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Annual gas demand forecasts for Western Australia

Final report

Prepared for the Australian Energy Market Operator

A Marsden Jacob Report

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Marsden Jacob Associates

ABN 66 663 324 657
ACN 072 233 204

economists@marsdenjacob.com.au

Authors

Grant Draper – Marsden Jacob Associates
Peter McKenzie– Marsden Jacob Associates
Philip Jones– Marsden Jacob Associates
Rasmus Moerch – Marsden Jacob Associates

About Us

Established in 1996, Marsden Jacob Associates has grown to be Australia's leading dedicated natural resource economics, policy and strategy advisory. We employ talented economists and policy advisors who specialise in solving practical, real world problems relating to water, energy, environment, natural resources, agriculture, earth resources, public policy and transport. We work with a wide range of cross-disciplinary partner firms to deliver best project outcomes for our clients.

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Acronyms and abbreviations

ACCC	Australian Competition and Consumer Commission
AEMO	Australian Energy Market Operator
CCGT	combined cycle gas turbine
CO2e	carbon dioxide equivalent gases
CDD	cooling degree days
DJTSI	Department of Jobs, Tourism, Science and Innovation formerly a part of Department of Mines and Petroleum
DMIRS	Department of Mines, Industry Regulation and Safety
DMP	former Department of Mines and Petroleum, see DMIRS and JTSI.
CNG	Compressed natural gas
ESOO	Electricity Statement of Opportunities
FID	Financial investment decision
GBB	Gas Bulletin Board
GJ	gigajoule
GPG	Gas powered generation
GSI	Gas Services Information
GSOO	Gas Statement of opportunities
GW	gigawatt
GWh	gigawatt hour
HDD	heating degree days
HECGT	high efficiency gas turbines
LDC	load duration curve
LNG	liquefied natural gas
LRET	Large-scale Renewable Energy Target
MW	megawatt
MW_{AC}	megawatt (alternating current)
MWh	megawatt hour
NWIS	North West Interconnected System
OCGT	open-cycle gas turbine
PJ	petajoule
PoE	probability of exceedance
PV	photovoltaic
RET	Renewable Energy Target
RFQ	Request for tender
SRES	Small-scale Renewable Energy Scheme
SWIS	the South West interconnected system
TJ	Tera joules
WEM	Wholesale Electricity Market (Western Australia)

Glossary of Terms

East Region	Goldfields, Kalgoorlie as well as Esperance GB zones
Committed projects	Projects considered to have achieved FID or are expected to achieve FID.
Consumption	Energy consumed overtime and measured in units such as TJ/day of gas or MWh of electricity.
Demand	Energy consumed for a specific period and measured in units such as PJ, GJ and or TJ.
Final investment decision	Final decision of the capital investment decision process. Typically made after completion of permits and financial arrangements, when commercially binding contracts can be executed, and procurement of services awarded.
Metro/Southwest	Metro/Southwest consisting of Mid-West, Parmelia, Metro, and South West GBB zones.
Levelised cost	Net present value of the unit-cost of electricity over the lifetime of a generating asset (proxy for the average price the asset must receive to break even over its lifetime).
Load curve	Load illustrated in chronological order (i.e. energy demand data)
Load duration curve	Load illustrated in descending order of magnitude (demand data) with a measure of duration (interval) or (utilisation percentage) on the X-axis.
North Region	Karratha, Dampier, Pilbara and Telfer GBB zones.
Stylized fact	Empirical findings that are consistent across a wide range of technology, markets and time periods.

1. Introduction

1.1 Background

The West Australian Gas Statement of Opportunities (**GSOO**) provides information on gas demand and supply for 10 years. This includes annual gas demand forecasts over the 10-year period 2019 to 2028.

These demand forecasts consider:

- economic (including gas and commodity prices) and demographic drivers;
- short term weather variations;
- annual and monthly electricity demand forecasts, which drive the use of gas powered generation (**GPG**); and
- other factors such as technology (for example: uptake of reverse cycle air conditioners) which drive changes in gas demand in Western Australia.

Marsden Jacob was appointed by the Australian Energy Market Operator (**AEMO**) to develop gas demand forecasts on a monthly, financial and calendar year basis, for the period 2019 to 2028.

1.2 Scope of Work

Marsden Jacob was engaged to develop annual gas demand forecasts by financial year (1 July to 30 June), by calendar year (1 January to 31 December), and monthly for the forecast period (2019 to 2028) for five scenarios.

The scenarios include the following:

- Three growth scenarios: Base, low and high economic growth scenarios provided by AEMO; and
- Two additional scenarios:
  - One investigating the impact of achieving a 26% reduction in CO_2e emissions from SWIS generation relative to 2005 levels earlier (by 2027) than the 2030 target year. The mix of generation in the SWIS is altered based on economic merit to ensure that, in aggregate, SWIS power stations meet CO_2e emissions reductions on an approximately linear trajectory as specified by AEMO. This resulted in a decrease in the output from some existing generators in the SWIS (no longer commercial to operate some generators).
  - Another scenario investigating a business as usual case where all existing SWIS generation continues to operate.

The annual and monthly forecasts are for all gas inlet points and pipelines (terajoules (**TJ**) per day) and consider the following:

(a) New gas consuming projects and expansions to existing gas consuming facilities in Western Australia that have already attained favourable financial investment decision (**FID**), or those likely to commence during the forecast period.

(b) Potential increases in the domestic use of compressed natural gas (**CNG**)/Liquefied Natural Gas (**LNG**) from existing projects via remote power or transportation in Western Australia.

(c) The sensitivity of domestic gas demand to Western Australia domestic gas prices.

(d) The different drivers of gas demand (while considering the price sensitivity of gas demand) for the following consumption categories:

i. Mining (section 4.3).

ii. Minerals processing (section 4.4).

iii. Gas powered generators (section 4.8).

iv. Industry (section 4.6).

v. Distribution (section 4.7).

vi. Gas shipping and storage. Note that this is considered separately. It is excluded from the gas demand forecast totals (section 4.9).

These categories are further defined in section 2.1.

(e) The use of natural gas in the areas covered by the SWIS, and non-SWIS gas consumption for the remainder of the State. In addition, further aggregation of existing Gas Bulletin Board (**GBB**) zones to geographical areas: North Region, East Region, and the Metro/Southwest Region, as defined in section 2.1.

(f) Project driven demand (large end user demand) and non-project driven demand (small end user demand within the low-pressure gas networks).

1.3 Purpose of this report

In developing gas demand forecasts, Marsden Jacob has prepared this report on the forecasting methodology. This report outlines the following: the implemented methodology by industry segment, modelled relationships and data sources, and key input parameters and assumptions used to develop the forecasts.

1.4 Structure of this report

The structure of this report is based on major gas use segments. Each section discusses the key drivers of gas demand in each gas use segment, the methods used to derive gas demand and key input assumptions.

The report includes the following chapters:

1. Introduction
2. Gas use in Western Australia
3. Drivers for gas demand
4. Methodology

2. Gas use Western Australia

Gas use in Western Australia is dominated by mining and mineral processing, gas powered generation and industrial use, whereas residential demand only accounts for a very small share of total demand.

Demand for Western Australian natural gas can be classified as either export demand or domestic demand. Exported gas tends to be processed onshore (close to production centres) and then shipped to Asian markets in the form of LNG.

Domestic gas demand is largely used for:

- mining operations in the Pilbara (e.g. iron ore), the Kalgoorlie and Goldfields region (e.g. gold mining); and
- mineral processing and electricity generation in the Southwest region.

The focus on this report is to develop a forecasting methodology for domestic demand in Western Australia.

2.1 Gas use in Western Australia

In 2017, mining and mineral processing gas use segments accounted for 55 per cent of domestic gas demand in Western Australia, with public electricity generation accounting for 21 per cent (the latter gas use includes mines connected to the electricity networks)[1]. Much of the gas used in mining and minerals processing is essentially for power generation, which implies that around three quarters of gas used within Western Australia is for power generation. The residential gas market in Western Australia is small (accounting for only 2 per cent of annual gas use in Western Australia).

The principal users of natural gas in Western Australia include the following industries:

- Iron ore, gold, and nickel mines
- Alumina refineries and nickel smelters (e.g. also uses steam produced from gas boilers, cogeneration units and emerging lithium processing facilities)
- Electricity generation in the SWIS and NWIS
- Industrial users such as brickworks, cement manufacturers, and chemicals plants
- Production of LNG (export or domestic), compressed natural gas (**CNG**), and liquefied petroleum gas (**LPG**)
- Petroleum processing

Some of the major gas users include Alcoa (alumina), Synergy (power generation), Alinta (power production and gas retail), Yara Fertilisers (ammonia) and BHP Billiton (e.g. mining and mineral processing).

[1] The primary electricity networks are the SWIS and the NWIS.

The main segments of gas demand (average TJ/day) in Western Australia (excluding gas used in LNG for export production, but including gas utilised in the commissioning of LNG facilities) is shown in Table 1. In addition to the SWIS/non-SWIS segregation, this includes a further breakdown of gas consumption in Western Australia by the following three geographical regions:

- East (includes the GBB zone Goldfields, Kalgoorlie as well as Esperance)
- North (includes GBB zones Karratha, Dampier, Pilbara and Telfer)
- Metro/Southwest (includes the GBB zones Mid-West, Parmelia, Metro/Southwest)

Table 1: Western Australian Gas Demand (excluding gas used in LNG production) - TJ/day, calendar year

Sector	2013	2014	2015	2016	2017	2018 (est)
Mining	158	157	174	213	227	264
Mineral processing	335	333	338	340	341	350
GPG	248	249	246	234	228	203
Industry	171	163	173	170	187	157
Distribution	57	57	57	58	54	66
Total	**968**	**959**	**989**	**1,015**	**1,037**	**1,041**
Region	2013	2014	2015	2016	2017	2018 (est)
East	74	77	86	102	107	113
Metro/Southwest	680	674	680	666	666	269
North	214	207	224	247	264	659
Total	**968**	**959**	**989**	**1,015**	**1,037**	**1,041**

Source: AEMO, Gas Bulletin Board data (downloaded August 2018)

Notes:

(a) 2018 estimate is based on data for the period ending 14 August 2018.

(b) Excludes gas used in gas shipping (e.g. compressor stations and unaccounted for gas) which is around 20 TJ/day.

(c) Excludes gas used in LNG and domestic gas production (that is, gas which is extracted and consumed and does not enter a GBB pipeline) but includes pipeline gas used in the construction and commissioning of LNG and domestic gas facilities (i.e. Gas Production).

(d) Industry includes LPG, petroleum, LNG for the domestic market, brickworks, cement manufacturers, chemicals plants and gas used in the construction phase of LNG and domestic gas projects. Yara Fertilisers had a major outage during July and August 2018 and this impact on gas use has been removed in 2018.

(e) Gas Distribution includes residential and business gas use delivered through the South West and Kalgoorlie distribution systems.

(f) Some gas allocated to SWIS GPG from the Gas Bulletin Board data has been re-allocated to Mineral Processing, since several co-generation facilities in the SWIS use gas to provide electricity and produce steam – the latter used in mineral processing.

The following gas use segments are used in this report:[2]

- Mining – includes GPG gas consumption used specifically to power mine sites, such as iron ore, gold, and nickel mines;
- Mineral Processing – includes alumina refineries, nickel smelters, lithium ion and titanium oxide production;
- GPG – gas used in grid connected generators primarily used for power supply to residential and commercial customers in townships or cities.
- Industry – includes ammonia, oil and gas processing (e.g. LPG, petroleum, LNG for the domestic market), brickworks, cement manufacturers, chemicals plants and gas used in the construction phase of LNG and domestic gas projects.
- Gas distribution – residential and business customers connected to the gas distribution networks in the Metro/Southwest region, Kalgoorlie and Esperance, and mainly relates to the residential and business customers on the low-pressure network owned and operated by ATCO.
- Gas used for shipping, storage and unaccounted for gas (which is excluded from the forecast but accounted for separately).

Large gas consumers in the SWIS include minerals processing (Alcoa's Kwinana, Wagerup, and Pinjarra alumina refineries and BHP Billiton's Kwinana nickel refinery) and electricity generators (such as Kwinana and Cockburn power stations). Depressed commodity prices for alumina, mineral sands and nickel have prevented growth in the development of new facilities, which has kept gas demand static in the SWIS over the last four years.

Non-SWIS consumption is primarily for power generation required by mining projects and local townships. Around 3,519 MW of gas generation capacity is located at remote mine sites and in regional centres (such as Halls Creek and Leonora). There is about 444 MW of diesel-fuelled generation capacity in the non-SWIS area. Some of this generating capacity may be converted to gas, particularly if diesel remains more expensive, which would create additional opportunities for increased gas consumption in the future.

[2] Nickel and lithium involve both mining and processing. For consistency with past treatment the nickel is included in the mining segment, whereas lithium – after discussions with the AEMO – has been included in the mineral processing segment.

3. Drivers for gas demand

Key issues for developing a ten-year gas forecast are understanding the drivers of domestic gas use in Western Australia including the energy and mineral commodity price outlook (e.g. exports), economic and demographic factors, changes to power generation (particularly uptake of renewable energy), and climatic factors.

Over the last five years, depressed commodity prices for alumina, mineral sands and nickel have prevented growth in the development of new minerals processing facilities, which has kept gas demand static in the SWIS. However, non-SWIS gas consumption has risen due to the opening of new mines mainly in the Pilbara region (e.g. iron ore).

