Gas Supply Adequacy Methodology Information Paper

March 2019

For the 2019 Gas Statement of Opportunities for eastern and south-eastern Australia

Important notice

PURPOSE

AEMO has prepared this document to provide information about the methodology and assumptions used to produce supply adequacy forecasts for the 2019 Gas Statement of Opportunities under the National Gas Law and Part 15D of the National Gas Rules.

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VERSION CONTROL

Version	Release date	Changes
1	6/5/2019	

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1. Introduction

This document describes the methodology and assumptions used to assess supply adequacy for the 2019 Gas Statement of Opportunities (GSOO)[1].

The GSOO reports on the adequacy of eastern and south-eastern Australian gas markets to supply maximum daily demand and annual consumption over a 20-year outlook period. The adequacy assessment is performed using a model of gas supply and demand (gas model) that includes representations of:

- Reserves and resources.
- Existing, committed, and proposed new and expanded gas processing facilities.
- Existing, committed, and proposed new and expanded gas transmission pipelines.
- Existing, committed, and proposed new and expanded gas storage facilities.
- Gas consumption forecasts for residential, commercial, and industrial customers, gas-powered generation (GPG), and liquefied natural gas (LNG) exports.

The GSOO model accommodates the provisions of the Australian Domestic Gas Security Mechanism (ADGSM).

The gas model balances daily supply and demand at least-cost, by considering gas supply contract commitments, gas reserve and resource availability, and pipeline and processing infrastructure constraints.

Key outputs of the gas model include daily pipeline flows, gas production, and potential shortfalls.

The analysis is repeated for a range of scenarios and sensitivities, as outlined in the 2019 GSOO, to determine the robustness of outcomes to changes in modelled assumptions. Specific detail on scenarios used in the 2019 GSOO is available in the GSOO report.

1.1 Shared assumptions with other AEMO publications

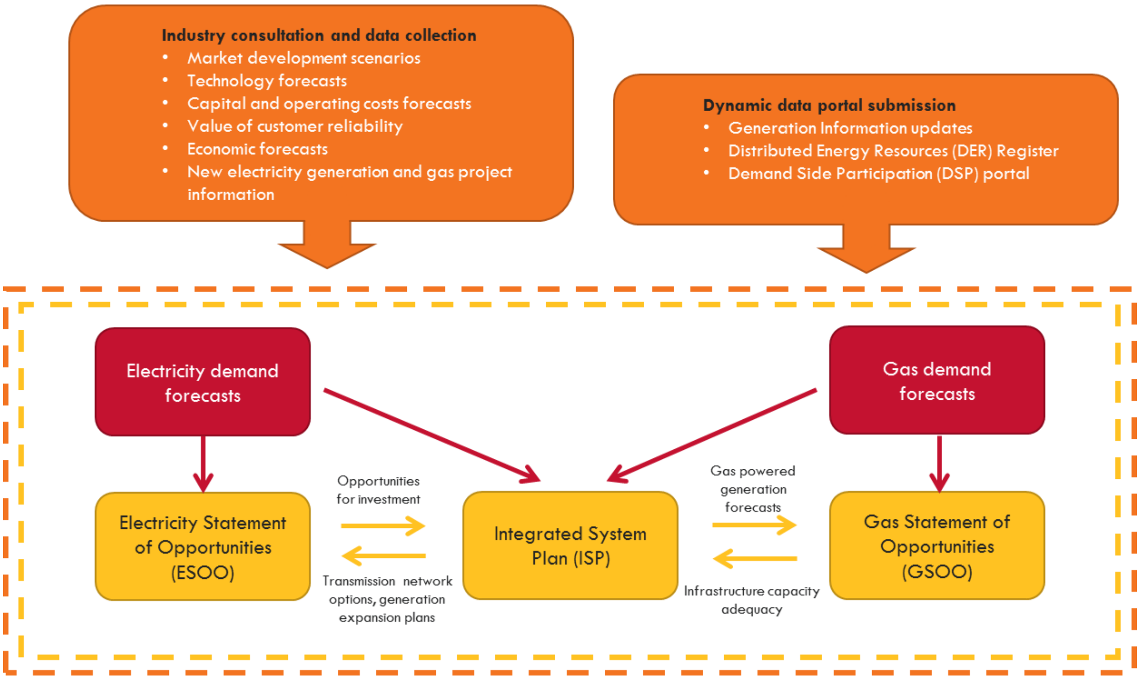
The GSOO is part of a comprehensive suite of forecasting publications published by AEMO, an overview of which is shown in Figure 1. The GSOO is an integrated component within the forecasting function of AEMO, and coordination across these publications ensures maximum internal consistency and allows robust insights across the energy landscape to be compiled. As an example, the methodologies used in determining the long-term evolution of the National Electricity Market (NEM) provided by AEMO's Integrated System Plan (ISP) are applied by the GSOO in forecasting expected gas consumption from GPG.

