# FORECASTING METHODOLOGY INFORMATION PAPER

NATIONAL GAS FORECASTING REPORT 2015

Published: **December 2015**

AEMO

AUSTRALIAN ENERGY MARKET OPERATOR

# IMPORTANT NOTICE

## Purpose

AEMO has prepared this document to provide information about methodology, data and assumptions used to produce the 2015 National Gas Forecasting Report, as at the date of publication.

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## Acknowledgement

AEMO acknowledges the support, co-operation and contribution of all participants in providing data and information used in this document.

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# CHAPTER 1. INTRODUCTION

The National Gas Forecasting Report (NGFR) provides regional forecasts for Queensland, New South Wales, Victoria, Tasmania and South Australia. The regional forecasts are the sum of a number of component forecasts, each having a distinct forecasting methodology. These are:

- Liquefied natural gas (LNG).
- Gas-powered generation (GPG).
- Industrial.
- Residential and commercial.

Section 1.2 below has definitions of each component.

For annual consumption, each of these component forecasts is modelled separately, and then summed at the regional level. Chapters 2−5 describe the methodologies used for each component.

Maximum Demand forecasts provide an annual projection of maximum daily demand for each region. This requires the component forecasts to be coincident on the day of the system peak, so the maximum demand methodology uses an integrated modelling approach that forecasts the component models jointly to produce a forecast of maximum coincident daily demand. This methodology is explained in Chapter 6.[1]

## 1.1 Summary of NGFR scenarios

The 2015 NGFR forecasts annual consumption and maximum demand for three scenarios representing high, medium and low energy (gas and electricity) consumption from a centralised source (natural gas transmission pipelines in southern and eastern Australia and power system assets of the National Electricity Market (NEM)).

Table 1 summarises the main assumptions of each scenarios.[2]

**Table 1 2015 NGFR component scenario mapping**

| | Residential and commercial | Industrial | Gas-powered generation | Energy efficiency |
|---|---|---|---|---|
| **High** | High number of customers | Low gas prices, higher commodity prices, favourable economic conditions. | High electricity consumption | Slow uptake |
| **Medium** | Medium number of customers | Medium gas and commodity price, economic conditions. | Medium electricity consumption | Moderate uptake |
| **Low** | Low number of customers | High gas prices, lower commodity prices and less favourable economic conditions. | Low electricity consumption | Rapid uptake |

## 1.2 Key definitions

**Annual gas consumption** refers to gas consumed over a calendar year, and can include residential and commercial consumption, industrial consumption, GPG consumption, or transmission and distribution losses. Gas used for LNG processing and exports is considered separately. Unless otherwise specified, annual consumption data excludes transmission losses.

[1] System peak demand is typically not coincident with maximum GPG, and the methodology in Chapter 6 uses average GPG. For maximum demand GPG methodology, see Chapter 3.

[2] For more detail about scenarios see the 2015 NGFR: http://www.aemo.com.au/Gas/Planning/Forecasting/National-Gas-Forecasting-Report

**Distribution losses** refers to gas leakage and metering uncertainties in the distribution network. This is calculated as a percentage of total residential and commercial consumption and industrial consumption connected to the distribution networks.

**Effective degree days** (EDD) is a measure that combines a range of weather factors that affect energy demand.

**Gas-powered generation** (GPG) refers to generation plant producing electricity by using gas as a fuel for turbines, boilers, or engines. In the NGFR forecasts, this only includes GPG that is connected to the NEM. The GPG forecasts are based on AEMO's electricity market modelling results from the National Transmission Network Development Plan (NTNDP).

**Industrial**, also known as Tariff D, refers to users that generally consume more than 10 TJ of gas per year. Industrial consumption includes gas usage by industrial and large commercial users, and some GPG that is not connected to the NEM, for example, GPG around Mt Isa.

**Liquefied natural gas** (LNG) refers to natural gas that has been converted to liquid form.

**Maximum demand** (MD) refers to the highest daily demand occurring during the year. This can include residential and commercial demand, industrial demand, GPG demand, or distribution losses. Gas used for LNG production is considered separately. Unless otherwise specified, maximum demand includes transmission losses.

**Per customer connection** refers to the average consumption per residential and commercial gas connection. Expressing consumption on this basis largely removes the impact of population growth, and allows commentary about underlying consumer behaviour patterns.