Developing accurate forecasts of gas demand is highly dependent on a number of key factors, such as:

- Developing gas demand outlooks for GPG (mining and non-mining related), alumina, ammonia and large commercial and industrial customers.
- Understanding the impact of the emerging lithium mining and processing facilities in Western Australia, which will increase both gas and electricity demand in the SWIS and non-SWIS regions.

The key drivers of future demand and the potential for fuel switching for some of the most significant gas user segments in Western Australia are discussed in the subsequent sections.

3.1 Mining

A significant proportion of gas demand in Western Australia is for onsite power generation to facilitate mining (e.g. iron ore, copper, gold, and nickel)[3].

Mining is driven by long term global demand for resources which in turn affects exploration and mine developments, which typically take several years to develop. Once a facility is built, the mine will generally operate at a steady capacity factor to extract the ore/mineral.

If commodity prices increase, existing mines may have some ability to increase production, but are limited by the capacity of the mine. If commodity prices fall to low levels, the mine may not be able to recover the cash costs associated with operation and thus close either temporarily or permanently. Therefore, Marsden Jacob does not expect short to medium term commodity prices[4] to be particularly relevant to forecasting of gas use with gold being the exception due to the particular nature of gold for investment purposes.

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3 Marsden Jacob note that the AEMO requested that lithium be treated as mineral processing, similarly to aluminium.

4 The AEMO provided Marsden Jacob with commodity price forecasts until 2028.

The establishment of new mines and facilities is a function of the trajectory of future individual commodity prices. These prices are in turn a function of economic activity in Asia, the major destination for our mineral exports. The higher the forward curve for commodities, the more likely that new mines are established and increase gas use in the sector.

There is about 444 MW of diesel-fuelled generation capacity in the non-SWIS area, primarily used to support mining activities.[5] Some of this generating capacity may be converted to gas, particularly if diesel remains more expensive, which would create additional opportunities for increased gas consumption in the future. However, both the diesel tax rebate for power generation and solar photovoltaic (**PV**) and batteries reduce the incentives for miners to convert from diesel to gas powered generation in remote regions.

3.2 Mineral Processing

The mineral processing sector in Western Australia is dominated by alumina production, with an emerging lithium hydroxide segment. Mineral processing is closely linked to mining of bauxite and lithium. Mineral processing is driven by similar factors to mining in that:

- there is limited scope to vary production based on short term prices
- expansion takes years to develop
- decisions are based on long term assessments of global demand for aluminium/bauxite (and lithium hydroxide/lithium ore), and these typically take several years to undertake.

Once a facility is built, the mineral processing plant will generally operate at a steady capacity factor to process the ore/mineral.

Higher gas prices will impact cash margins for existing alumina operations in Western Australia and could potentially affect future developments (e.g. expansion of Alcoa's Wagerup Facility). Gas use can be affected by gas prices, which if sufficiently high, might incentivise coal substitution to meet both power generation and steam requirements. Given the historically depressed commodity prices for alumina, these companies do not have a high tolerance (or willingness to bear) for significantly higher gas commodity prices. However, this might be countered by emission reduction targets that provide incentives to substitute coal for gas or renewables.

In addition to alumina, which accounts for the majority of gas in this segment, mineral processing also includes nickel and mineral sands and lithium hydroxide, the latter expected to be the main driver for growth in this segment due to growth in global demand.

3.3 GPG

Future gas use in the GPG sector depends on the relative competitiveness of coal, gas and renewables generation (including the expected entry of large-scale renewable plants in the SWIS), as well as future electricity consumption.

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[5] Compiled by Marsden Jacob from public and private information supplied by the Energy Supply Association of Australia, Department of Finance (Public Utilities Office) and ACIL Allen consulting.

After the mid-2020's, it is expected that large-scale renewables will enter the market to help achieve emission reduction targets[6] (which requires some existing plant to reduce output as well) and/or demand growth to justify new investment.

A major factor in future gas use in Western Australia will be the reduced dispatch of older coal fired power plant due to increased renewable penetration, or as required to achieve emission reduction targets, and whether there will be any future investment in coal plant in the Wholesale Electricity Market (**WEM**).

Marsden Jacob is of the view that no new large-scale coal powered generation will be built in the SWIS over the forecast period for the following reasons:

- Commonwealth Government commitments to limit future carbon emissions (e.g. 26 per cent reduction in emissions by 2030 on 2005 levels to meet Paris Climate Change Agreement commitments) would be a major disincentive for any future investment in baseload coal plant. A likely result is that that both gas peaking and baseload generation will continue to be utilised in the future to meet demand.[7]
- Major electricity suppliers throughout Australia have stated that new coal generation is not a viable option, the reasons being carbon risk and the declining cost of renewable generation.[8] The higher risk associated with developing coal fired power stations was noted in the Finkel Review (June 2017) to the Australian government.[9]
- Currently coal generators in the SWIS obtain their coal supplies from coal produced in the Collie region. Coal is supplied to the coal power stations at a cost below $2.70/GJ[10]. If additional coal were required to supply a new coal fired power station, it is likely that a comparable coal supply capacity would have to be developed. This would mean higher coal prices and long term 'take or pay' commitments than currently provided to the coal power stations. In addition, shrinking minimum demand due to solar power will reduce the incentive for new coal fired base load generation.[11]

3.4 Industry

The Western Australian industry sector (related to gas use) is dominated by ammonia production (CSBP Ammonia – Wesfarmers), Yara Fertilisers, domestic LNG production (Maitland LNG and Wesfarmers LNG) and LPG production (Wesfarmers LPG). Ammonia is a key input into fertiliser production. Ammonia is produced using natural gas as a feedstock; production is centred on locations where low cost gas is available.

Gas use by large users is mainly comprised of a few fertiliser and gas processing customers, which exhibit very stable production not withstanding regular scheduled shutdowns for maintenance. Existing facilities generally operate at a steady capacity factor and are not dissimilar to the mineral processing sector in this respect.

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6 LRET (33,000 GWh by 2020) and/or other emission reduction targets to meet Paris Climate Change Agreement commitment, noting that emission reduction targets post LRET continue to be subject to significant future policy uncertainty.

7 Peaking gas units are typically Open Cycle Gas Turbines, while baseload gas units are typically Combined Cycle Gas Turbines.

8 Various media reports including: http://www.abc.net.au/news/2017-02-16/coal-power-generator-says-new-plants-not-viable/8277210.

9 https://www.energy.gov.au/government-priorities/energy-markets/independent-review-future-security-national-electricity-market.

10 Marsden Jacob analysis 2018

11 In combination with batteries, solar power may also reduce the demand for gas peak generation over time. Please refer to Chapter 3.7 for a discussion about the impact of renewable generation outside of the SWIS.

If commodity prices increase, some scope exists to increase production, but is limited by the capacity of the facility, while economic growth and commodity prices (in some instances) may contribute to expansion of capacity and increased gas use.

3.5 Distribution

After accounting for large industrial, mineral processing and mining users consuming gas from low pressure distribution networks, gas use for residential and commercial purposes is primarily affected by weather conditions that drive cyclical behaviour for space heating and cooling, with some incremental changes affected by demographic, economic and technological factors, such as the uptake of rooftop PV and split system air-conditioning.

3.6 Shipping and storage

Gas use by transmission pipelines and storage is fairly stable, relatively small and largely associated with overall gas use by end use customers. It therefore shows the characteristics of its customers (e.g. seasonal patterns if connected to distribution systems).

Gas use for storage goes through phases and may be quite high when storage facilities are being filled. However, ultimately gas stored is consumed, and storage facilities mainly shift the supply profile over time. Similar to gas used for transmission (aside from when facilities are being filled), gas storage is largely associated with end use customers and therefore exhibit their customers' characteristics.[12]

Gas use for transmission and storage is included for information only and has not been included in the forecast totals.

3.7 Renewable generation beyond the SWIS

3.7.1 Overview of future opportunities outside the SWIS

Due to Western Australia's dependence on energy-intensive mining activities, Western Australia has a higher reliance on an integrated gas network than in the Eastern States, where a higher population density and more evenly distributed industrial demand made an integrated electricity network more economical. As a result, Western Australia has a high dependence on using natural gas as fuel for power generators co-located with mining operations. Around 3,519 MW of gas generation capacity is located at remote mine sites and in regional centres (such as Halls Creek and Leonora).[13]

For those regions without access to the gas pipeline, diesel generators are used to power mines and remote townships. There is about 444 MW of diesel-fuelled generation capacity in the non-SWIS area. Some of this generating capacity may be converted to gas, particularly if diesel remains more expensive, which would create additional opportunities for increased gas consumption in the future.[14]

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12 For instance, Mondarra shows some seasonal pattern, whereas Tubridgi (used largely for mining does not).

13 AEMO, 2016 Gas Statement of Opportunities, For Western Australia, December 2016, p. 46.

14 AEMO, 2016 Gas Statement of Opportunities, For Western Australia, December 2016, p.46.

Growth in non-SWIS generation is a function of future commodity prices for LNG, iron ore and other minerals. These prices are in turn a function of economic activity in South East Asia, the major destination for our energy and mineral exports.

There are currently limited choices on fuel for power generation (i.e. diesel and natural gas) outside the SWIS. However, if gas or diesel prices were to increase significantly, then users may be required to substitute gas or diesel plant with renewable energy or coal fired generation (if commercially attractive).

Some of the non-SWIS renewable projects developed or in development are outlined below:

- Degrussa Solar Project (constructed) - The $40M DeGrussa Solar Project was successfully commissioned at Sandfire's DeGrussa Copper-Gold Mine in June 2016. It is the largest integrated off-grid solar and battery storage facility in Australia. The project consists of a 10 MW_{AC} solar PV system, a 6 MW lithium-ion battery storage facility, which is electrically connected to the existing 19MW diesel-fired power station.[15]
- Waste to Energy Project (committed)[16] – New Energy Corporation is developing a waste to energy generation project near the Boodarie Industrial Estate in Port Hedland. The facility will be able to process waste of between 70,000 to 130,000 tonnes per annum and have a maximum generation capacity of up to 18 MW.
- Onslow Microgrid – The Western Australian Government and Chevron Wheatstone Project (adjacent LNG project) are investing in the creation of a microgrid in the town of Onslow that integrates a solar farm and small-scale gas plant (5.25 MW) with battery storage. The project was completed in early 2018.[17]
- Several other renewable energy investments (mainly solar plant) are being developed in the Pilbara region. This includes the Karratha Airport 1 MW solar plant, Yara Pilbara Fertilisers solar plant and Horizon Power solar/diesel plant in remote communities.[18]
- Alinta Energy is developing battery storage alongside its generation plant at Newman to improve the heat rate of its OCGT plant. This will help the plant to be more competitive with CCGT plant located in the region.[19] This is also an opportunity for Alinta Energy to install battery storage alongside its Port Hedland OCGT units as well.

3.7.2 Levelised costs of generation technologies in remote areas

Marsden Jacob has calculated the levelised costs for both large-scale solar (fixed mounted) and single cycle high efficiency gas turbine and combined cycle plant that could be installed in the Pilbara in the future (see Table 2).[20] Marsden Jacob has assumed a real discount rate of 7.5 per cent and a payback period of 20 years – assets will last longer but there is significant uncertainty of ongoing revenues beyond 20 years in remote areas of Western Australia.

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15 http://www.sandfire.com.au/operations/degrussa/solar-power-project.html .
16 http://www.newenergycorp.com.au/projects/pilbara-wa/project-information/
17 https://onestepoffthegrid.com.au/w-plans-australias-biggest-solarstorage-micro-grid-onslow/
18 https://arena.gov.au/projects/karratha-airport-solar-plant/, https://ammoniaindustry.com/yara-solar-ammonia-pilot-plant-for-start-up-in-2019/, and https://www.horizonpower.com.au/our-community/projects/
19 https://www.alintaenergy.com.au/about-us/news/alinta-energy-switches-on-big-pilbara-battery
20 Levelised cost of electricity generation is the discounted lifetime cost of ownership of using a generation asset converted into an equivalent unit cost of generation in $/MWh. See https://hub.globalccsinstitute.com/publications/uk-electricity-generation-costs-update/21-definition-levelised-cost.

Based on Marsden Jacob's assumptions (delivered gas price of $8/GJ)[21], the levelised costs of solar plant in 2018 are lower than that of either an open or combined cycle gas plant. However, solar plant only has a capacity factor of 26 per cent and cannot provide baseload power to a mine which is running 24 hours per day, 7 days a week. The solar plant can be used during the day to power the mine, with gas plant used to supply power when renewable power is not available.

Table 2: Levelised costs of gas plant and solar plant (2018 dollars)

	LM2500 + G4 Single Cycle	LMS2500 Combined Cycle	Solar Plant PV
Gross (MW)	34.54	32.80	30.00
Capacity (MW)	32.12	30.50	30.00
Gross Heat Rate (GJ/MWh, LHV)	9.67	6.89	
VOM $/MWh	10	7	1
Capital Cost $/MW/annum	213,739	371,758	197,405
Capacity Factor	75%	75%	26%
Generation (GWh/annum)	211.0	200.4	68.3
Levelised Cost ($/MWh)	119.9	118.7	87.7

Source: MJA analysis

Table 3 provides a comparison of the levelised costs of large-scale solar in future years as the capital costs of solar are expected to fall overtime.

Table 3: Levelised costs of solar plant in future years (2018 dollars)

Unit costs ($/Mwh)	2018	2022	2026
Solar	87.7	78.0	67.7

Source: Marsden Jacob (2018)

This analysis indicates that mining operations (and other commercial customers outside the SWIS) have an incentive to invest in solar plant to reduce operating costs. Due to their intermittency, solar plants will not displace gas plant entirely, but they could reduce the amount of gas and diesel generation that is required to maintain operations at mine sites or in servicing town sites.