AEMO publishes methodology documents to support all major planning publications. These are available on AEMO's website[2] and provide additional relevant background to GSOO data and modelling assumptions.

[1] AEMO. 2019 Gas Statement of Opportunities. Available: http://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities.

[2] Forecasting methodologies are available for each publication, and centralised at the following address: http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies.

Figure 1 AEMO's major forecasting publications



1.2 Supporting material

A suite of resources has been published on the AEMO website to support the content in this methodology document and the 2019 GSOO report and can be found in Table 1.

Table 1 Links to other supporting information

Source	Website address
2019 GSOO inputs and stakeholder survey information (for updated processing capacity of each facility used in the GSOO)	http://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities
2019 Gas Statement of Opportunities methodology – demand forecast	http://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities
Archive of previous GSOO reports	http://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities
National Electricity and Gas Forecasting Portal (AEMO Forecasting Portal)	http://forecasting.aemo.com.au
Gas Bulletin Board (GBB)	https://www.aemo.com.au/Gas/Gas-Bulletin-Board
2018 Integrated System Plan	https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan

2. Gas model

2.1 Model description

The GSOO model is an energy supply model that simulates daily gas supply and demand balances over the 20-year timeframe. The model uses linear programming techniques to calculate the least-cost supplies of gas to enable delivery to demand centres, subject to different infrastructure and operational constraints:

- The direction and capacity of the pipeline network to deliver gas to demand centres
- The capacity of gas processing facilities to deliver sufficient gas into the pipeline network
- The capacity and availability of storage facilities to store excess gas for later injection into the pipeline network
- The availability of reserves and resources to maintain processing throughput, and
- Annual production limitations from each field or group of fields.

The model computes energy balances at all levels of a gas system from reservoirs or basins to the demand centres, supplies energy services at minimum total system cost, and balances gas commodity in each gas network node and time period. Outputs consist of gas productions, pipeline flows, and potential shortfalls.

The linear programming formulation for the model is given by:

For each day and year,

Minimize: NPV ($\sum_{fields} Operation\ cost + \sum_{pipelines} operation\ cost + \sum_{processing\ units} operation\ cost + \sum_{storage\ facilities} operation\ cost + \sum_{demand\ centers} shortfall\ penalty$)

Subject to:

- Energy system balance
- Supply/demand balance
- Nodal capacity balance
- Pipeline capacity constraints
- Production capacity constraints
- Gas storage capacity constraints

The gas model does not explicitly model pipeline pressure constraints, pipeline gas transportation agreements, or intra-day flows. The gas model does not calculate the optimum pipeline or field expansion projects to ensure all gas shortfalls are eliminated, instead the GSOO studies the impact of a range of different expansions as sensitivities, without commenting on which may be the best or most cost-effective solution.

2.2 Data sources

AEMO uses a variety of sources to prepare the inputs to the gas model, as shown in Table 2:

Table 2 Key inputs and the related data sources for the gas model

Input	Source
Demand projections	AEMO Forecasting Portal
Capacity of reserves and resources	Core Energy Group and gas industry participants
Production costs	Core Energy Group
Transmission costs	Gas industry participants. Where data was not provided and/or was considered confidential, AEMO used data supplied by Core Energy Group.
Pipeline, processing, storage facility capabilities and daily rates	Gas industry participants. Where data was not provided and/or was considered confidential, AEMO used data supplied by Core Energy Group.
Annual field production limits	Core Energy Group, gas industry participants, and internal AEMO analysis.

2.2.1 Gas industry participants survey

AEMO surveyed gas industry participants to obtain detailed gas information including:

- Processing facility capacities, and potential or committed future expansions.
- Pipeline capacities, and potential or committed future expansions.
- LNG facility capacities, and potential or committed future expansions.
- Gas project developments (including reserves).
- Storage facility capacities and potential or committed future developments.

