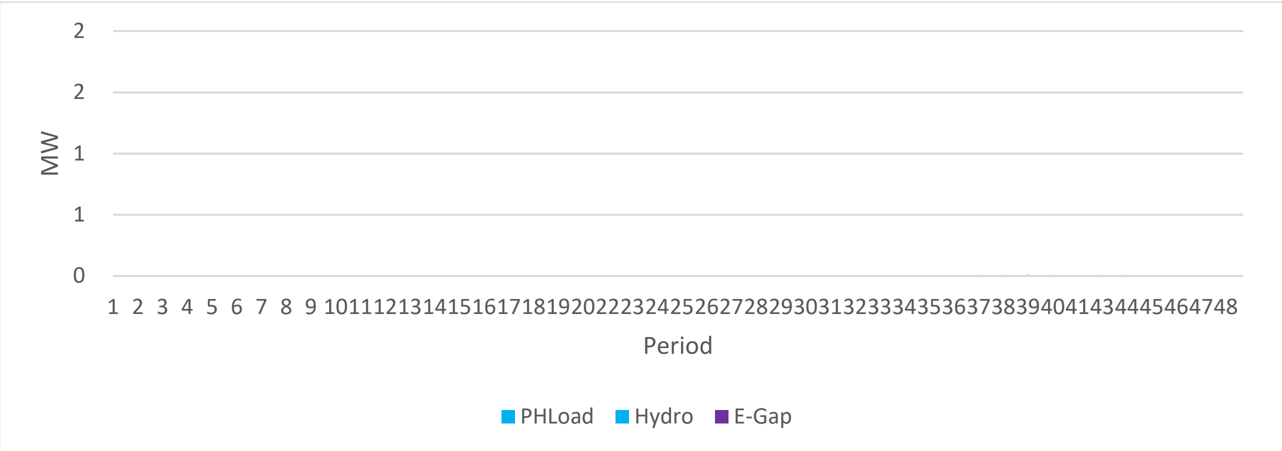

Figure 36: South West Queensland energy-gap for SummWD under sB

Table 19 details statistics for SWQ energy flows

Table 20: South West Queensland salient statistics under sB

SWQ Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(1,392)	(1,018)	(967)	(1,088)	89%	(961)
Coal	1,984	1,583	1,378	1,596	86%	1,596
Gas	851	1,084	591	2,091	28%	181
Solar	784	149	544	2,430	22%	155
Wind	473	395	328	779	42%	295
E-G	0	0	0	0	0%	0
Exports (node)	(3,107)	(2,507)	(2,158)	(4,749)	45%	(2,084)
Imports (node)	617	492	429	1,076	40%	437
Solar_spill	275	0	191	1,892	10%	0
Wind_spill	6	0	4	376	1%	0
Solar spill %	26%	0%	26%			
Wind spill %	1%	0%	1%			