3.7.3 Uptake of large-scale PV in the North and East Region

Given the compelling commercial case for solar generation in the North and East regions of Western Australia, in the low case, AEMO and Marsden Jacob have assumed that solar generation was installed by gas users in the mining industry outside the SWIS. Specifically, it is assumed that 20 per cent of new generation requirements (i.e. measured in terms of energy requirements not capacity) installed to support the mining sector are solar generators.

This assumption has the effect of dampening gas use in the North and East region, although the same amount of gas fired generation capacity will need to be installed to meet baseload operational requirements (i.e. operating 24 hours a day, 7 days a week).

[21] Based on a pipeline cost of $1.50/GJ and commodity gas of $6.50/GJ in 2018 dollars.

4. Our methodology

AEMO and Marsden Jacob developed five scenarios. For each of these, Marsden Jacob forecast gas use by industry sector and region using macroeconomic, population and commodity market forecasts provided by AEMO and a combination of statistical methods, regression analysis and energy market simulation modelling using Marsden Jacob WEM model (PROPHET Market Simulation).

This chapter provides an outline of the methodology in the context of the scenarios developed by AEMO and Marsden Jacob.

4.1 Basic approach

The general approach adopted for each gas use sector was to:

- review Gas Bulletin Board data for trends and patterns and investigate any weather-related patterns using heating and cooling degree days from the Bureau of Meteorology.
- identify logical drivers for gas use for each sector; and
- analyse the relationship between gas use and identified drivers and investigate if a basic statistical approach, regression analysis, or simulation modelling would deliver the best results.

Subsequently, Marsden Jacob adjusted this approach based on the assumptions for the five scenarios developed with AEMO, in addition to forecast drivers (including forecast variables provided by AEMO).

4.2 Scenarios

The AEMO and Marsden Jacob developed five scenarios based on plausible growth paths and emission reduction scenarios. A summary of the Western Australian wholesale gas market and SWIS scenarios is summarised in Table 4 (see page 20):

- Scenario 1 – Base (forecasts for major projects and economic variables)
- Scenario 2 – Low (forecasts for major projects and economic variables)
- Scenario 3 – High (forecasts for major projects and economic variables)
- Scenario 4 – Base scenario assumptions but with no change to existing scheduled generation dispatch.
- Scenario 5 – Base scenario with COP21[22] emission reduction targets met by SWIS generators by 2026-27, facilitated by backing off the output from coal-fired power plants in the SWIS and renewable plant investment.

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[22] COP21 refers to the Conference of the Parties 21st session held in Paris in 2015, whereby the Australian Government committed to a 26 to 28 per cent reduction in emissions on 2005 levels by 2030.

4.2.1 AEMO forecasts for scenarios

AEMO provided Marsden Jacob with forecasts for macroeconomic variables (including GSP, SFD, and CPI), population and commodity production and prices[23]. These were used where a relationship for the forecast of gas use is identified, and where the forecasts include scenarios (base, high and low).

23 See the 2018 WA GSOO for further information on Economic Forecasts

Table 4:Western Australian gas market and SWIS GPG scenarios

Scenario No. Scenario Name Western Australian Wholesale gas market	1 Base	2 Low	3 High	4 SWIS powerplant dispatch unchanged	5 Accelerated SWIS Emission Reductions
Economic growth	Base	Low	High	Base	Base
Population growth	Base	Low	High	Base	Base
Commodities production	Base	Low	High	Base	Base
Gas prices	Base	High	Low	Base	Base
Non-SWIS GPG gas consumption	Base	Low demand plus new solar capacity built to support remote mining and industry.	High	Base	Base
SWIS GPG gas consumption	**Base**	**Low**	**High**	**SWIS powerplant dispatch unchanged**	**Accelerated SWIS Emission Reductions**
Peak Demand, Operational Consumption and PV and battery storage installation rates.	ESOO Expected	ESOO Low	ESOO High	ESOO Expected	ESOO Expected
New large-Scale Renewable Energy Investment and Commonwealth Emission Reduction Targets	Economic renewables under existing incentives	Economic renewables under existing incentives	Economic renewables under existing incentives	Economic renewables under existing incentives	Paris Accord emissions reduction target[24] achieved early in the SWIS (2027)
New Plant Investment	New coal-fired generation and CCGT are excluded. Only investment in renewables, conventional OCGT (heavy frame units), OCGT-Aero, diesel generation, along with battery storage is permitted.				
Existing generation plant	Some coal plus gas plant no longer dispatched as assumed to be economically rational.			No change to thermal plants being dispatched	Some coal plus gas plant no longer dispatched to meet emissions targets.

Source: AEMO and Marsden Jacob analysis

[24] Australia's 2030 climate change target is available at: http://www.environment.gov.au/climate-change/publications/factsheet-australias-2030-climate-change-target.

4.2.2 Major new projects in Western Australia

Committed mining and mineral processing projects in Western Australia

In conjunction with AEMO, Marsden Jacob developed a list of committed mining and mineral processing projects over the forecast period. The projects listed have either achieved FID or are likely to achieve FID during the forecast period.

Table 5: Major new mining and mineral processing projects

Project	Company	Industry	Region	Estimated Commencement Date
Further developments at Robe Valley and West Angelas	Rio Tinto	Mining	North	Jan-2019
Tropicana expansion (additional capacity)	AngloGold Ashanti	Mining	East	Jan-2019
Sunrise Dam (additional capacity)	AngloGoldAshanti	Mining	East	Jan-2019
Gruyere Gold Project JV	Gold Road Resources	Mining	East	Feb-2019
Kwinana expansion	Nickel West	Mineral processing	Metro/Southwest	Apr-2019
Kwinana Lithium Plant Stage 1* and 2	Tianqui Lithium	Mineral processing	Metro/Southwest	Jul-2019
Koodaideri	Mount Bruce Mining	Mining	North	Jul-2020
Eliwana Mine and Rail Project	Fortescue Metals Group	Mining	North	Dec-2020
South Flank Iron Ore Mine	BHP Billiton Iron Ore	Mining	North	Jul-2021

Source: DJTSI, DMIRS, various company websites, AEMO and Marsden Jacob analysis
* Stage 1 is not in historical GBB data yet.

These projects will add around 50 TJ/day to gas demand in the state over the forecast period. These projects have been included in all five gas demand scenarios over the forecast period.

Additional projects

AEMO and Marsden Jacob have also developed a list of thirteen prospective projects that may proceed during the forecast period but have not yet achieved FID, including several lithium hydroxide processing plants. These projects will add another 57 TJ/day to the High Demand Scenario.

4.3 Gas use by mining

Forecast gas use for the mining sector was based on the following approach:

- For existing facilities, Marsden Jacob determined gas use by existing facilities by taking the average of historical gas usage data, ensuring that any regular decrease in demand associated with outages or maintenance periods is reflected in the projected usage. Rather than incorporating all gas usage data in developing the average demand for a mine, usage in the most recent 12-month period was emphasised, if there were no unusual gas usage patterns due to forced mine outages or mine commissioning.
- For new facilities (e.g. committed, see section 4.2.2) Marsden Jacob estimated gas use based on known or typical energy technologies of existing facilities.

Non-specific growth was based on economic growth and mineral production and price forecasts supplied by AEMO. Depending on the nature of the mining sector, a combination of extrapolation (using historical monthly averages) and regression analysis was used to estimate expected gas use associated with the production forecasts. Subsequently, adjustments were made to avoid double counting between non-specific growth and identified new facilities. That is, specific project growth was subtracted from the non-specific growth forecasts.

4.3.1 Existing mines

Aside from gold, Marsden Jacob has found gas use by the mining segment typically only has a weak relationship with mineral prices. Once constructed, unless the mine is expanded or closed[25], the mine will typically operate at a constant level regardless of movements in commodity prices (except if unit prices were to fall below the cash costs of the mine).[26]

Our review of the Gas Bulletin Board data has shown that gas usage by existing mines is not weather related, nor is there an obvious trend growth or cyclical impact.

For the development of average gas use, Marsden Jacob undertook normal statistical tests to ensure that the use of average demand would not bias forecast results (e.g. tests for heteroscedasticity, autocorrelation and missing variables).

4.3.2 New mines

AEMO and Marsden Jacob together have reviewed the list of committed projects and projects under consideration published by the Department of Mines, Industry Regulation and Safety (**DMIRS**), the Department of Jobs, Tourism, Science and Innovation (**DJTSI**) (formerly Department of State Development) (see Prospect Magazine editions) and in public domain company reports.

Based on forecasts of future commodity prices and likely long run marginal costs of development (annualised $/unit), Marsden Jacob and AEMO formed a view on which projects were likely to commence during the 10-year study period (see Section 4.2.2).

In addition, Marsden Jacob also developed a forecasts of smaller Greenfield mines based on historical trends of mining production in the development of mines (by commodity) in Western Australia. These trends were based on historical increases in mining production and likely increase in gas use (e.g. tonnes per GJ). Gas use was based on Marsden Jacob's understanding of typical electricity requirements of mines (MWh/tonne by commodity type), the generator heat rate (GJ/MWh) for various mines and an estimation of gas required to meet the required level of production over a time period.

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25 Mining expansions were accounted for partially through major projects (Chapter 0), or non-specific growth. Mining closures such as the closure of the Windimurra mine in September 2015, are difficult to account for but clearly.

26 Mine cash costs typically include which direct costs incurred in mining and processing (labour, power, reagents, materials), freight, government charges, administration and selling costs. Mining closures will only be incorporated if identified (similar to the approach of major projects). None have been identified at this point.

4.3.3 Estimating growth in gas use by mining

Marsden Jacob considered a range of variables including commodity prices and commodity production. The results are provided in the following tables.

Table 6: Regression for gold gas use and gas production

Regression Statistics	
Multiple R	0.908834043
R Square	0.825979318
Adjusted R Square	0.767972424
Standard Error	4.121502568
Observations	5

	Coefficients	Standard Error	t Stat	P-value
Intercept	-86.45270959	37.419556	-2.310361693	0.10399657
Gold - t	260.4870986	69.030567	3.773503702	0.032587653

Source: Marsden Jacob analysis

Table 7: Regression for iron ore gas use and gas production

Regression Statistics	
Multiple R	0.9859736
R Square	0.972144
Adjusted R Square	0.9628586
Standard Error	4.5019167
Observations	5

	Coefficients	Standard Error	t Stat	P-value
Intercept	-142.83088	26.78723992	-5.332049196	0.012893132
Iron Ore - Mt	0.1204027	0.011767105	10.23213911	0.001989923

Source: Marsden Jacob analysis

Commodity prices

Aside from gold, our analysis found that commodity prices did not explain gas use. Our analysis found that there is a relationship between the gold price and aggregate monthly gas use by the gold mining sector, although monthly deviations in gold mining activity due to other factors such as planned and forced outages, commissioning of new plants and shutdowns of mines that have exhausted a gold seam reduce the degree to which the gold price explains gas use.

Commodity production

Marsden Jacob also considered historical commodity production. This was found to be highly correlated with gas use for iron ore (correlation coefficient of 0.987) and for gold mining (correlation coefficient of 0.914), but not for other minerals (nickel and copper). This can be a function of how many mines have access to gas pipelines in Western Australia (i.e. most iron ore and gold mines have access).

This suggests that the existing relationships between gas use and mining production (or energy intensity) can be used to estimate future gas use based on production forecasts. Marsden Jacob used regression analysis to calculate the relationships between mineral production and gas use for gold and iron ore. Forecasts of nickel gas use is based on the estimated energy intensity figure for nickel use by major projects (68.35 TJ/kilo tonne) and then multiplying this figure by production forecasts. For vanadium, copper and oil, gas use was assumed to be constant over the forecast period.

Approach for forecasting gas use by commodity

Based on analysis of the relationships between mining gas use by commodity and other variables, the approach taken includes the following:

- Iron ore and gold mining gas forecasts were based on regression equations that determined the relationship between historical mineral production and gas use.
- Forecasts of nickel gas use is based on the estimated energy intensity figure for nickel mining by major projects (68.35 TJ/kilo tonne) and then multiplying this figure by production forecasts.
- For other minerals (e.g. copper and vanadium) it is assumed that there is no non-specific natural growth in gas use by these mines.
- Gas use by major projects covers mining (e.g. iron ore, gold and vanadium). To avoid double counting of growth, first forecast iron ore and gold mining gas use is forecast as outlined above (using production forecasts), from which gas use required by specific projects is deducted, if major projects' mining demand growth exceeds growth calculated from production forecasts, and vice versa.[27]

4.4 Gas use by mineral processing

The mineral processing sector in Western Australia is dominated by alumina production:

- Alcoa's plant in the South West of Western Australia is currently powered entirely by natural gas. Of this, it is assumed that ~30 per cent is used directly in the process of converting bauxite to alumina, and ~70 per cent goes to power and steam production in three cogeneration plants, based on anecdotal evidence.
- South 32's alumina facility was previously powered by a combination of natural gas and coal. The coal was used in a steam cycle power plant and the gas was used for direct firing and in a cogeneration plant; the latter produced steam and fed electricity into the grid. However, the gas fired cogeneration plant (120 MW) was closed in 2016 due to a combination of higher future gas prices and an excess of baseload generation (both coal and gas plant) in the SWIS.[28]

4.4.1 Gas use for existing facilities

Figure 1 shows that the relationship between the alumina price index and gas consumed for alumina production is not significant in this gas use segment.