**Probability of Exceedance** (POE) refers to the likelihood that a maximum demand forecast will be met or exceeded, reflecting the sensitivity of forecasts to changes in weather patterns in any given year. The 2015 NGFR provides these forecasts:

- **1-in-2** maximum demand, also known as a 50% POE, means the projection is expected to be exceeded, on average, one out of every two years (or 50% of the time).
- **1-in-20** maximum demand, also known as a 5% POE, means the projection is expected to be exceeded, on average, one out of every 20 years (or 5% of the time).

**Residential and commercial**, also known as Tariff V, refers to residential and small-to-medium-sized commercial users consuming less than 10 terajoules (TJ) of gas per year. Unless otherwise specified, historical residential and commercial data is not weather-corrected.

**Transmission losses** refers to gas that is unaccounted for or consumed for operational purposes (such as compressor fuel) when transported through high-pressure transmission pipelines to lower-pressure distribution networks. Transmission losses are calculated as a percentage of total residential and commercial, industrial, and GPG consumption, and distribution losses.

**Winter** refers to June to August and **summer** refers to December to February.

## 1.3 NGFR datafile

A datafile is available on request that provides the main input and output data for the component forecasts that are summed to produce the NGFR regional forecasts.

## 1.4 Improvements to the 2015 NGFR methodology

This is the second NGFR produced by AEMO. Following the first NGFR in 2014, AEMO consulted widely with industry to seek improvements to the methods, assumptions and input data.

AEMO has updated the forecasts to account for a changed domestic and international context and respond to changes in key demand drivers such as business conditions for manufacturing, domestic and international gas prices, and the circumstances of particular gas-consuming industries and users.

Key improvements made in the 2015 NGFR include:

- Consultation with LNG producers, large industrial gas users, and the gas industry in general, to test and refine forecasting assumptions, methods and outcomes.
- Updated wholesale gas price projections, and revised gas costs for GPG.
- More detailed modelling of the residential and commercial sector, to improve insights on gas to electric appliance switching, energy efficiency, and changes to retail gas prices.
- Improvements in industrial consumption models to separate growth sectors such as the services industry and food/beverage manufacturing sectors.
- Modelling of new gas connection projections using dwelling construction and population forecasts.
- Calibration of weather models to longer-term trends.

# CHAPTER 2. LIQUEFIED NATURAL GAS (LNG) – ANNUAL GAS CONSUMPTION

In preparing the 2015 National Electricity Forecasting Report (NEFR), AEMO engaged Lewis Grey Advisory (LGA) to estimate projections of gas and electricity consumption used in the production and export of LNG. LGA updated these estimates for the 2015 NGFR, after the 2015 NEFR was published.

LGA's estimates enabled a number of key assumptions to be refined, based on recent market data. AEMO and LGA also met with all LNG producers to collect and validate information to assist the forecasting process.

As a result, LNG consumption forecasts have changed since the publication of the 2014 NGFR and the 2015 NEFR.

## 2.1 Differences since 2014 NGFR

Key differences in methodology since the 2014 NGFR are:

- Changes to assumed start-up timing. Australia Pacific LNG (APLNG) has shifted the start of its first train from mid-2015 to the last quarter of 2015, and its second train from late 2015 to mid-2016.
- Assumed quantity of gas used in liquefaction was reduced from 8.0% to 7.6% in aggregate.
- A seasonal pattern in gas use for liquefaction has been added.
- Projected increased use of gas in processing. An additional 1% of gas usage at the wellhead is assumed at electrically-driven upstream plants for Queensland Curtis LNG (QCLNG) and APLNG.

## 2.2 Methodology

The LNG forecasts were developed by modelling the supply chain backwards, using a range of public data and the outcomes of technical engagement with the LNG producers.