This information is up to date as of December 2018, although AEMO endeavoured to incorporate more up-to-date information where practical.

Collated results from the survey of gas industry participants are available on AEMO's website[3].

Production forecasts were also obtained from gas industry participants for use in the gas supply adequacy modelling, but given the confidential nature of this data, AEMO will not make this data publicly available.

2.3 Model implementation

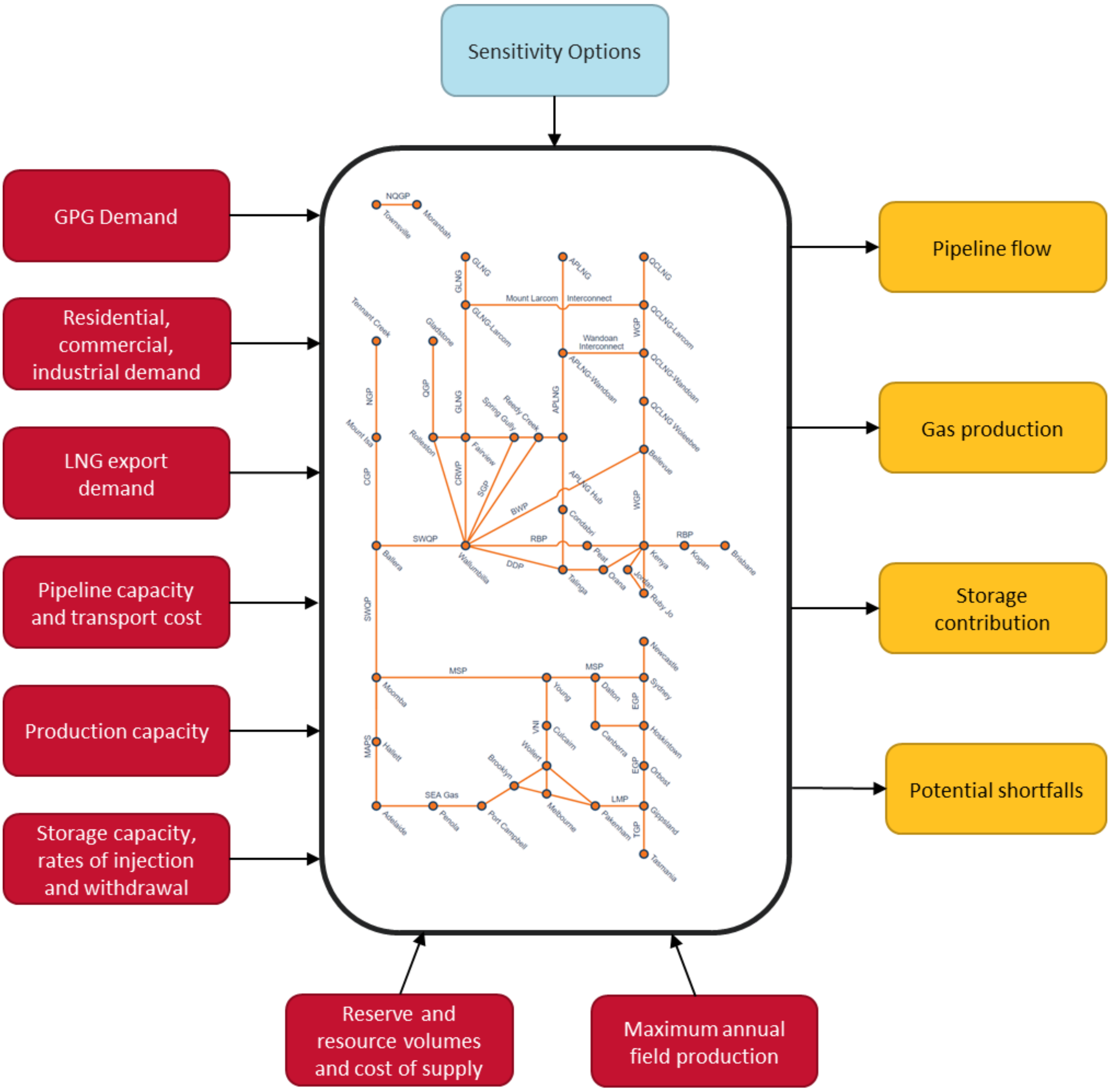
2.3.1 Gas network

Capacities from existing transmission and processing infrastructure, as well as publicly announced infrastructure augmentations are used to determine total gas network capacity to facilitate supply. Infrastructure augmentations may be treated as either certain to progress and included in the base modelling, or more uncertain, and studied as only sensitivities.