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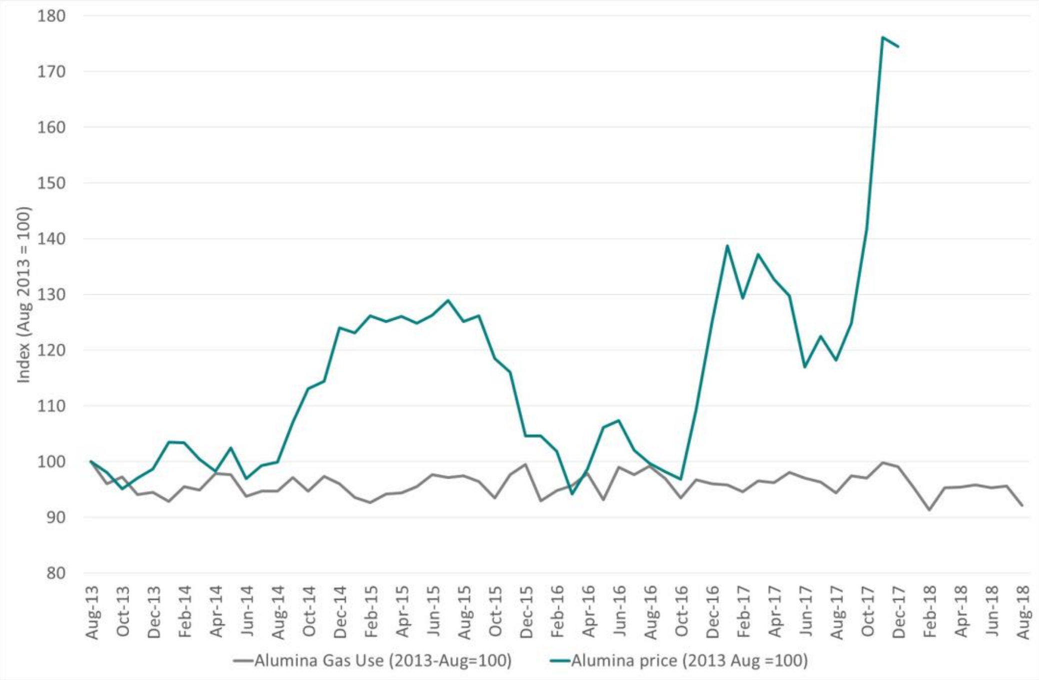
27 Where total growth based on monthly growth rates exceeds that of total estimated growth based on major projects, only the incremental growth was added. Where total growth based on monthly growth rates fall below the total estimated growth based on major projects, only the latter was used.

28 Note that gas use for steam has previously been included in SWIS GPG.

Figure 2 shows the monthly gas use by the four alumina plants operating in Western Australia (excluding gas used for the cogeneration units that does provide electricity to the grid). Gas use for generating steam for bauxite processing is included in mineral processing gas use. Notwithstanding short-term variations in gas use[29], this suggests that future gas use for existing facilities can be modelled largely based on historical usage profiles (2013 to 2018).

Figure 1: Alumina gas use in Western Australia and alumina price (Index = Aug 2013)



Source: DMIRS, 2018 Major Commodities Resource File & AEMO Gas Bulletin Board data, August 2018.

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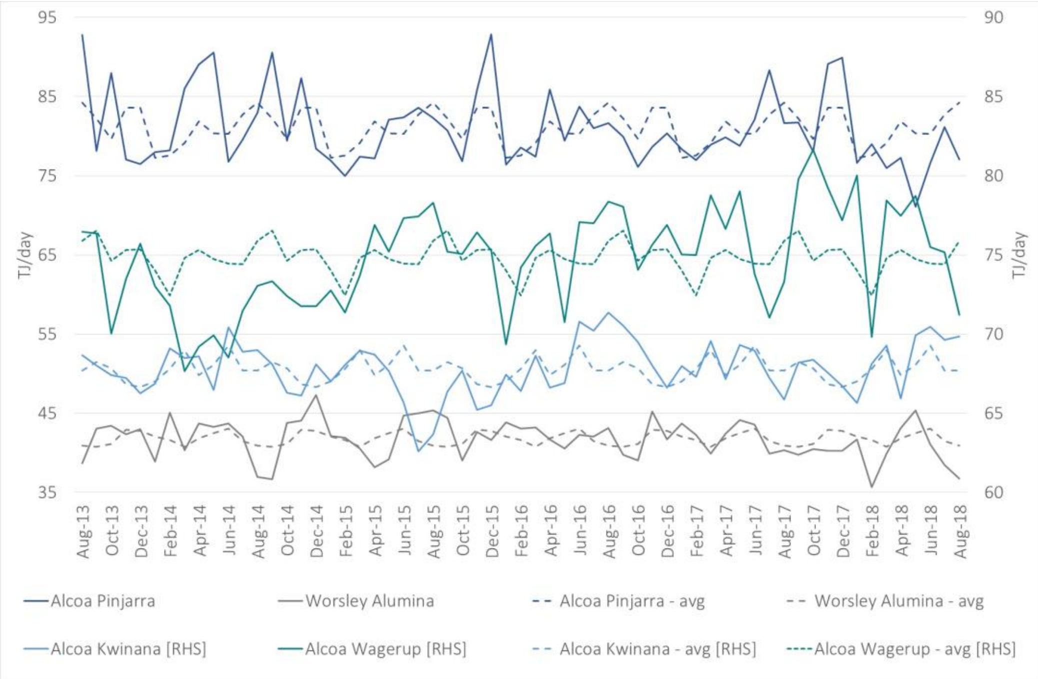
29 Worsley Alumina smelter is expected to recover in 2019 from a weaker period of production in the second half of 2017 and the start of 2018 (in part due to planned maintenance). Worsley is expected ramp back up to their full capacity of 4.6Mt per annum from 2019

Figure 2: Alumina gas usage profiles - historical and average (2013 to 2018)



Source: AEMO, Gas Bulletin Board Data, August 2018

4.4.2 Gas use for new mineral processing facilities

AEMO and Marsden Jacob created a list of major projects to include in the different scenarios based on a review of committed projects and projects under consideration (see 4.2.2).[30] For the 10-year outlook period, a number of lithium hydroxide projects were identified, which have been included in the mineral processing industry (not mining) given the value adding which occurs in processing.

In addition, the production forecasts provided by AEMO and historical trends in production were considered, which provides an indicator of the development of facilities (by commodity) in Western Australia.

The increases in mineral processing gas use from major projects likely to commence was compared with historical trends and production forecasts, using the same methodology as outlined in the mining section to avoid double counting.[31]

The main differences between scenarios are attributable to differences in new major projects (see 4.2.2), or constraints on carbon emissions in the SWIS affecting gas used for steam on the margins. Steam gas was modelled as a part of GPG (SWIS)[32] and re-allocated to mineral processing. As a result, the emission constraint affects this small component of mineral processing.

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30 Including those published by DMIRS and DJTSI (various prospect Magazine editions) and various others including some unspecified projects obtained from the AEMO.

31 For lithium, given the nascent nature of lithium in Western Australia, specific lithium projects identified were used to build up rather forecast lithium production provided by the AEMO.

32 See section 4.5.

4.5 GPG in the SWIS

For gas use by GPG in the SWIS, Marsden Jacob used our inhouse PROPHET simulation model to forecast gas use for each of the scenarios using the three operational consumption scenarios, relative cost for the portfolio of electricity generation technologies, and constraints imposed by the SWIS powerplant dispatch unchanged and accelerated SWIS emissions reduction scenario.

For gas use by GPG in the NWIS (currently around 43 TJ/day), forecasts were based on statistical analysis to determine relationships between population growth and/or GSP, and gas usage.

The SWIS has a relatively high penetration of gas generation relative to other electricity systems in Australia (40.7 per cent of electricity generated in the SWIS for the 2016-17 financial year was from GPG[33], compared to only 9% in the NEM[34]). In the past, this has been driven by access to low cost gas resources from the Carnarvon Basin (e.g. North West Shelf JV and Varanus Island producers).

With the increasing penetration of renewable energy facilities in the SWIS, the role of gas plant may change in the future. That is, gas plant could be used increasingly to maintain supply reliability and ramp up when renewable generation is not available (e.g. weather-related events).

Around 3,081 MW of generation capable of using gas (including dual-fuelled gas/diesel) is currently installed in the SWIS – two-thirds of which is peaking and mid-merit capacity (in terms of nameplate MW, not energy production).

An important feature of gas use by GPG is that it has the highest variation between minimum and maximum gas use due to weather effects (together with gas used through the distribution system) as compared with other industry segments.

4.5.1 Models

GPG demand in the SWIS was calculated using gas demand forecasts derived from Marsden Jacob's PROPHET simulation model of the WEM.

PROPHET simulation is an electricity market model that enables forecasting of market quantities and price for each trading interval over multiple years (typically 10 to 20 years). The model calculates the generation merit order (on an economic basis) of plant in the WEM on a half-hourly basis, considering minimum generation constraints and fuel constraints for individual facilities, and also incorporates transmission constraints.

The Western Australian Government is currently planning to introduce constrained network access in 2022.[35] Currently they are considering the introduction of either Partially or Fully Constrained Access in the WEM. In the Partial case, only generators commencing post 2022 would be constrained, whereas under Fully Constrained Access, all generators would be subject to constrained network access.

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33 AEMO, 2018 Wholesale Electricity Statement of Opportunities, Figures and Data.

34 https://www.aemo.com.au/-/media/Files/Electricity/NEM/National-Electricity-Market-Fact-Sheet.pdf .

35 Department of Treasury | Public Utilities Office, Improving access to the Western Power Network, Proposed approach to implement constrained network access, 9 August 2018.

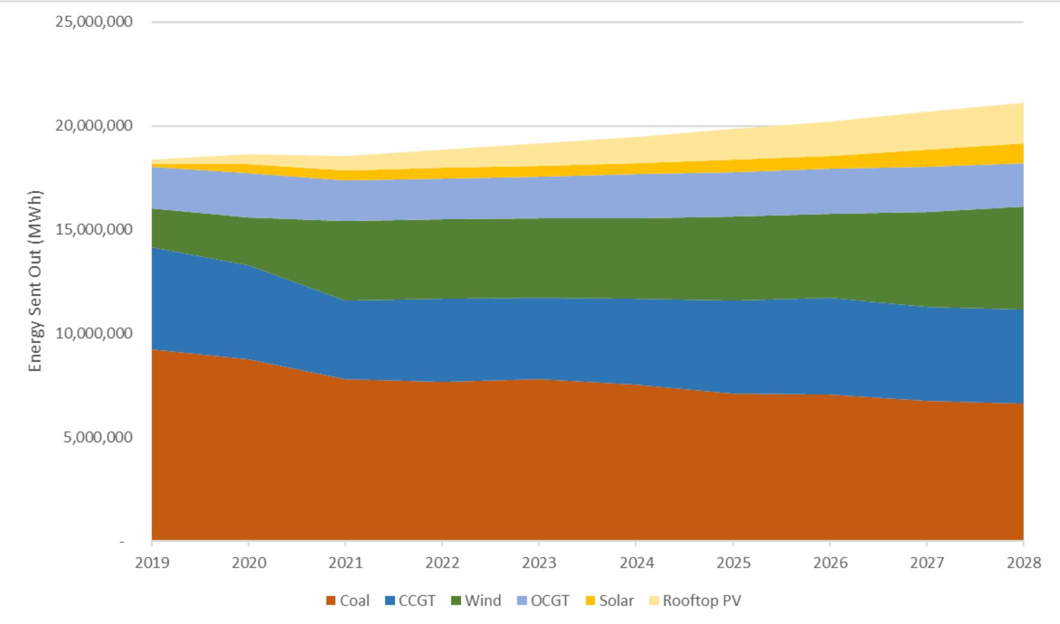
In many locations, it was found that the network constraint equations bound frequently with a relatively small amount of additional new entrant capacity, including Western Power's North Country region. As a result, new investment is constrained by the capacity of the network. For instance, in the North Country region only around 40 MW of new wind generation was economic without significant network upgrades after four of the committed and prospective projects, with total nameplate capacity of 360 MW, were included.[36] Given the number of projects which are being considered in the North Country region (additional wind farms), some of the transmission constraints that apply to North Country generators were relaxed. This is equivalent to assuming that Western Power undertakes transmission upgrades (e.g. second circuit 330 kV line to Eneabba) in that region.

Meeting emission reduction targets has been incorporated into the model under the SWIS accelerated emission reduction scenario. The outputs of the model include generation by each generating unit in the WEM and fuel used (derived from the heat rates of each plant). Generation by plant type is shown in Figure 3 below for the Base Case scenario in the WEM (CCGT and OCGT plant use natural gas).[37]

Shown in Figure 4 below is gas generation for the following three cases: Base, SWIS Power Plant Dispatch Unchanged, and Accelerated Emission Reductions. What this shows is that gas generation increases if COP21 emission reduction targets are put in place in the SWIS. If emission reduction targets are not put in place, coal generation is forecast to continue to displace gas plant in the WEM given it has the lowest Short Run Marginal Cost.

The model was used to determine the annual/monthly dispatch of gas plant in the WEM, and hence the demand for gas, as well as the gas generation profile on peak gas demand days (which usually occurs in Winter).