A full explanation of the forecasting methodology can be found in the Lewis Grey Advisory report from the 2015 NEFR.[3]

Refinements to this methodology, including explanation for updated assumptions can be found in the updated Lewis Grey Advisory report that accompanies the NGFR.[4]

[3] Lewis Grey Advisory, Projections of Gas and Electricity Used in LNG; 15 April 2015. Available at: http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report/~/media/Files/Electricity/Planning/Reports/NEFR/2015/Projections%20of%20Gas%20and%20Electricity%20Used%20in%20LNG%20%20Public%20Report%20%20Final.ashx

[4] Lewis Grey Advisory, Updated Projections of Gas and Electricity Used in LNG; 26 October 2015. Available at: http://www.aemo.com.au/Gas/Planning/Forecasting/~/media/Files/Gas/Planning/Reports/NGFR/2015/Projections%20of%20Gas%20and%20Electricity%20Used%20in%20LNG.ashx

# CHAPTER 3. GAS-POWERED GENERATION (GPG) – ANNUAL GAS CONSUMPTION AND MAXIMUM DEMAND

This chapter describes the methodology and key assumptions AEMO used to forecast GPG annual gas consumption in supplying electricity to the National Electricity Market (NEM). The methodology and assumptions in this chapter were also used to forecast GPG maximum demand.

AEMO's GPG modelling considered the significant changes that could occur to the mix of technologies making up the electricity generation fleet, and to the day-to-day behaviour of generator participants.

Key drivers impacting AEMO's GPG gas consumption and maximum demand forecasts were:

- Changing trends forecast in electricity annual operational consumption.
- Extreme weather conditions and discrete events that could impact electricity maximum demands.
- Climate change policy as at November 2015, such as the Renewable Energy Target and Direct Action Plan.
- Construction, capital costs, maintenance, and running costs for new generation technologies.
- Projected retirement of existing generation, including 3,473 MW of announced withdrawals over the next 10 years.[5]
- Forecast fuel costs for different existing and new technologies.
- Forced outage rates based on actual historical performance.

To appropriately model these drivers, AEMO produced GPG gas consumption and maximum demand forecasts in two sequential stages:

**Stage 1: Investment modelling**

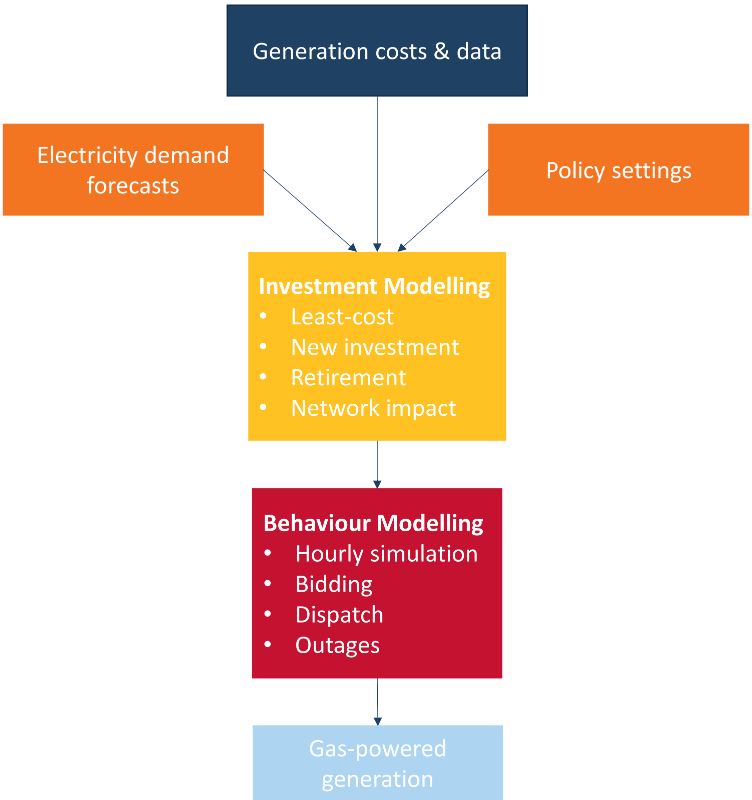
Investment modelling determined the level of the new generator investments (i.e. GPG, Wind, Biomass etc.) and retirements required to maintain power system reliability at the lowest cost.

**Stage 2: Behaviour modelling**

Behaviour modelling simulated how all generators would behave and incorporated the new investment levels calculated in stage 1. It allowed AEMO to forecast annual generation mix, annual gas consumption and maximum demand to produce electricity in the NEM in the next 20 years, measured through a detailed simulation of hour-by-hour dispatch. The simulation took account of generator forced outages, transmission network constraints, variability of intermittent generation, and profit-oriented bidding.