[3] AEMO. 2019 Gas Processing, Transmission, and Storage Facilities, available at http://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities.

A representation of the gas model, with its inputs and outputs, is shown in Figure 2.

Figure 2 Model inputs and outputs

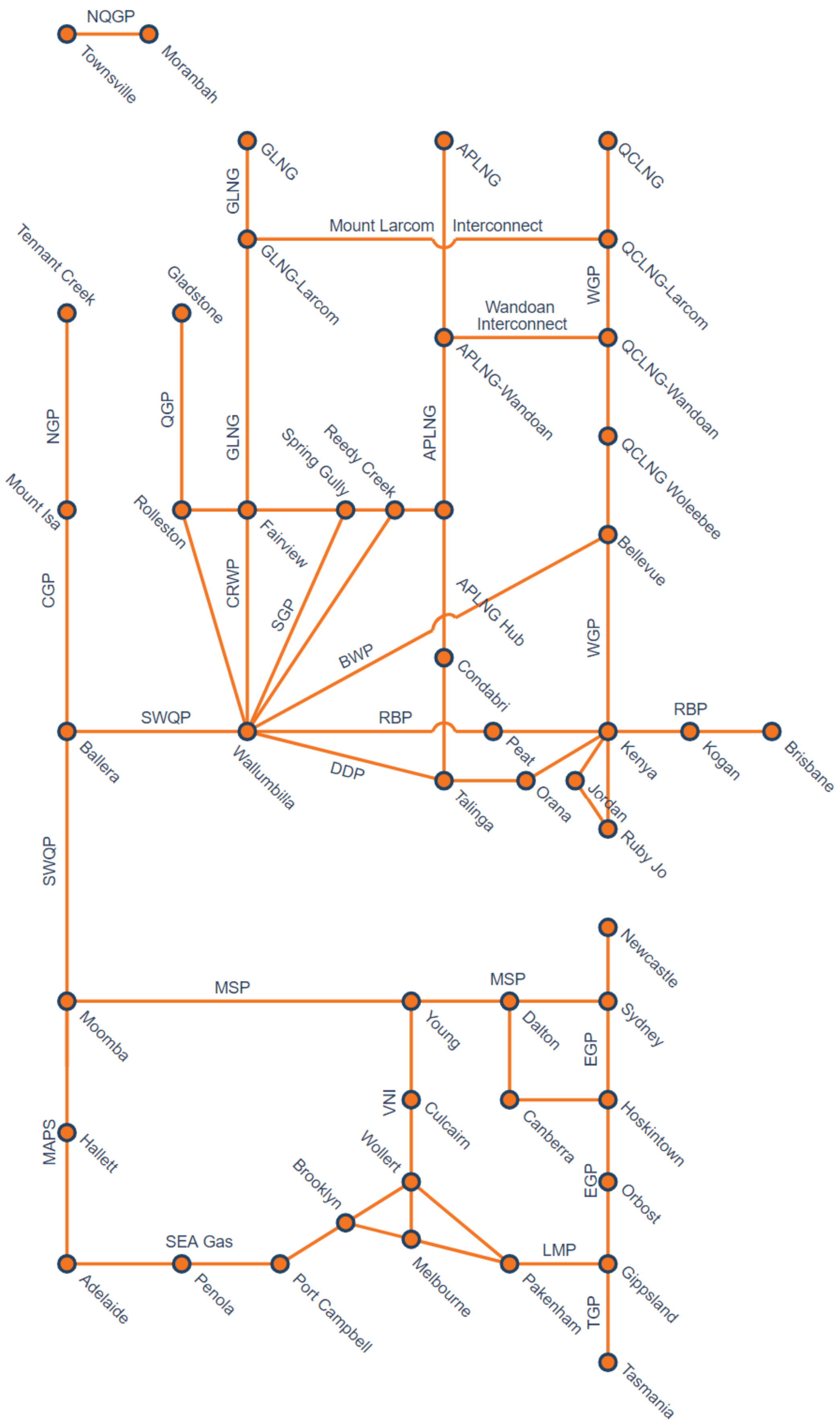


The eastern and south-eastern gas network is represented by a series of connected nodes. At each node, gas may be injected into or withdrawn from the network where production facilities and loads are connected respectively.