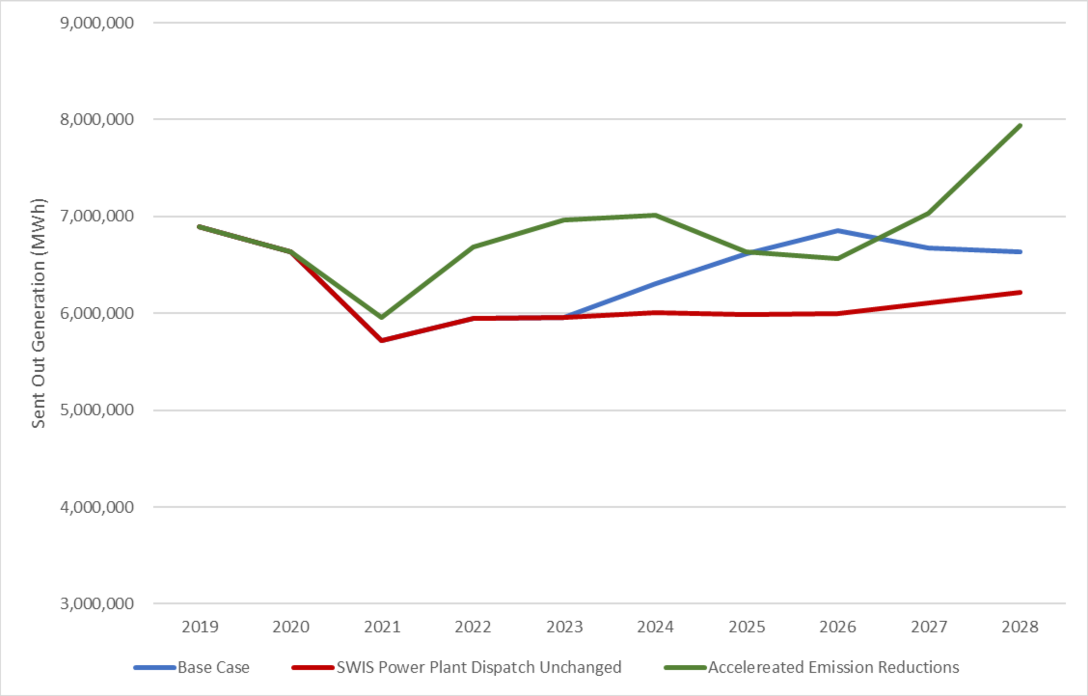
Figure 3: Base Case WEM Forecast: Generation by plant type (GWh)



Source: Marsden Jacob market simulation (2018)

36 EY, Modelling the impacts of constrained network access, Public report, For the Public Utilities Office, 1 October 2018.
37 No new CCGT plants are expected due to the relative cost, whereas for OCGT include existing and new plants.

Figure 4: SWIS GPG Gas Generation by Scenario (MWh)



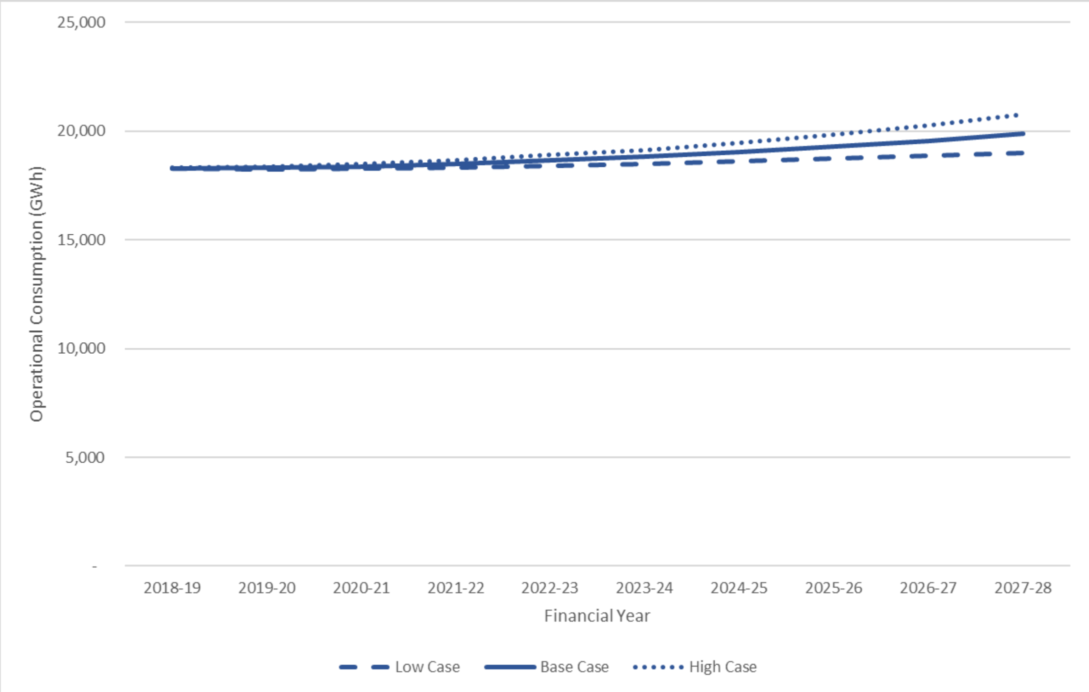
Source: Marsden Jacob market simulation (2018)

4.5.2 Methodology

The PROPHET Model was run under three operational consumption scenarios consistent with the AEMO WEM ESOO (June 2018).[38] Electricity consumption for the three scenarios is shown in Figure 5.

[38] https://www.aemo.com.au/Electricity/Wholesale-Electricity-Market-WEM/Planning-and-forecasting/WEM-Electricity-Statement-of-Opportunities

Figure 5: Operational Electricity Consumption Forecasts in the SWIS (GWh)



Source: Marsden Jacob and AEMO ESOO (2018)

While the Low, Base and High Scenarios covered the period 2018-19 to 2027-28, in order to accommodate calendar year analysis, the analysis was extended through December 2028.

While increased PV penetration can lower annual electricity consumption and GPG gas use, it can also make peak demand for gas more volatile. With households more dependent on solar energy production, variations in solar radiation due to cloud cover could result in the sudden loss of hundreds of MW of generation capacity in the SWIS within a short period of time. This requires dispatchable generation (mainly gas plant) to ramp up rapidly to cover the loss of the solar generation.

Outside the SWIS, most renewable investment is expected to be solar plant due to the relative cost and flexibility. This solar plant will need to be supported by existing and new gas plant over the 10-year forecast period.

Peak demand in the WEM is also based on the ESOO 2018 Peak Demand Forecasts. Marsden Jacob modelling use peak demand that is based on the 50 per cent probability of exceedance (**PoE**) level.

On the supply side, three scenarios were developed with different large-scale renewable build programs over the same period, based on differing assumptions for plant dispatch from existing plants and emission reduction targets:

- Economic renewables under existing incentives and assumed changes to thermal plant dispatch.
- Scenario 4 is based on no changes to thermal plants being dispatched in the SWIS.

- Scenario 5 assumes an emission reduction trajectory consistent with achieving COP21 by 2027 with enough renewable investment to ensure that emissions from the electricity sector in the SWIS are 26 per cent below its 2005 levels by 2027. In this scenario, older coal fired power plant becomes uneconomical in 2023 and in 2027.
- Renewable energy projects have been included in all the above-mentioned renewable supply scenarios are listed below, while additional (non-specific) renewables were required under scenario 5.

A list of nine renewable projects, totalling 762 MW in nameplate capacity, were assumed to commence for this analysis. In addition to these assumptions relating to renewable investment and demand growth, assumptions were made regarding the following factors:

Gas Price – The assumed gas price is in line with the gas price used in the supply forecasts that was supplied to AEMO by an external consultant.

Coal Price - In October 2014, the Minister for Energy announced an increase in the price paid by Synergy for Coal from Premier Coal at $7/tonne.[39] It is assumed that this price increase took effect in 2016-17. Incorporating annual CPI increases and the one-off increase in contract coal price with Premier Coal, Marsden Jacob estimated that prices in 2017-18 are $2.61/GJ (2018 dollars). Because of poorer quality coal that has been mined in recent times, it is assumed that the real price per GJ of coal increases by 1 per cent per annum over the forecast period; reflecting the declining quality of the two existing mines.

The comparison of natural gas and coal prices in Western Australia highlights that coal is relatively cheap compared to natural gas in Western Australia. However, commitments to reduce overall emissions (and/or emission intensity levels), low electricity consumption growth, and the continued decline in the cost of renewable energy plant will likely result in no future investment in coal-fired generation in Western Australia.

Plant dispatch – Our analysis indicates that there are likely to be significant changes to plant dispatch in the SWIS over the next 10 years. It is expected that generation from coal plant will decrease, while dispatches of renewable and gas plant are likely to increase.

In the base, low and high scenarios some generation, notably older coal-fired plant, is no longer dispatched in the SWIS from the end of 2023. This is expected either because plants have reached the end of their technical life, or for commercial reasons.

The SWIS power plant dispatch unchanged scenario assumes no change to the existing thermal power plant facilities that are dispatched.

To meet SWIS generations share of the COP 21 target by 2027, the accelerated SWIS emissions reduction scenario modelled a proportion of older coal-fired generation as no longer dispatched, starting from the end of 2021. A further proportion is assumed to no longer be dispatched beyond 2026. This results in roughly half of current SWIS coal-fired generation no longer being dispatched in this scenario beyond 2026.

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39 Media statement: http://www.abc.net.au/news/2014-10-14/synergy-to-pay-more-for-coal-to-save-wa-jobs/5813720

New Plant Entry – As outlined earlier, it is expected that no new coal plant will enter the SWIS over the forecast period. While baseload gas plant (i.e. CCGT) could enter the SWIS, given the intermittency of renewable plant, it is likely to be more economic to install high efficiency gas turbines (**HEGT's**) i.e. aero derivative gas units, that can supply energy efficiently and quickly ramp up and down in response to changes in renewable energy production in the future. In this study, it is assumed that a combination of HEGT's and OCGT's is built in the second half of the forecast period to supply energy and maintain reliability of supply in conjunction with renewable plant.

4.5.3 Normalised electrical load duration curve for annual and monthly load forecasts

Developing annual and monthly gas consumption for SWIS GPGs requires an annual normalised load duration curve (**LDC**) (17,520 electricity demand intervals in a normal year stacked from highest load to lowest). A typical LDC is shown below.

While past LDCs can be used for this purpose, the historical LDC for weather needs to be normalised. To do this, the number of cooling degree days (**CDD**) and heating degree days (**HDD**) in each historical year (as measured by degrees of temperature adjustment) are considered.

CDDs and HDDs provide an indication of the level of comfort and are based on the average daily temperature. The average daily temperature is calculated as follows: [maximum daily temperature + minimum daily temperature] / 2. If the average daily temperature falls below comfort levels (18 degrees Celsius), heating is required and if it is above comfort levels (24 degrees Celsius), cooling is required.

Historical CDD and HDD for past calendar years (going back to 2003) were used for the three regions identified by the AEMO: Metro/Southwest, East and North regions. All regions vary around long-term averages, and the size of the temperature adjustments required clearly reflect the climate, with the northern region requiring a particularly large temperature adjustment compared to the other regions (see Appendix B).[40]

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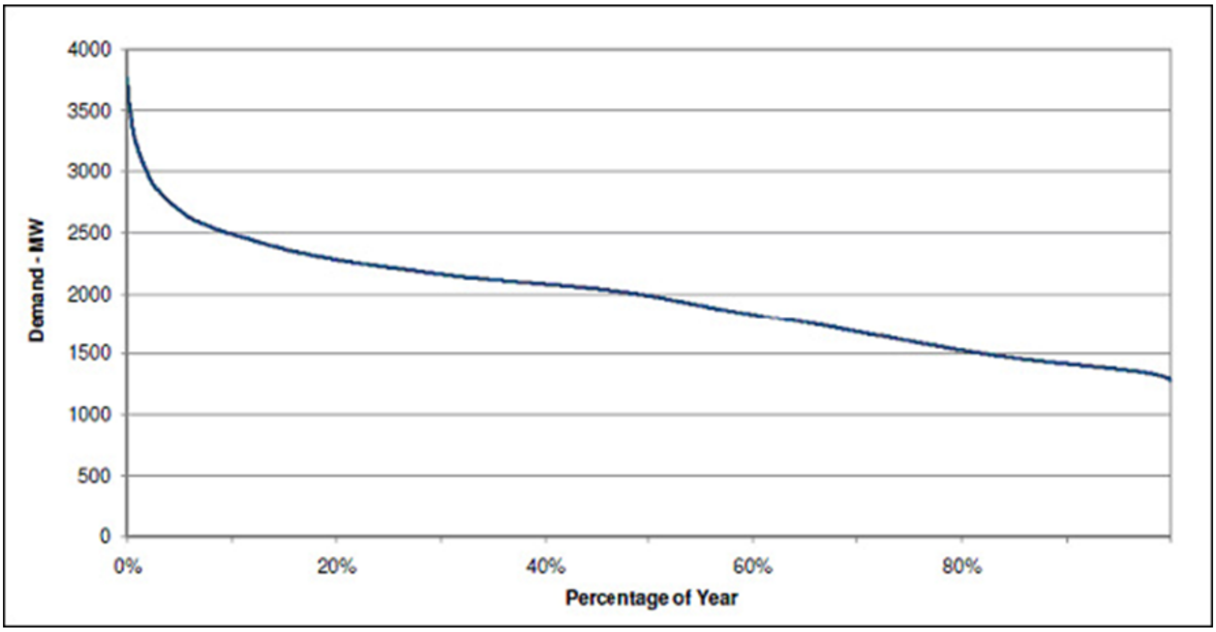
40 The temperature adjustments are applied to the relevant share of load. For instance, for the SWIS which includes the Metro/Southwestand East regions the load supplied to the region is normalised by CCD and HDD for the Metro/Southwestregion.