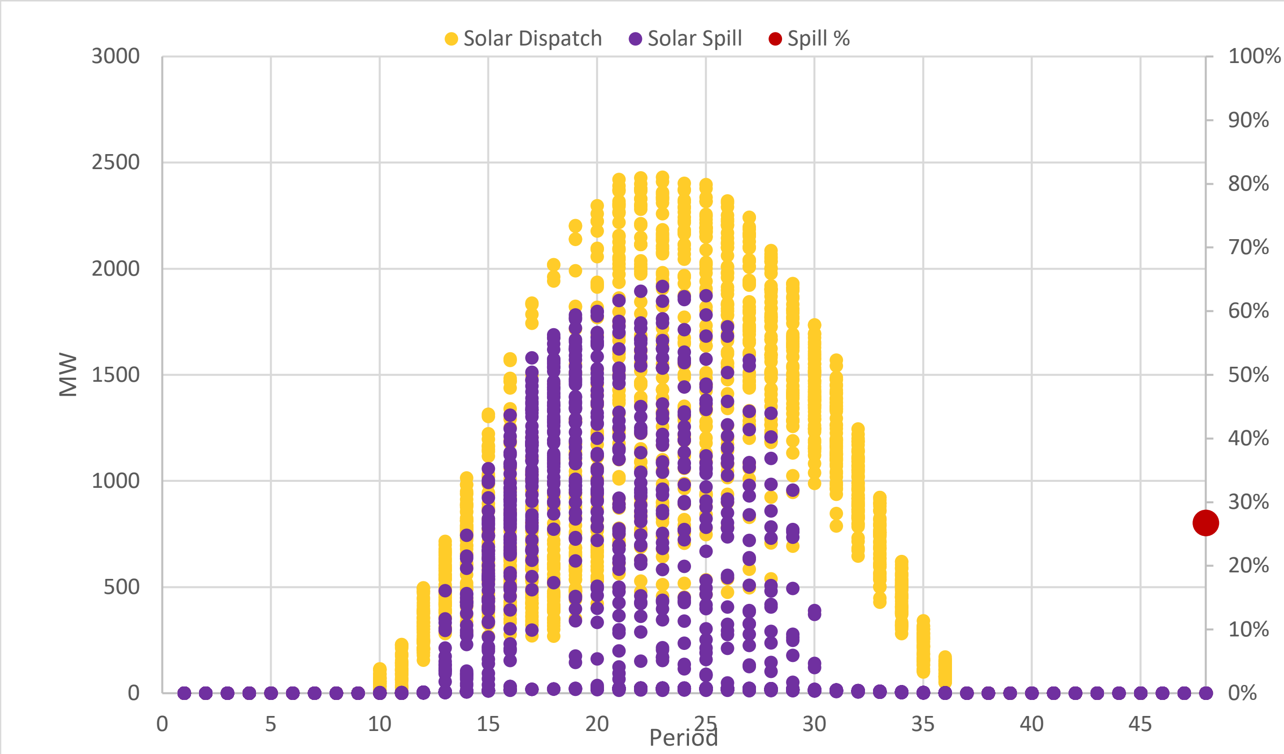

Figure 37: South West Queensland solar dispatch and curtailment under sB

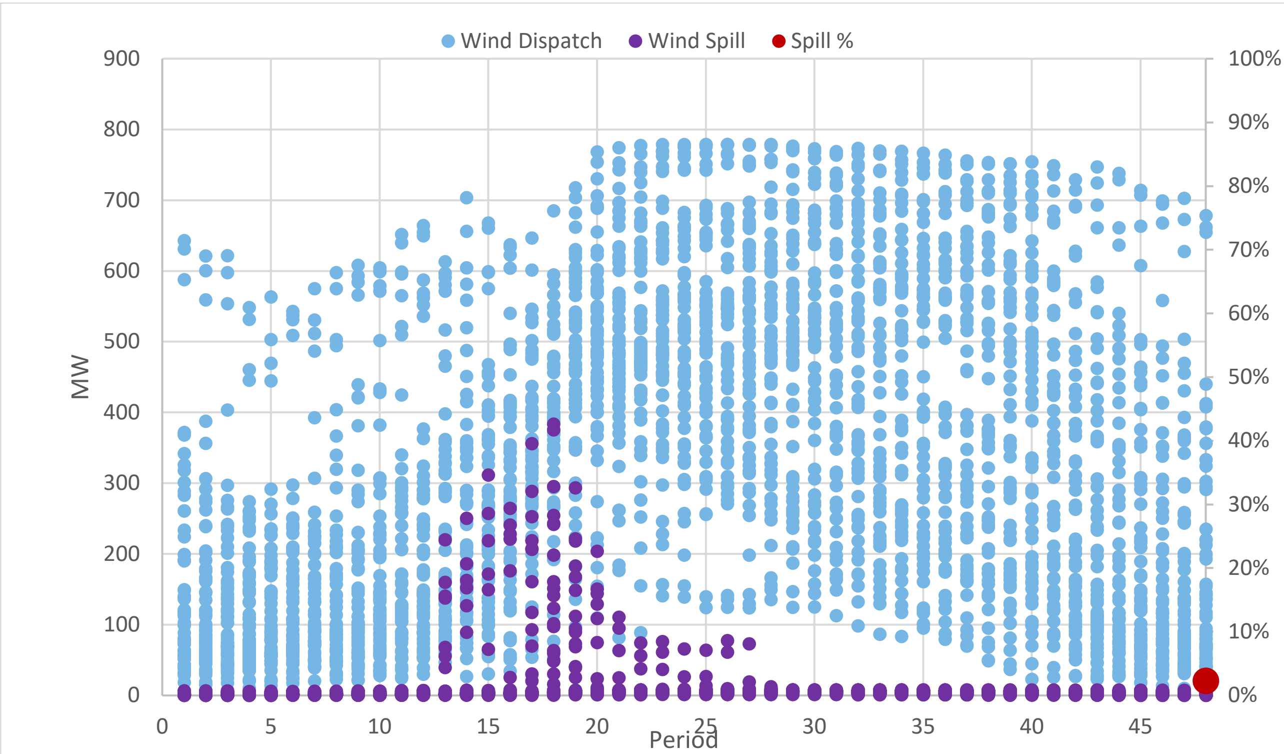

Figure 38: South West Queensland wind dispatch and curtailment under sB

14. SOUTH MORETON details for summer weekdays

Table 20 provides a summary of generating capacity assumptions for South Moreton (SM) node

Table 21: South Moreton capacity assumptions under sB

SM capacity assumptions	Current [13] (MW)	2030 (MW)	Notes
Gas	385	-	
Storage/Other/ E-G		-	
TOTAL	700	-	