Connections between nodes define paths which gas can flow between. Together, nodes and their associated connections define a topology. The topology of the gas model, shown in Figure 3, is designed to capture key features of the physical gas network such as pipelines, storages and producing fields.

In many cases, a connection (or series of connections) represents an actual pipeline. Pipeline transmission costs are considered in the gas model optimisation.

Figure 3 Gas model topology for 2019 GSOO



2.3.2 Gas fields and basins

The gas model represents field and basin as quantities of gas supply connected at a specific location in the gas model topology, able to be produced by a particular processing facility or facilities.

A modelled field or basin may correspond to:

- A real-world field (for example, Minerva or Longtom).
- An aggregation of fields (for example, the Casino, Henry and Netherby fields are represented by a single field in the gas model).

The decision as to whether a field is modelled as a specific single field, an aggregation of fields or at overall basin level is based on the level of information available, whether from publicly available sources, stakeholder surveys or consultant advice. To reduce model complexity, if the level of information is available regarding individual field formations, but the granularity does not impact the modelled solution, the fields are aggregated to a meaningful level.

Reserves and resources

In the gas model, reserves and resources are consumed over the 20-year outlook period based on estimates of annual supply availability, assuming 100% conversion to production is possible if required. In determining the rate of field depletion, the model considers the maximum production from each field, contract commitments, demand requirements and the cost of production.

The reserves and resources categorisations considered by the 2019 GSOO are 2P developed reserves, 2P undeveloped reserves, 2C contingent resources, and Prospective resources.

Further detail about reserve quantities used in the 2019 GSOO is available on AEMO's website[4].

The probability of gas existing in the ground and being considered commercially viable is not the only uncertainty related to future production. AEMO has further considered the level of certainty around whether projects will proceed to develop the identified volumes of reserves or resources.

For the 2019 GSOO, AEMO has considered the following definitions:

- **Committed** projects are actively under development planning and have passed final investment decision (FID).
- **Anticipated** projects are actively under development planning utilising existing production infrastructure, so there is a reasonable likelihood of them proceeding. These anticipated projects may include quantities of undeveloped reserves and contingent resources.
- **Uncertain** projects are those projects that are considered much more uncertain to be developed and are not as far along the development planning path. In the long term to 2038, uncertain projects include uncertain 2C contingent and prospective resources that are accessible by existing pipeline and processing infrastructure.

Annual field production limits

The gas model satisfies demand by allocating remaining reserves and resources on a least cost basis by considering cost of production together with the cost of transporting the gas to the demand location subject to physical market constraints.

AEMO has used production forecasts provided by industry participants to provide an upper limit for the amount of gas expected out of each field or group of fields for each year. Where forecasts are unavailable in the long term, AEMO considered that sufficient development and exploration occurs such that rates of gas production are maintained to the end of the outlook period.

AEMO separately assessed the production limits for three cases:

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[4] Available at http://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities.

- Existing and committed projects only
- Existing, committed and anticipated projects
- Existing, committed, anticipated and uncertain projects.

All three production limitations provide the GSOO's range of possible supply outcomes.

Gas fields and processing facilities

Gas production at processing facilities is determined by the gas model at a daily resolution. At each daily step, a modelled processing facility may supply gas up to its processing capacity.

Each reserve and resource category of each field has a separate production cost, with the cost becoming more expensive in the order of:

- 2P developed reserves
- 2P undeveloped reserves
- 2C contingent resources
- Prospective resources.

The cost of each tranche of gas at each field is directly related to the geological and economical complexities of that specific field, and as such, the 2C resources at one location may be less expensive than the 2P developed reserves at another location, for example.

This cost is applied to every unit of gas produced by the associated processing facility.

Each processing facility[5] in the gas model may be associated with one or more fields.

2.3.3 Storage

The gas model optimises gas storage operation after allowing for the cost for both injection into and withdrawal from a storage facility. The injection and withdrawal behaviour of each storage facility is optimised to meet local peak demand fluctuations at least cost.

The gas model also aims to replenish annual storage inventory to ensure that storage levels at the beginning of each year are the same by the end of the year and stored gas is available for future years.