Figure 6: Load Duration Curve for the SWIS



Source: Public Utilities Office

In addition to weather adjustments, adjustments were made to the historical LDC to derive the baseline LDC, which requires consideration of:

- Population and state final demand, which drive annual growth in gas use.
- Penetration of rooftop PV. Typically, rooftop PV reduces demand in those trading intervals from 5:00 to 18:00 in summer and 8:00 to 16:00 in winter.[41]

4.6 Gas demand by industry

Industry refers to major gas users, such as ammonia, fertiliser and gas producing facilities.

Industrial gas use tends to be less cyclical than for the mining and minerals processing sectors. It is expected that recent average usage volumes can be utilised to assist the development of gas demand forecasts for this sector, accounting for regular drop-offs for maintenance and removing any unusual patterns (i.e. forced outages).

4.6.1 Gas use by major users

The gas industry segment is dominated by ammonia production (CSBP Ammonia – Wesfarmers and Yara Fertilisers), domestic LNG production (Maitland and Wesfarmers), and LPG production (Wesfarmers LPG).

Ammonia is a key input into fertiliser production. Ammonia is produced from natural gas with production, typically centred on locations where low-cost gas is available. Ammonia can also be produced via coal gasification but there are higher capital costs involved.

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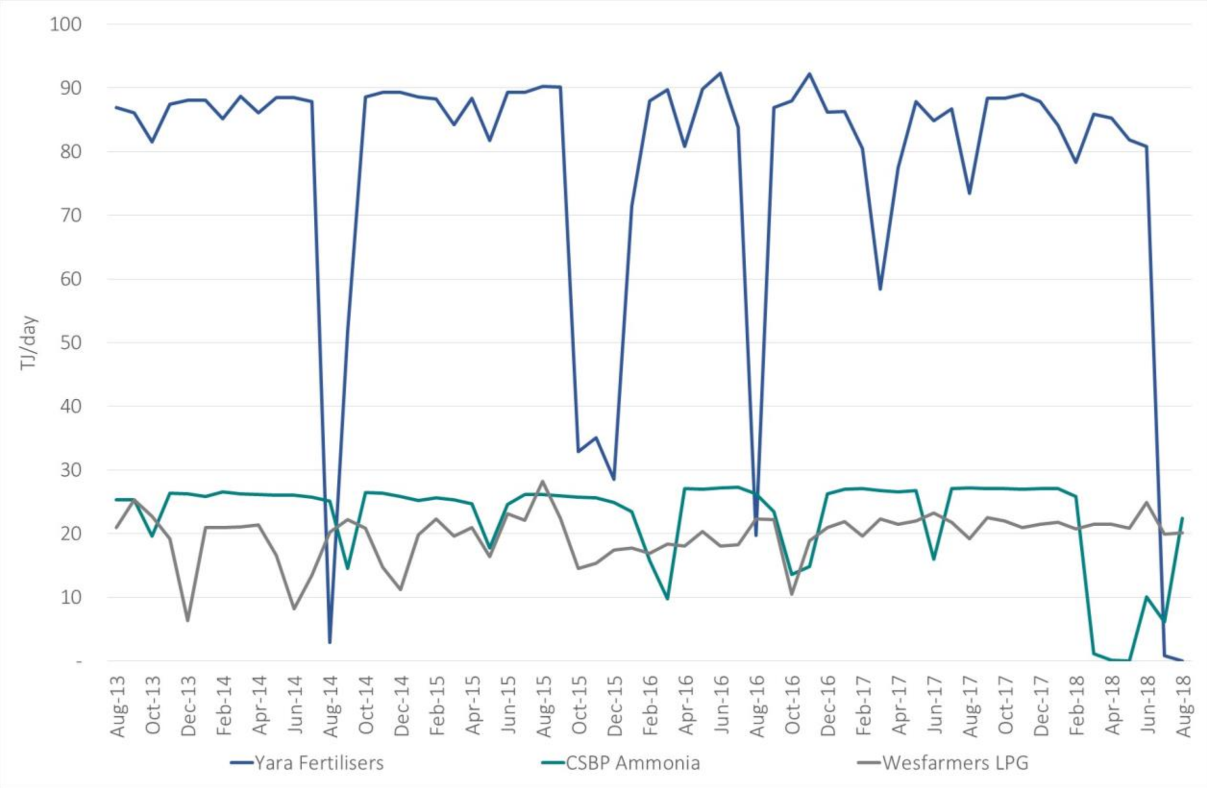
41 See Figure 9 of https://www.aemo.com.au/-/media/Files/Electricity/WEM/Planning_and_Forecasting/ESOO/2018/2018-WEM-ESOO-Report.pdf

The two major ammonia producing facilities in Western Australia are at Yara Fertilisers and CSBP (Kwinana).

Figure 7 shows the monthly gas consumption of the two-ammonia plant and Wesfarmer's LPG plant. Gas consumption is constant, apart from major shutdowns of facilities.

Figure 7: Gas consumption by major industry users



Source: AEMO, Gas Bulletin Board Data, August 2018

Gas usage by existing industrial facilities is not correlated with changes in weather, nor is there an obvious growth trend or cyclical impact.

Historical gas use was considered in the development of an average demand profile for use in developing the sector's gas demand forecast. The historical gas consumption for these facilities was adjusted to account for unusual gas usage patterns, due to forced outages or maintenance. For example, Yara fertilisers was offline in July and August 2018, which led to a very large drop in gas consumption (Figure 7).[42]

[42] Drop off occur due to outages and maintenance. Regular drop offs relate to maintenance, typically during the winter months, whereas irregular drop offs typically refer to outages, or operational issues the lead to unscheduled maintenance.

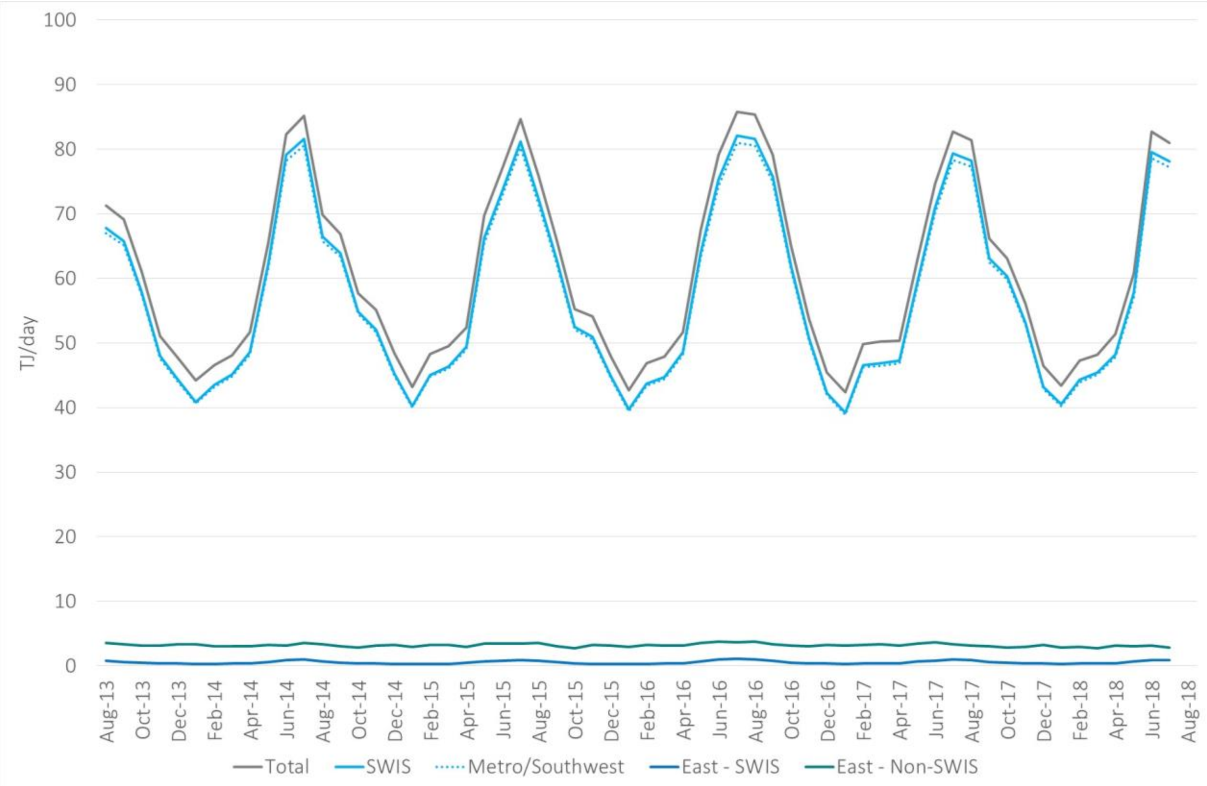
AEMO and Marsden Jacob did not identify any new industrial facilities to explicitly add to the forecast, and no additional industrial loads have been included over the 10-year study period. Perdaman Group is investigating building a urea project on the Burrup Peninsula, near to the Karratha Gas Plant and Pluto LNG project. In November 2018, Perdaman signed a Gas Sale and Purchase Agreement with Woodside Energy for the supply of 125 TJ/day gas to the proposed 2 MTPA urea plant, to be sourced from the Scarborough field, starting between 2023 and 2025 for a period of 20 years. However, this has not been included in the base or high case as it did not meet the prospective project requirements defined in the GSOO.

4.7 Gas use by distribution networks

The distribution segment (consisting of low-pressure distribution networks) relates to residential and commercial gas users supplied through low pressure distribution systems (including natural gas used in transportation).[43] These users account for a small proportion of gas use . Consumption is fairly stable, but is weather dependent.

Figure 8 shows gas use through distribution networks. The smaller networks have similar weather dependent use to the SWIS but are shown at the same scale to illustrate what areas drive distribution gas use.

Figure 8: Gas use through distribution networks



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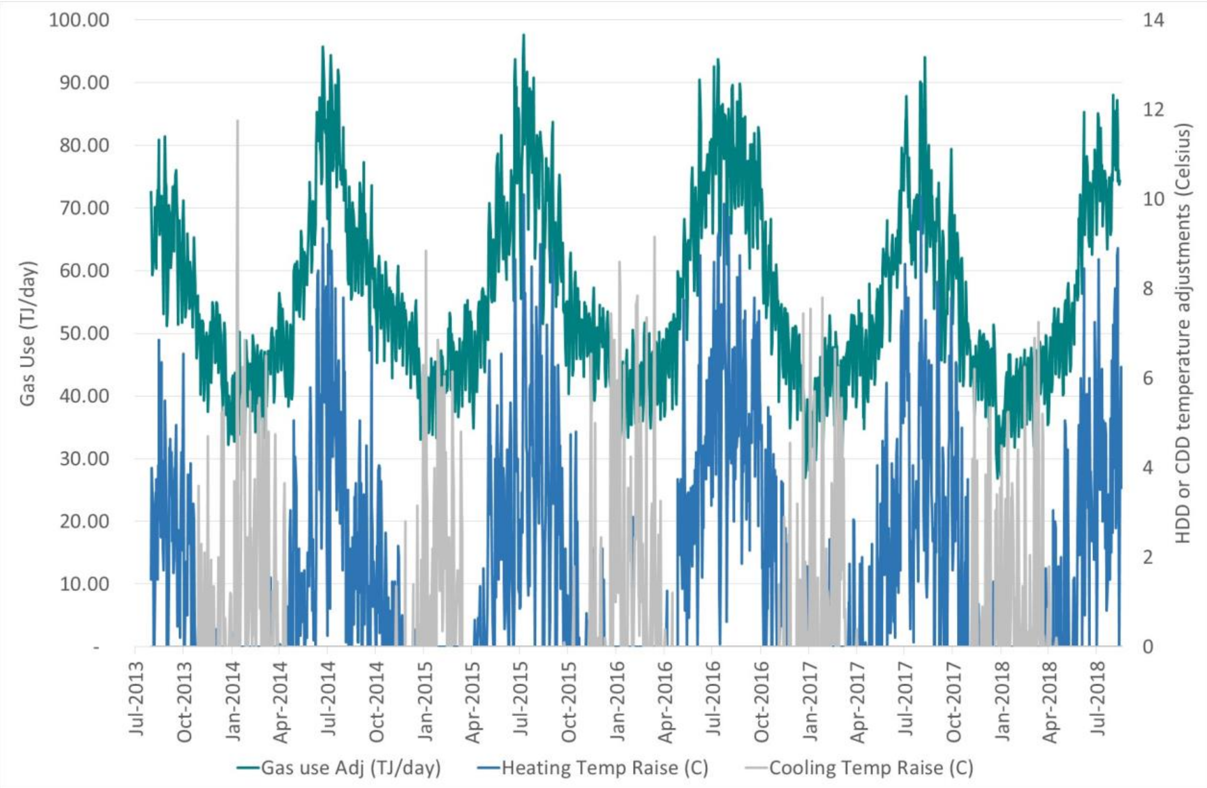
43 It excludes power production for minerals and industry (no mineral processing outside the SWIS.

Gas use in the SWIS is shown in Figure 9 below, along with the average temperature adjustment that households and businesses require to be comfortable in homes and business premises. There is a clear relationship between space heating requirements and gas use from this segment, whereas cooling has little effect on gas use in the distribution network.

Figure 9: Distribution gas use (SWIS) and temperature adjustments



Source: Bureau of Meteorology Max and Min Temperature Data, AEMO, Gas Bulletin Board Data, August 2018 and Marsden Jacob Associates analysis (2018).