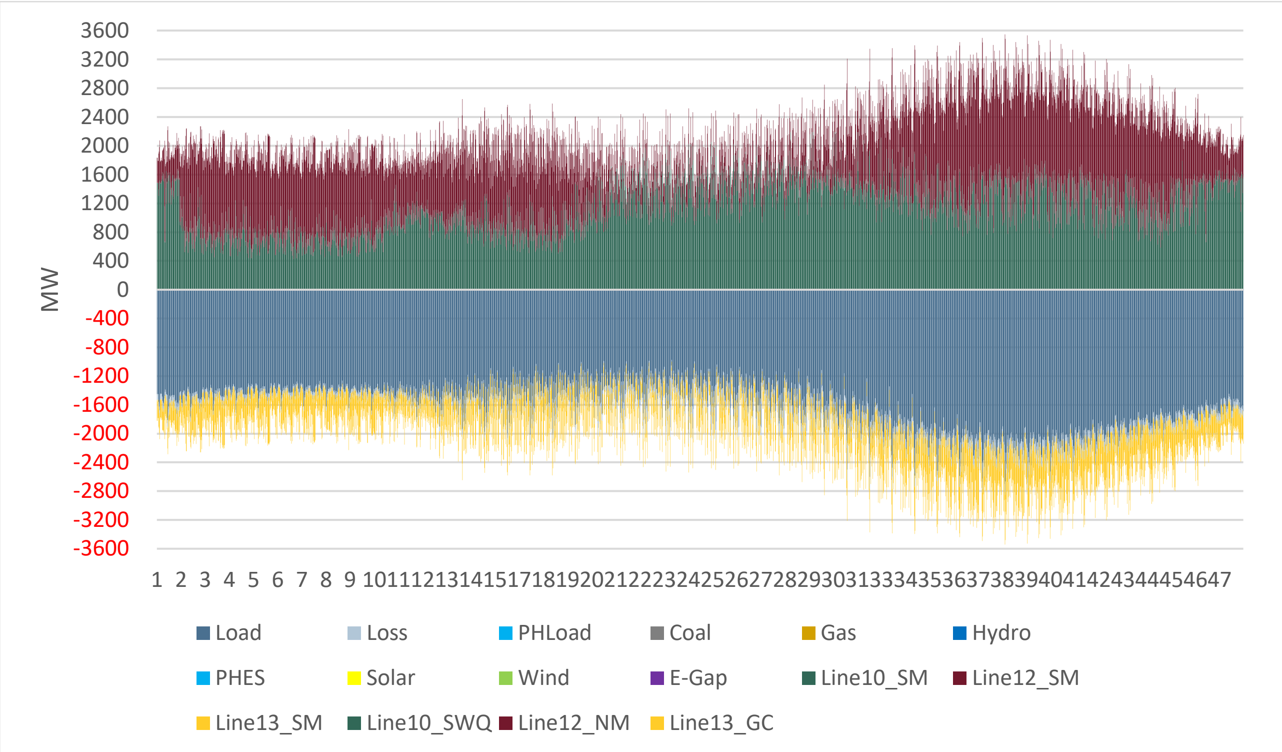

Figure 39: South Moreton energy flows for SummWD under sB

Figure 38 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 from North Moreton node which occurs throughout the day, increasing during evening peak
- the green coloured series indicates imports from SWQ node which occurs throughout the day, increasing during evening peak

[13] Source: AEMO Generation Information July 2020

- the gold coloured series indicates exports to Gold Coast which occurs throughout the day
- the steel-blue coloured series indicates SM load, averaging 1638MW
- the purple coloured series indicates E-G in SM node which is zero. Figure 38 shows detail.

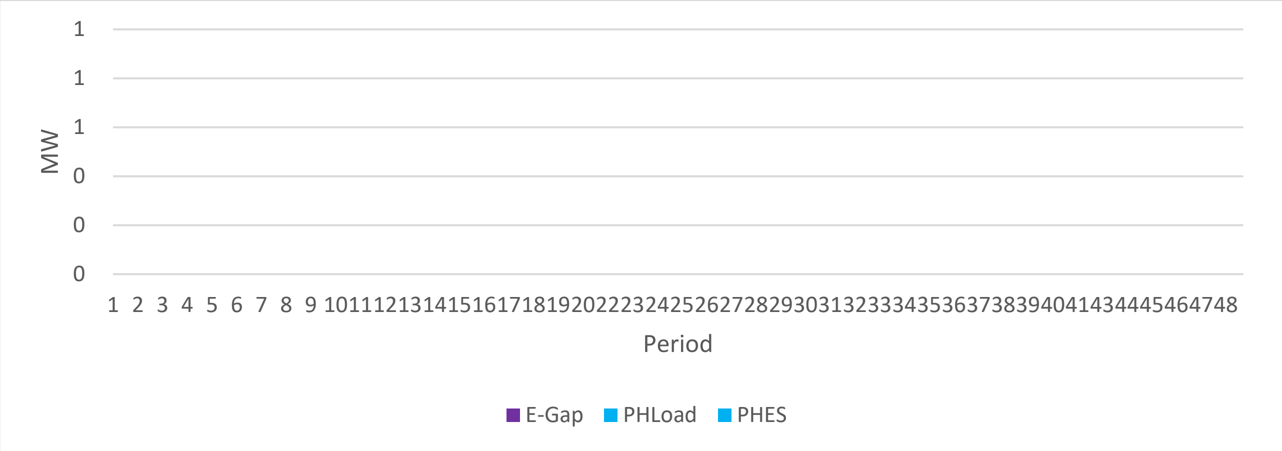

Figure 40: South Moreton energy-gap for SummWD under sB

Table 21 details statistics for SM energy flows

Table 22: South Moreton salient statistics under sB

SM Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(2,358)	(2,091)	(1,638)	(2,700)	61%	(1,550)
Gas	0	0	0	0	0%	0
E-G	0	0	0	0	0%	0
Exports (node)	(615)	(576)	(427)	(970)	44%	(398)
Imports (node)	3,074	2,764	2,135	3,548	60%	2,049

15. NORTH MORETON details for summer weekdays

Table 22 summarises generating capacity assumptions for North Moreton (NM) node

Table 23: North Moreton capacity assumptions under sB

NM Capacity assumptions	Current [14] (MW)	2030 (MW)	Notes
PHES	570	1590	CF: AllYear 15%; SummWD 13% Curtail SummWD 20%; Max 1590MW
Storage/Other/ E-G		1944	CF: AllYear 23%; SummWD 23% Incidences: EvPeak 523 (87%), ONight 1067 (99%), Daylight 227 (19%)
TOTAL	570	3534	