2.3.4 Pipelines

AEMO considers all major pipelines shown in Figure 3. At each daily step, a modelled pipeline may flow up to its daily capacity limitation. Flow is optimised by taking into account transport cost – or pipeline tariffs – on each pipeline in the modelled system.

Pipeline linepack is considered by setting upper and lower limits that the pipeline volume must stay between.

For the 2019 GSOO, AEMO sought to improve its modelling of the Victorian Declared Transmission System (DTS) to better capture realistic daily and seasonal behaviour. AEMO considers pipeline capacity to be static in most cases, however, for the South West Pipeline (SWP), AEMO implemented a dynamic pipeline capacity to reflect the operational issues inherent in sending gas between Melbourne and Port Campbell.

- The SWP transportation capacity towards Melbourne increases as DTS demand increases.
- The SWP transportation capacity from Melbourne towards Port Campbell is at its maximum on days of low DTS demand and decreases as DTS demand increases.

[5] Similar to the 2018 GSOO, the Ballera processing facility has not been included in the 2019 GSOO. Gas flowing through the Ballera facility is not incremental to gas processed at the Moomba processing facility. The inclusion of both facilities would result in duplication of processing capacity as gas flowing through Ballera has been captured in the Moomba processing facility.

See the 2019 Victorian Gas Planning Report (VGPR)[6] for more detailed information on the SWP capacity limitations.

2.3.5 Transmission losses

The gas model captures gas losses along the pipeline network in addition to customer demand for gas. This accounted for up to 1% of total demand each year.

2.3.6 Daily demand profile development

AEMO developed daily demand profiles for all demand sectors included in the gas model.

For more information about the development of the forecasts for each demand sector and the key assumptions used, refer to the Gas Demand Forecasting Methodology Information Paper for the 2019 GSOO[7].

Industrial, commercial and residential demand

AEMO developed a daily reference profile for each GSOO demand centre, using historical data from either the Victorian DTS data (for Victorian demand only), flow data provided by pipeline operators (where available), or the Gas Bulletin Board.

The daily reference profile was then applied to annual consumption and maximum demand forecasts for the 20-year outlook period. This produced 20 years of daily demand for each residential, commercial, and industrial demand load.

GPG demand

Electricity market modelling simulations were used to produce hourly GPG generation data for the 20-year outlook period. AEMO combined this hourly generation data with estimates of fuel efficiency parameters for GPG[8], to develop gas consumption values for each GPG in each hour of the outlook period, which was then summed to a daily total for use in the gas supply model. Further information about electricity market modelling can be found on AEMO's website[9].

LNG export demand

AEMO developed a daily reference profile for LNG export load, using the daily load profile from the Gas Bulletin Board of each of the three LNG projects for the most recent 12 months. This load profile applied annual demand forecasts for the three LNG projects of QCLNG, APLNG, and GLNG, to develop daily profiles over 20 years for each of the three Curtis Island LNG projects.

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[6] 2019 Victorian Gas Planning Report, Section 5.2. Available at: http://aemo.com.au/Gas/National-planning-and-forecasting/Victorian-Gas-Planning-Report

[7] Demand Forecasting Methodology Information Paper, available at https://www.aemo.com.au/Gas/National-planning-and-forecasting/Gas-Statement-of-Opportunities.

[8] Available in the 2019 Input and Assumptions workbook, available at http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies..

[9] AEMO, *Market Modelling Methodologies*, July 2018. Available at http://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Market-Modelling-Methodology-Paper.pdf

3. Infrastructure changes from 2018 GSOO

Table 3 reflects notable pipeline and storage capacity changes since the 2018 GSOO.

Table 3 Infrastructure upgrade summary – 2019 GSOO compared to 2018 GSOO

Pipeline	New capacity (TJ/d)	Increase (TJ/d)*
Iona Underground Gas Storage	480	45
Dandenong storage facility	87	-70
VIC-NSW Interconnect (VNI); Young to Culcairn Forward direction	140	-10
VIC-NSW Interconnect (VNI); Culcairn to Wollert Forward direction Backward direction (winter)	125 201	-25 -22
Comet Ridge to Wallumbilla Pipeline	175	-25
Darling Downs Pipeline (DDP); Ruby Jo to Wallumbilla direction	540	10
GLNG Pipeline	1460	60
Longford to Melbourne Pipeline (LMP); Gippsland to Pakenham	990	-40
South West Pipeline (SWP)	Varies based on demand; dynamic capacities are applied for both directions.**	-
Wallumbilla Gladstone Pipeline (WGP)	1510	-78

* Negative values indicate capacity decrease
** See section 2.3.4 for more information.