[5] http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportunities

**Figure 1 GPG consumption methodology**




## 3.1 Stage 1: Investment modelling

AEMO's investment modelling focused on meeting future system reliability at the lowest electricity system capital and operating costs. AEMO used this model in its annual National Transmission Network Development Plan (NTNDP)[6], which optimised the electricity system's total operating cost for the next 25 years, and identified a plan for efficient new transmission and generation development and timing of existing generator retirements.

This stage only gave investment and retirement plans, which were then fed into stage 2 to simultaneously forecast GPG gas consumption and maximum demand.

The model took into account the likely range of costs for existing generators. These included the cost of retiring assets, and fixed and variable operating costs, fuel costs, and emission costs. In evaluating potential new generation investments, the model considered capital costs, fixed and variable operating costs, fuel costs, and emission costs.

It also incorporated the optimised capital cost of new transmission lines and link augmentation required to maintain power system reliability. Renewable energy targets and associated violation penalties were also included in the model.

As the model is large and complex, some simplifications were required. The model first arranged hourly electricity consumption data from low to high, then divided it into 20 blocks (called load blocks). AEMO considers twenty the optimal number of load blocks to deliver representative results that account for seasonal variation and electricity maximum demand coincidence between NEM regions. It also simplifies other time-varying data (for example, wind generation).

Key elements in the investment model are described in Table 2 below.

[6] http://www.aemo.com.au/Electricity/Planning/National-Transmission-Network-Development-Plan

**Table 2 Key elements in the investment model**

| Key element | Application in model | Rationale |
|---|---|---|
| Outlook period | Next 25 years, ensuring installed capacity is sufficient to meet electricity operational consumption, including a safety margin of spare reserve. | The horizon enables market trends to affect long-term investment and retirement plans that meet the NEM Reliability Standard. |
| Outlook resolution | 20 load blocks per month. | This number gave reduces model complexity without materially impacting accuracy or results. |
| Generation location | Existing units were modelled exactly, and prospective new units that are not yet located were grouped by technology into one of 16 NTNDP zones. | The 16 NTNDP zones represented areas where construction or fuel costs are likely to be similar. |
| Generator outages | Applied as a reduction in maximum possible plant energy production. | This calculation replaced the random sampling of forced outages. |
| Consumption | Regional electricity operational consumption, including adjustments for rooftop PV and small non-scheduled generation. | This allowed for appropriate treatment of PV and non-scheduled generation in the model. |
| Network | The five regional nodes with interconnectors. Its limitations were captured in the model through detailed power system studies at maximum demand. | This was an effective compromise between detail, modelling time required, and the ability to inject engineering expertise into the network development process. |

The investment model used PLEXOS for Power Systems software from Energy Exemplar. Further detailed information about the model and methodology is available on AEMO's website.[7]

## 3.2 Stage 2: Behaviour modelling

The behaviour modelling stage analysed NEM outcomes in more detail. AEMO's behaviour modelling used the investment and retirement plans produced by the investment model to simulate market dispatch at hourly resolution, to understand how individual generators might behave, because this impacts GPG forecasts.

The behaviour model used a Monte Carlo[8] mathematical approach to capture the impact of generator-forced outages consistent with the model and approach used in AEMO's annual Electricity Statement of Opportunities[9].

In the investment modelling stage, operating cost drove the investment decision, while in the behaviour stage, portfolio profitability drove generation dispatch. Portfolio profitability was modelled by assuming all business units can and will change their bid quantities simultaneously by trading volume versus price to increase their profits. This approach projected participants' risk appetite and short-term commercial decision-making behaviours.

AEMO's behaviour model applied a set of network constraint equations to control generator dispatch and ensure network limitations were applied. These constraints were a subset of the equations used in the operational dispatch process, and reflected only normal system operating conditions where all elements of the power system were in service.

[7] http://www.aemo.com.au/Electricity/Planning/Related-Information/Planning-http://www.aemo.com.au/Electricity/Planning/Related-Information/Planning-Assumptions.

[8] The Monte Carlo approach simulates the model iteratively, taking into account random events to ensure that the result is statistically robust.