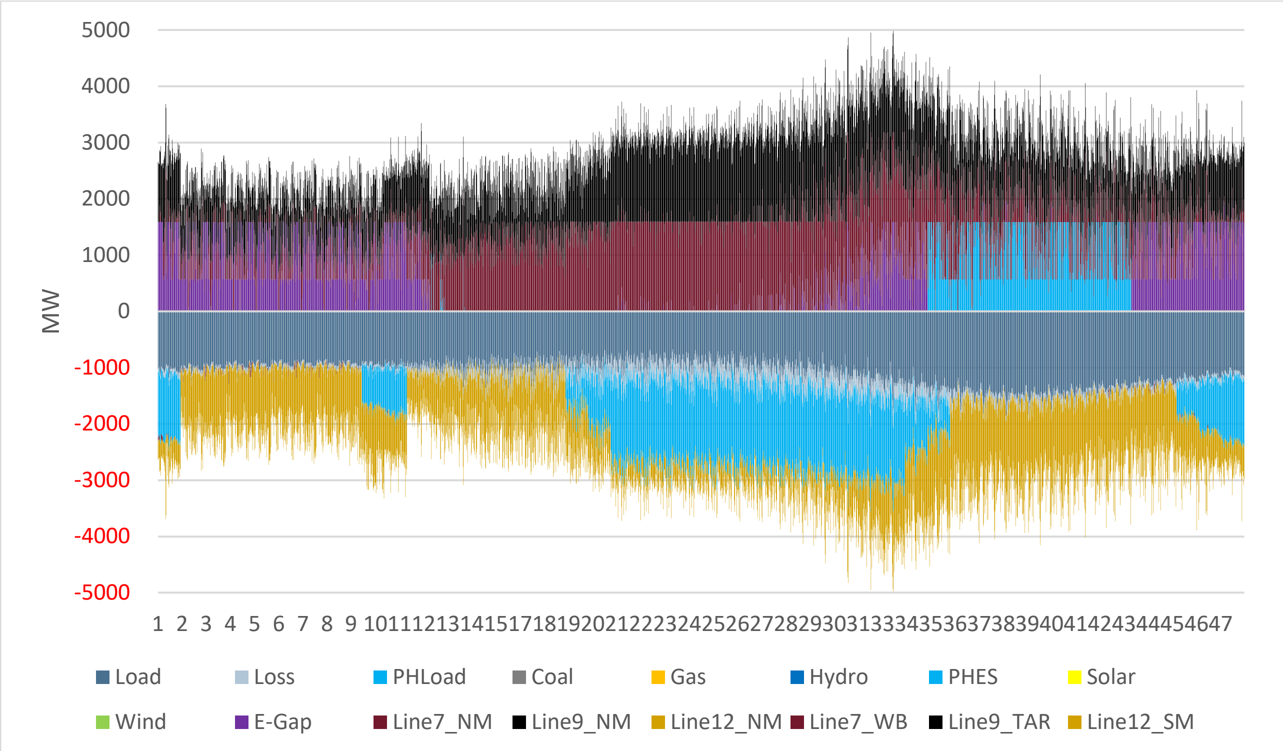

Figure 41: North Moreton energy flows for SummWD under sB

Figure 40 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 which occur primarily during daylight, decreasing after sundown

[14] Source: AEMO Generation Information July 2020

- the black coloured series indicates imports from TAR node, occurring throughout the day, but slightly lower after midnight
- gold coloured series indicates exports to SM (South Brisbane) throughout the day
- 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 and before morning peak, and 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 to meet demand overnight. (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 41 shows detail.