Pipelines

Abbreviation	Expanded name
BWP	Berwyndale Pipeline
CGP	Carpentaria Gas Pipeline
CRWP	Comet Ridge to Wallumbilla Pipeline
DDP	Darling Downs Pipeline
EGP	Eastern Gas Pipeline
LMP	Longford to Melbourne Pipeline
MAPs	Moomba to Adelaide Pipeline System
MSP	Moomba to Sydney Pipeline
NGP	Northern Gas Pipeline
NQGP	Northern Queensland Gas Pipeline
QGP	Queensland Gas Pipeline
SEA Gas Pipeline	South Eastern Australia Gas Pipeline
SGP	Spring Gully Pipeline
SWP	South West Pipeline
SWQP	South West Queensland Pipeline
TGP	Tasmania Gas Pipeline
VNI	Victoria – New South Wales interconnect
WGP	Wallumbilla to Gladstone Pipeline

Measures and abbreviations

Units of measure

Abbreviation	Unit of measure
PJ	Petajoules
TJ	Terajoules
TJ/d	Terajoules per day

Abbreviations

Abbreviation	Expanded name
ADGSM	Australian Domestic Gas Security Mechanism
AEMO	Australian Energy Market Operator
APLNG	Australia Pacific LNG
DTS	Declared Transmission System
FID	Final Investment Decision
GBB	Gas Bulletin Board
GLNG	Gladstone LNG
GPG	Gas-powered generation
GSOO	Gas Statement of Opportunities
ISP	Integrated System Plan
LNG	Liquefied Natural Gas
NEM	National Electricity Market
NPV	Net Present Value
QCLNG	Queensland Curtis LNG
VGPR	Victorian Gas Planning Report

Glossary

Term	Definition
2C contingent resources	Best estimate of contingent resources – equivalent to 2P, except for one or more contingencies or uncertainties currently impacting the likelihood of development. Can move to 2P classification once the contingencies are resolved.
2P reserves	The sum of proved and probable estimates of gas reserves. The best estimate of commercially recoverable reserves, often used as the basis for reports to share markets, gas contracts, and project economic justification.
annual consumption	Gas consumption reported for a given year.
contingent resources	Gas resources that are known but currently considered uncommercial based on once or more uncertainties (contingencies) such as commercial viability, quantities of gas, technical issues, or environmental approvals.
demand	Capacity or gas flow on an hourly or daily basis, or the electrical power requirement met by generating units.
developed reserves	Gas supply from existing wells.
Gas Bulletin Board (GBB)	A website (gbb.aemo.com.au) managed by AEMO that provides information on major interconnected gas processing facilities, gas transmission pipelines, gas storage facilities, and demand centres in eastern and south-eastern Australia. Also known as the Natural Gas Services Bulletin Board or the Bulletin Board.
gas-powered generation (GPG)	The generation of electricity using gas as a fuel for turbines, boilers, or engines.
Linepack	The pressurised volume of gas stored in the pipeline system. Linepack is essential for gas transportation through the pipeline network each day, and as a buffer for within-day balancing.
liquefied natural gas (LNG)	Natural gas that has been converted into liquid form for ease of storage or transport.
probable reserves	Estimated quantities of gas that have a reasonable probability of being produced under existing economic and operating conditions. Proved and probable reserves added together make up 2P reserves.
production	In the context of defining gas reserves, gas that has already been recovered and produced.
prospective resources	Gas volumes estimated to be recoverable from a prospective reservoir that has not yet been drilled. These estimates are therefore based on less direct evidence than other categories.
proved and probable	See 2P reserves.
proved reserves	Estimated quantities of gas that are reasonably certain to be recoverable in future under existing economic and operating conditions. Also known as 1P reserves.

Term	Definition
reservoir	In geology, a naturally occurring storage area that traps and holds oil and/or gas. Iona UGS is also referred to as a reservoir for gas storage.
reserves	Reserves are quantities of gas which are anticipated to be commercially recovered from known accumulations
resources	More uncertain and less commercially viable than reserves. See contingent resources and prospective resources.
undeveloped reserves	Gas supply from wells yet to be drilled.