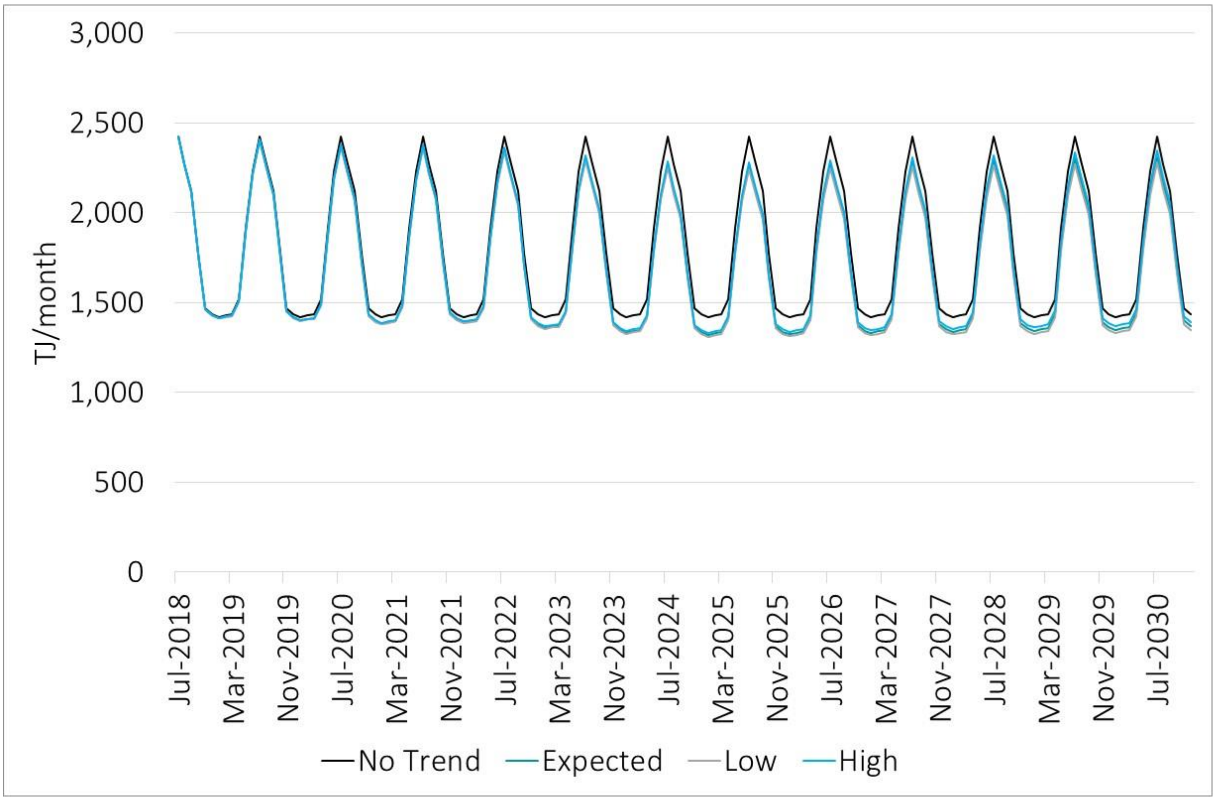
Note: This chart was split into two later to more clearly show HDD versus CDD effects, and relationships will also be tested using regression analyses.

Given the weather dominated influence on the demand for space heating in residential and business premises, annual and monthly gas use forecasts were prepared using regression analysis in order to explain the relationship between gas use and heating requirements (or – where there is no strong statistical relation – historical averages). Also considered were gas prices (growth), income (growth), domestic economic growth (growth), changes to technology (such as increasing use of reverse cycle air conditioners), and reduced use of older gas heaters.

Several regressions were run to determine total gas consumption, accounting for temperature and a range of economic variables, tariffs and a trend to capture structural changes, such as energy efficiency and uptake of reverse cycle air-conditioning, in combination with PV penetration substitution to renewable energy technologies.

The key variable is heating degree days, which almost entirely predicts the cyclical gas use over the historical period. In addition, gas use by distribution systems experience a slight declining trend.[44] Adopting a trend plus forecast growth rates by tariff class from the proposed access arrangement for the ATCO distribution system (including tariff impacts), Marsden Jacob derived the forecasts as shown in Figure 10.

Figure 10: Predicted gas use by distribution segment (SWIS)



Source: Marsden Jacob analysis (2018) using data from Bureau of Meteorology, AEMO, Gas Bulletin Board (August 2018)
Note: This includes the small component in the AEMO's East region (Kalgoorlie) shown separately in the following figure.

Figure 10 includes the forecast with no trend for illustrative purposes, but all of the forecasts have a slightly declining trend which Marsden Jacob believes better reflect the ongoing impacts of:

- Energy efficiency standards (e.g. building efficiency standards);
- Technology changes including growth in reverse cycle air conditioners, decline in the use of old gas heaters[45] and growth in rooftop PV.
- The proposed increases in gas access prices proposed in the ATCO access arrangement.[46]

44 ATCO's access arrangement proposal also reflects a declining trend, https://www.erawa.com.au/.
45 Which have already been banned in Victoria.
46

As noted earlier, distribution for the East region accounts for a very small component (aside from mining related gas use, which is included in mining gas use). This was forecast based on an annual average consumption profile.

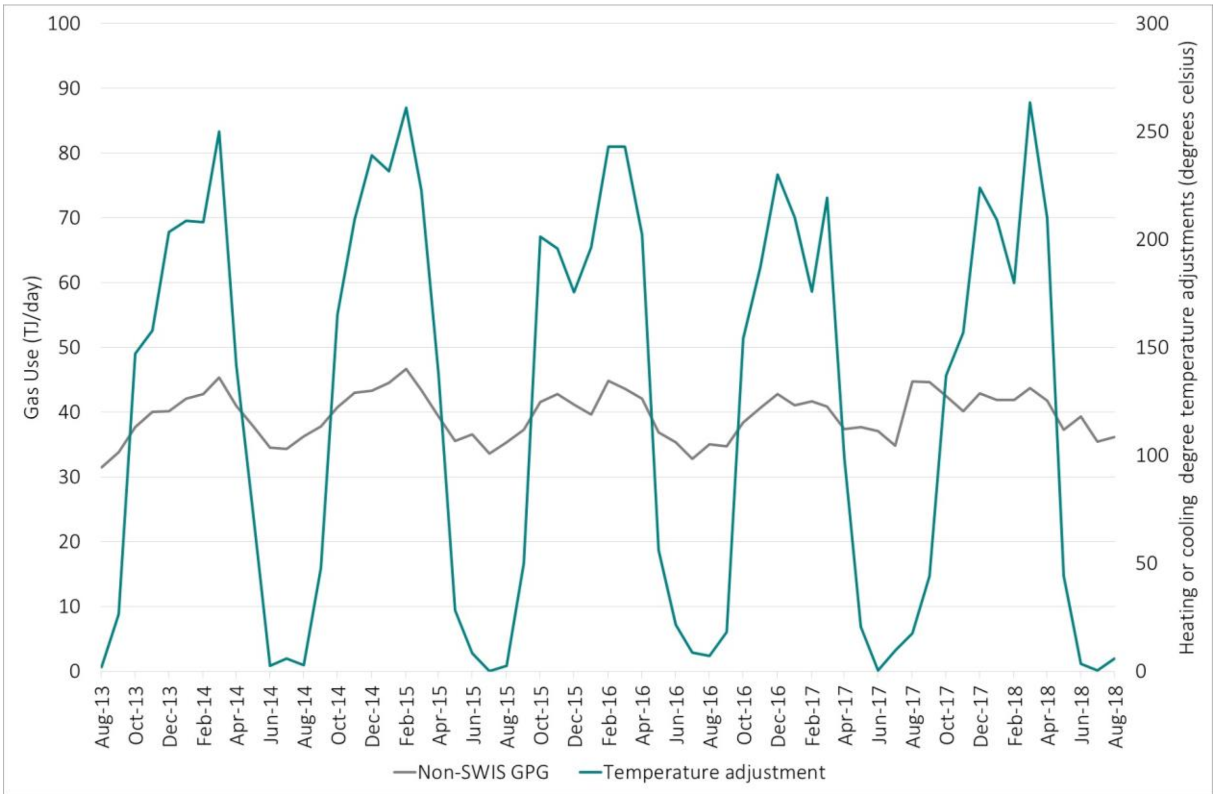
4.8 Gas use non-SWIS GPG

GPG gas use for the non-SWIS regions is shown below. The GPG generators include the following:

- Onslow Power Station
- Carnarvon Power Station
- Exmouth Power Station
- Karratha Power Station
- Newman Power Station
- Port Hedland Power Station, and
- South Hedland Power Station.

Figure 11 shows non-SWIS GPG gas which clearly follows a seasonal pattern driven by the demand for air conditioning in the Pilbara and Murchison regions.

Figure 11: GPG gas use (Non-SWIS/North) – TJ/day

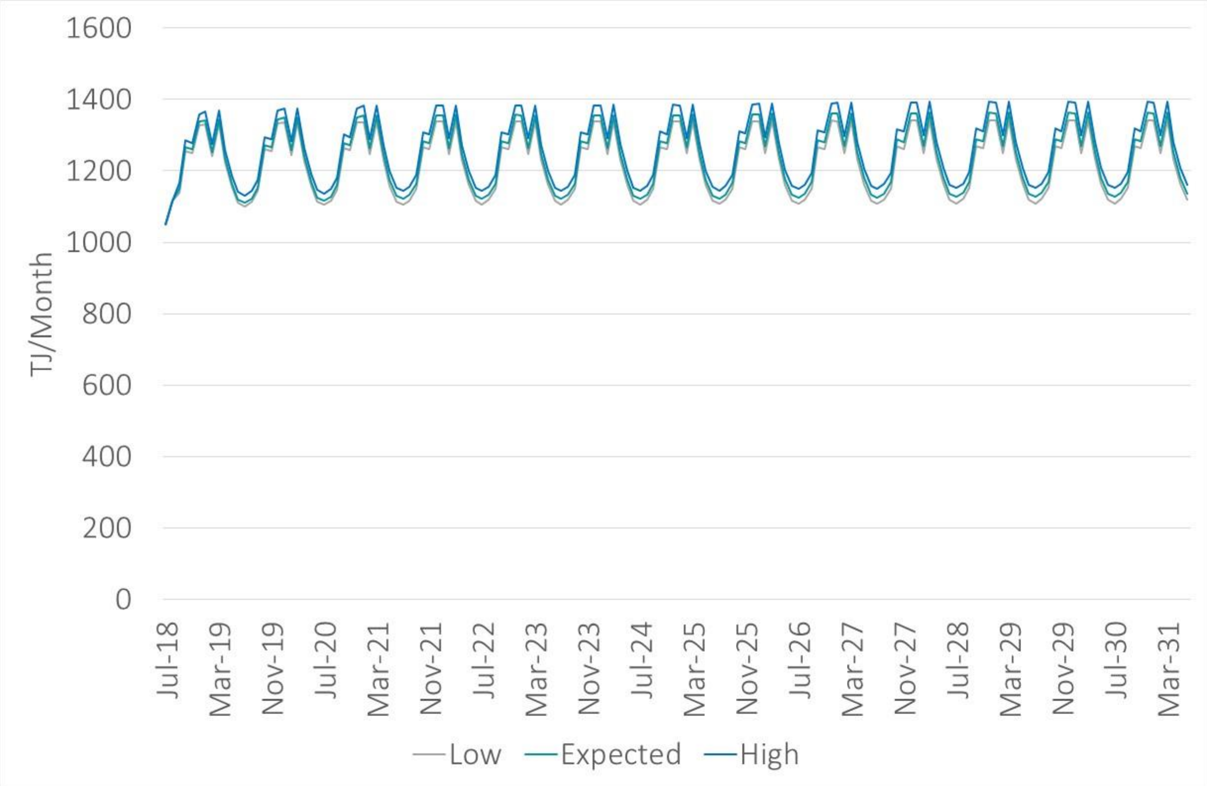


Source: AEMO, Gas Bulletin Board Data, August 2018

Future gas demand was estimated by calculating relationships between CDD and HDD and past gas use (regression analysis) and using these relationships to predict future gas demand.

The forecast, shown in Figure 12, largely reflects a fairly stable profile with Western Australia moving out of domestic recession.[47] A regression was run accounting for monthly patterns and a trend.

Figure 12: Predicted GPG gas use (Non-SWIS) – average TJ/month



Source: Marsden Jacob analysis

4.9 Gas shipping (transmission) and gas storage facilities

While not included in the forecast, gas use in gas transmission (e.g. compressor station use) and for the current gas storage facilities (Mondarra and Tubridgi) was estimated separately. This gas use component is historically around 20 TJ/day, and partially reflects end use and constraints imposed by the gas transport and storage infrastructure, and a shift in gas use associated with storage.

4.9.1 Gas storage facilities

Mondarra

Mondarra storage facility has a storage capacity of 18,000TJ, with 70 TJ/day injection and 150 TJ/day withdrawal capacities. The facility is located in Dongara at the intersection of Dampier to Bunbury Natural Gas Pipeline and Parmelia Gas Pipeline. Main users of the storage facility have been Synergy and Alinta Energy.