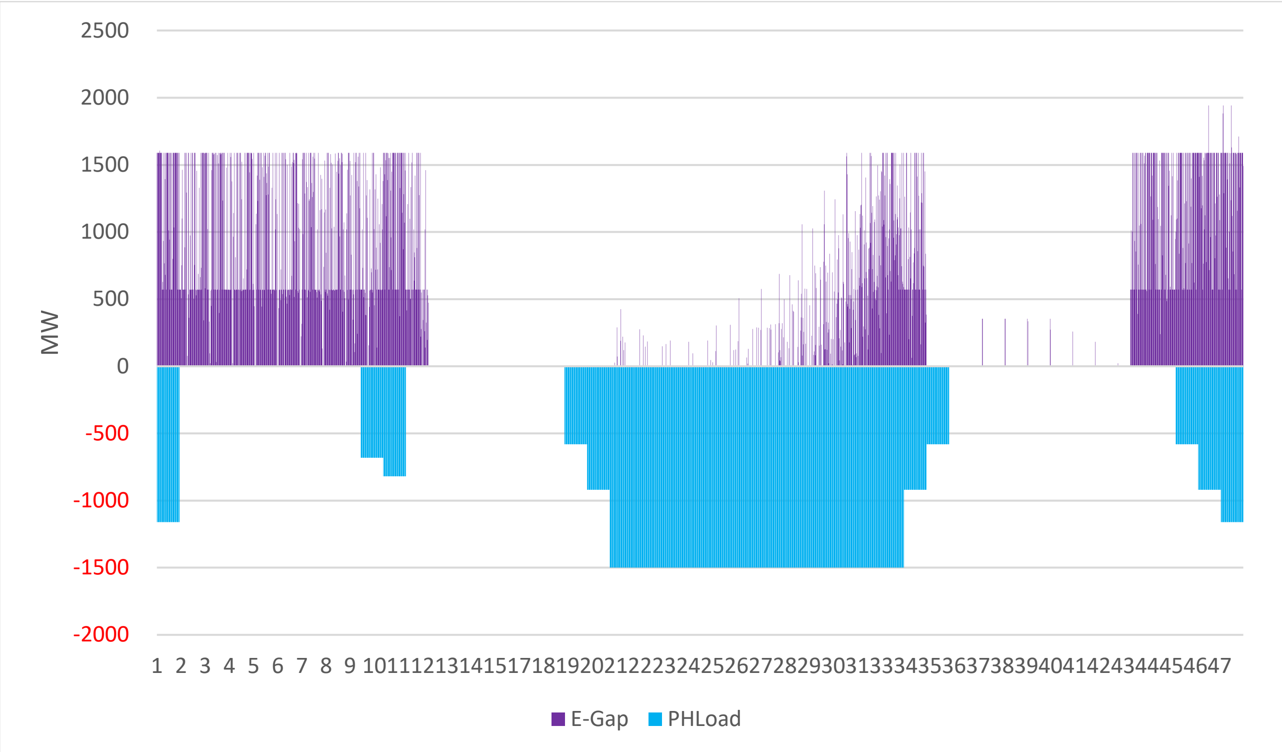

Figure 42: North Moreton energy-gap for SummWD under sB

Table 23 details statistics for NM energy flows

Table 24: North Moreton salient statistics under sB

NM Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(1,614)	(1,443)	(1,121)	(1,851)	61%	(1,059)
PH Load	(835)	(300)	(580)	(1,500)	39%	0
PHES	303	889	210	1,590	13%	0
E-G	652	205	453	1,944	23%	0
Exports (node)	(1,401)	(1,439)	(973)	(2,410)	40%	(960)
Imports (node)	3,111	2,243	2,160	3,776	57%	2,156

16. GOLD COAST details for summer weekdays

Table 24 summarises generating capacity assumptions for Gold Coast (GC) node

Table 25: Gold Coast capacity assumptions under sB

GC capacity assumptions	Current [15] (MW)	2030 (MW)		
Solar	-	-		
Wind	-	-		
Storage/Other/ E-G	-	-		
TOTAL	-	-		