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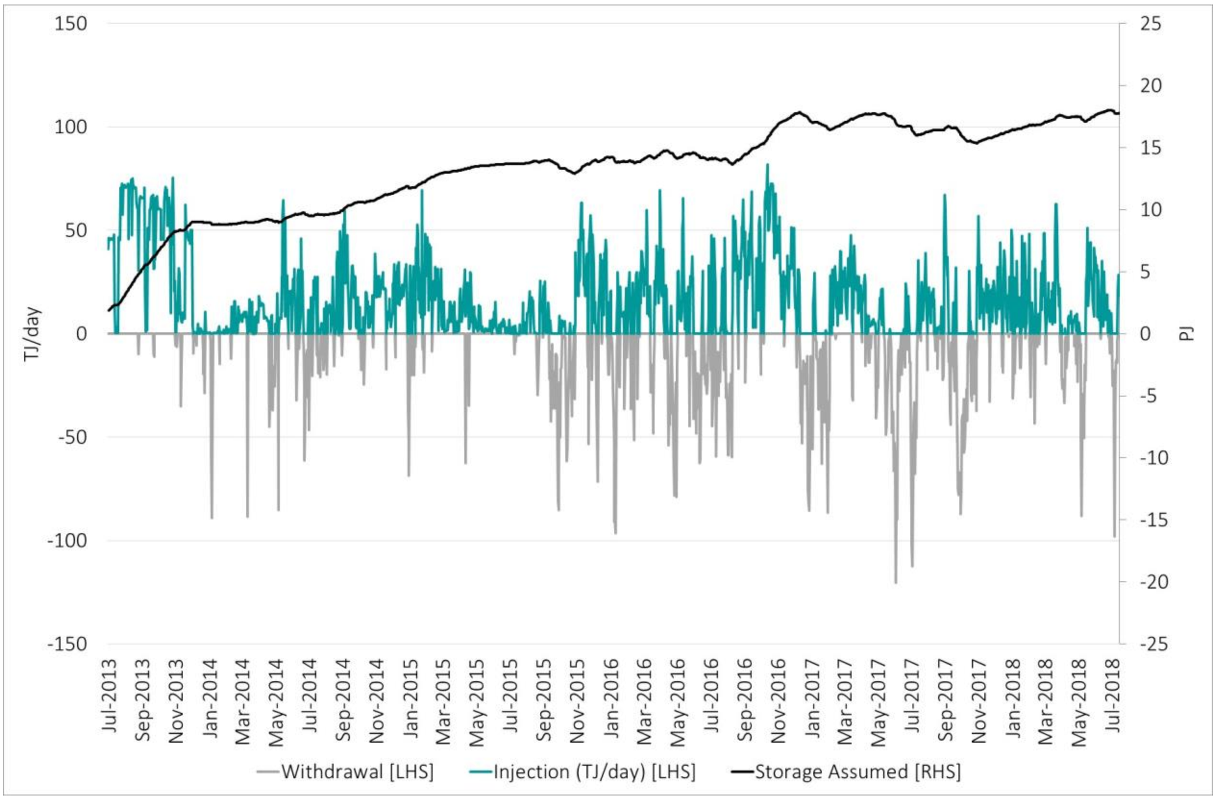
47 While the forecasts provided by the AEMO for the different scenarios separates the scenarios, they all reflect for the scenario

The injection rate has been at a higher level than historic measures, particularly in the calendar year 2016. Assuming the maximum storage level is 18,000 TJ, then the storage level has been close to maximum during recent periods as shown in Figure 13.

Figure 13: Assumed Mondarra storage levels



Source: AEMO, Gas Bulletin Board Data, August 2018

The withdrawal rate for Mondarra experiences a seasonal pattern due to its link to the ‘Metro’ and ‘South West’ zones where GPG is used to manage peak demand for energy.

The storage can be assumed to be used for managing flexibility for the main users’ (e.g. Alinta and Synergy) demand and supply portfolios for both electricity and gas. It was assumed that the storage facility will continue to support portfolio needs of its major users without any foreseeable interruptions, so for the purposes of this analysis, an annual average historical demand profile has been adopted.

Tubridgi

Western Australia’s second gas storage facility Tubridgi[48] only commenced operation in in September 2017, but due to rule change issue, did not begin reporting on the GBB until Jan 2018. Tubridgi has a capacity of around 42PJ.

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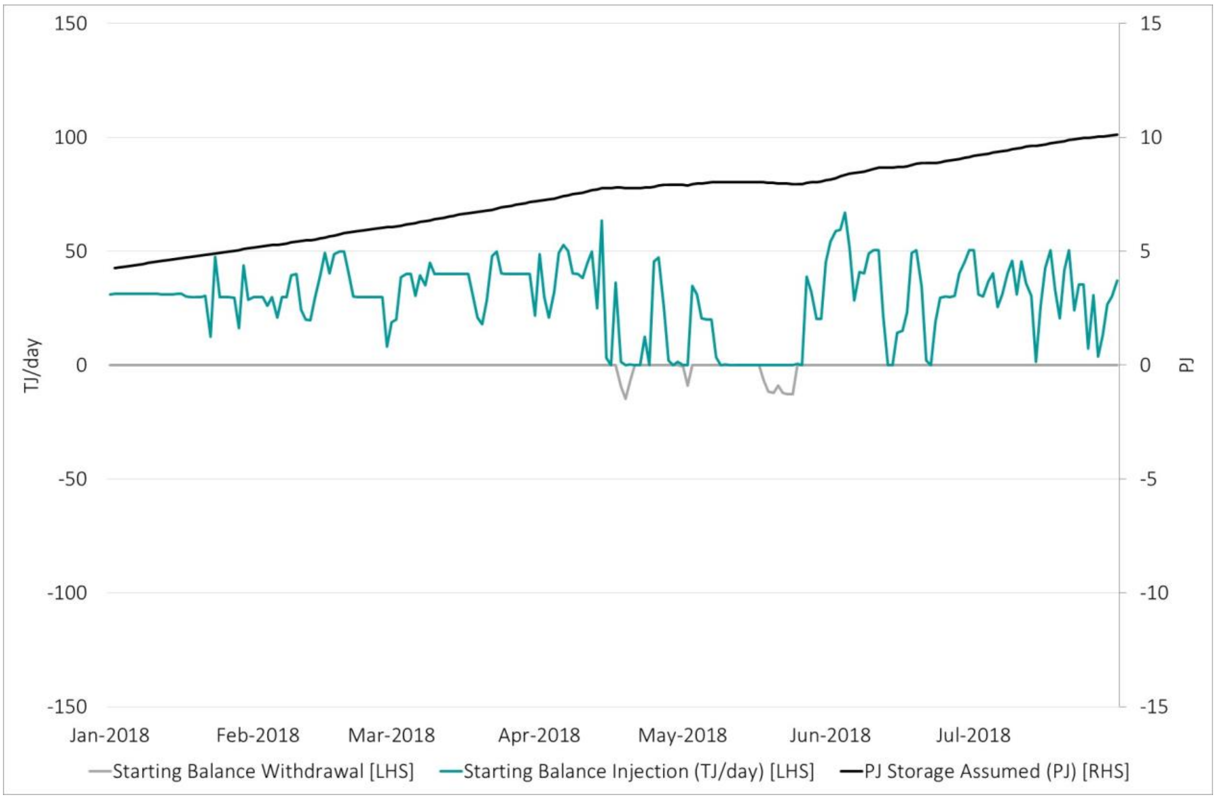
48 Utilises the depleted Tubridgi onshore gas reservoir, located approximately 30km from Onslow in the north west of Western Australia, and is located in close proximity to the Chevron-operated Wheatstone and BHP-operated Macedon domestic gas production facilities, and connected to Compressor Station 2 (CS2) on the Dampier to Bunbury Natural Gas Pipeline via existing gas transmission laterals.

Tubridgi's foundation customer, under a 10-year gas storage agreement, is CITIC Pacific Mining Management Limited, which operates the Sino Iron magnetite project at Cape Preston.[49] As shown in Figure 14, the facility is currently being filled, and shows no weather related injection or withdrawal patterns. At the current rate, it will take around 4 years to fill the storage.

Figure 14: Assumed Tubridgi storage levels



Source: GBB data and Marsden Jacob analysis

4.9.2 Gas shipping (transmission)

Gas used for shipping in transmission pipelines includes compression and unaccounted for gas. The trends on various pipelines are driven mainly by their end users consumption patterns.

There is some correlation to weather, as shown in Figure 15, for the DBP due to its connection with temperature dependent gas usage in the Metro/Southwest area (such as GPG, and residential and small use commercial customers).

In contrast, other pipelines are completely independent of weather effects, such as the Goldfields Gas Pipeline (shown in Figure 16), due to end use customers being associated with mining related activities.

Gas shipping usage is calculated based on the difference between injection amount ('IN') on pipelines and end user (such as distribution) withdrawal amount ('OUT'). The measure used is net 'IN' minus 'OUT' as a percentage of total 'IN').

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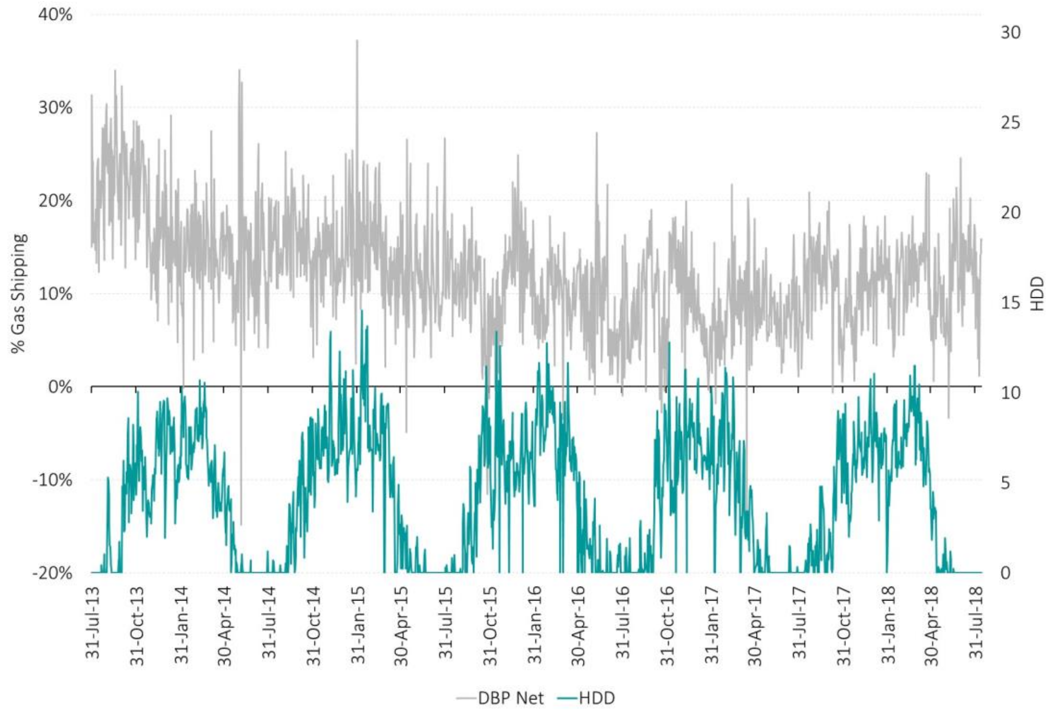
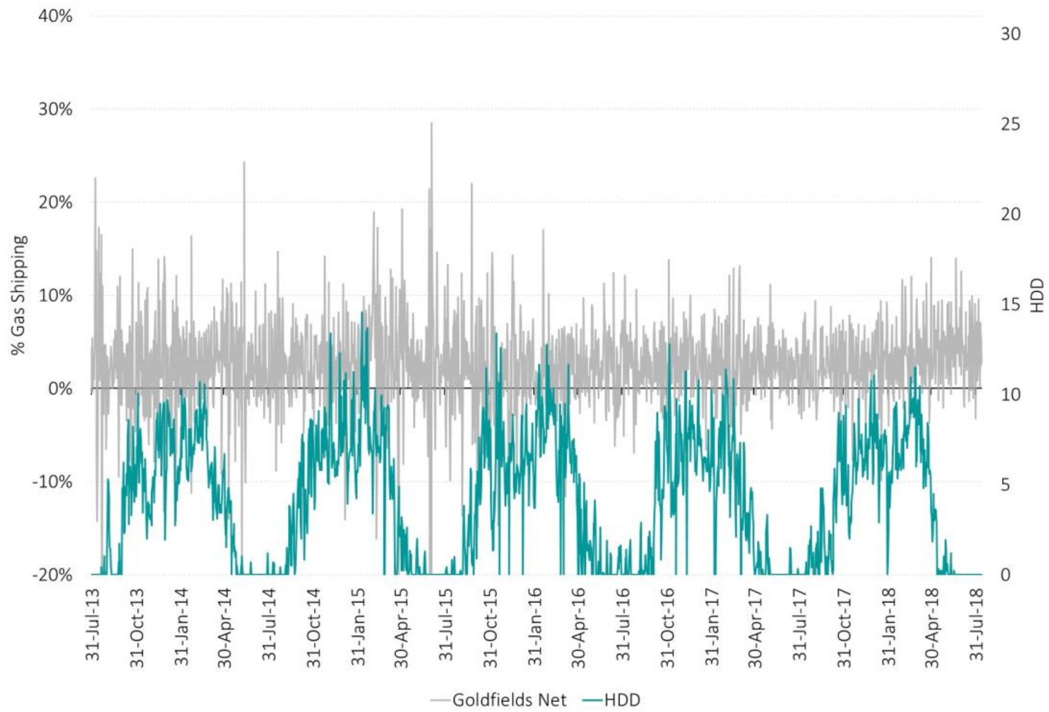
49 With options for a further 5 years

Figure 15: DBP pipeline percentage gas shipping and HDD



Source: Marsden Jacob analysis

Figure 16: Goldfields pipeline percentage gas shipping and HDD



Source: Marsden Jacob analysis