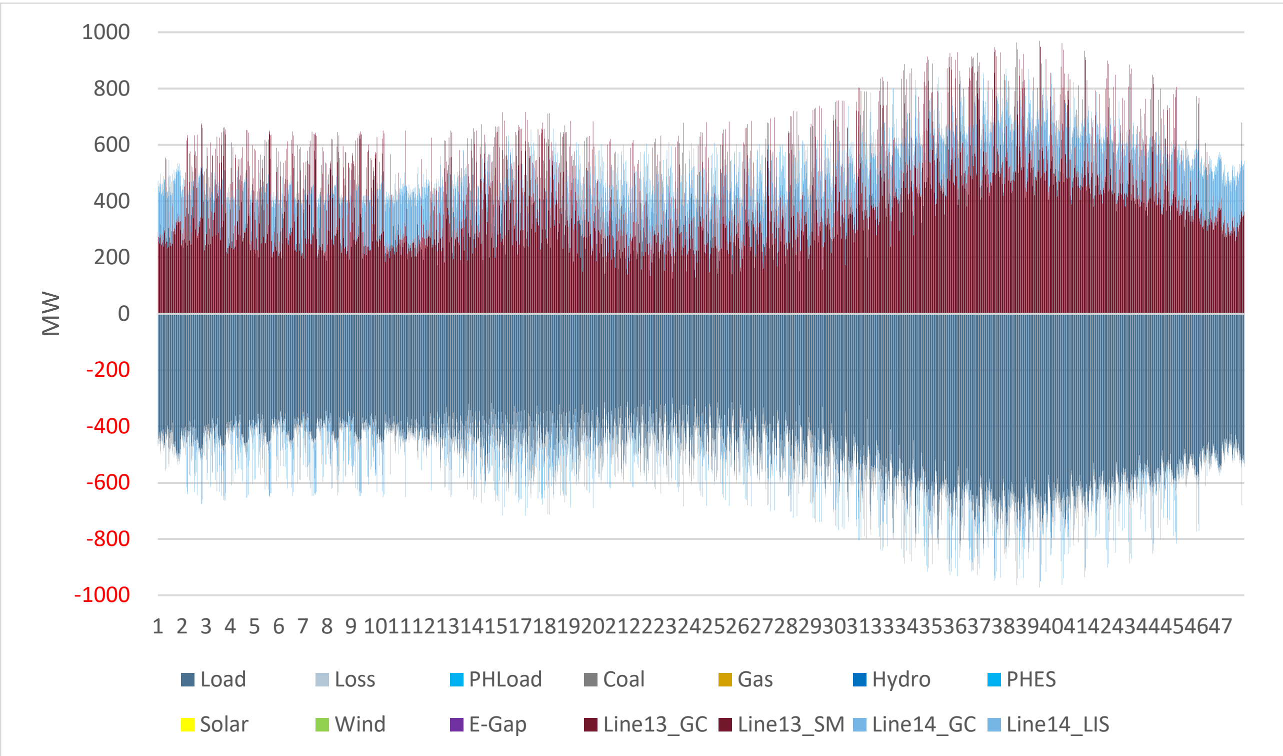

Figure 43: Gold Coast energy flows for Summer WD under sB

Figure 42 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) . Imports occur throughout the day but increase for evening peak.

[15] Source: AEMO Generation Information July 2020

- the light-blue coloured series indicates imports and exports from Lismore in NSW via DirectLink. GC appears reliant on imports from NSW throughout the day, but exports to NSW also occur throughout the day
- the steel-blue coloured series indicates load in GC, averaging 500MW
- There is no E-G in GC
- Table 25 details statistics for GC energy flows

Table 26: Gold Coast salient statistics under sB

GC Statistics	Energy (GWh)	EvenPeak (MW)	AveAll (MW)	Max (MW)	CF (%)	Median (MW)
Load	(720)	(653)	(500)	(848)	59%	(473)
E-G	0	0	0	0	0%	0
Exports (node)	(48)	(32)	(33)	(180)	18%	0
Imports (node)	783	700	544	970	56%	527

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.

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