[9] http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportunities

**Table 3 Key elements in the behaviour model**

| Key Element | Application in model | Rationale |
|---|---|---|
| Outlook period | 20 years. | The long term outlook period allowed modelling of the impacts of long-term changes in the generation fleet and electricity consumption. |
| Outlook resolution | Hourly. | While the NEM is dispatched at five-minute resolution, hourly was sufficient to forecast annual gas consumption and maximum demand while capturing granular intra-day generator behaviour patterns. |
| Generation | All units were modelled exactly, including any new build in the investment modelling. | This level of detail was required to assess realistic hourly generation patterns on a unit-by-unit basis. |
| Generator-forced outages | Applied using a Monte Carlo approach. | The more detailed nature of the behavioural modelling is sensitive to generator outages, and a probabilistic approach accounted for a broad distribution of potential outcomes. |
| Consumption | Regional. | Regional electricity consumption is sufficient for most long-term investment modelling. |
| Network | Full set of system normal network constraint equations. | This level of detail was required to assess hourly generation impact on network limitation. |

The behaviour model used PLEXOS for Power Systems software from Energy Exemplar. Further information on the model and methodology is available on AEMO's website.[10]

### 3.2.1 Data aggregation in the behaviour model

AEMO used 10% Probability of Exceedance (POE) and 50% POE electricity maximum demand to account for the extreme and moderate weather conditions that drive electricity maximum demand and stress the electricity network. This process resulted in a 25-year hourly electricity profile, which was then used in the behaviour model.

As generation units are not always available and are subject to unplanned outages, simulated unit outages were imposed and applied using random sampling. The model simulated eight forced-outage patterns on the hourly electricity profile using the 10% POE and four forced-outage patterns on the 50% POE electricity maximum demand. This process calculated the gas consumption and maximum demand forecast simultaneously. Each GPG unit's annual gas consumption was calculated as an average annual gas consumption from all simulation results. These were then aggregated geographically to get total annual regional and zonal energy consumption.

The hourly modelling results were also aggregated to daily resolution for reporting maximum demand. The 1-in-20 gas maximum demand and 1-in-2 gas maximum demand were calculated by taking the original simulation results for the maximum day, and capturing the 95th percentile and 50th percentile consumption values.

For South Australia, the 1-in-20 maximum demand was based on a specific scenario where there is limited import from Victoria during peak seasonal day and wind is blowing consistent with wind contribution to peak demand.

### 3.2.2 Contract Position

Generators typically sell electricity quantities in advance, either on the ASX through standard products, or via an Over-the-Counter (OTC) transaction, both of which are contracts for difference. As the NEM is a gross pool market, generators are then required to bid in these quantities into the market if they want to receive the spot price for those amounts. Although they are not obliged to generate at these levels of electricity production themselves, they are incentivised to do so if the forecast spot price is higher than

[10] http://www.aemo.com.au/Electricity/Planning/Related-Information/Planning-Assumptions.

their production costs. These contracts are assumed to be on a portfolio basis, and some companies may have a fleet of generation of different technologies to serve these presold contracts.

Generators bid into the market by detailing their generation availability under ten price and quantity bands. AEMO has assumed contract levels for a generator by summing the generator's historical bid quantities at bid prices lower than the spot price or their assumed short run marginal costs.

## 3.3 GPG key inputs and assumptions

### 3.3.1 Inputs

Simulating electricity investment and operating behaviour over a 20-year horizon requires a large set of input data. Table 4 describes the key process inputs, their importance, and how they are sourced.

**Table 4 Key input data used in projecting GPG consumption**

| Key input | Importance | Data source |
|---|---|---|
| **Electricity operational consumption (including rooftop PV)** | Electricity operational consumption directly impacts investment required in new GPG, and the economics of dispatching it when built. | National Electricity Forecasting Report (NEFR).[11] |
| **Emissions cost trajectory** | An imposed price on emissions changes the relative operating costs between technologies, and may incentivise use of gas over coal, or use of renewables over gas. | Economic forecasts as an input into the NEFR. |
| **Large-scale renewable energy target (LRET)** | The LRET requires electricity retailers to purchase renewable generation certificates, driving investment in renewable generation.<br>Installation of new renewable generation could erode the capacity factor of existing units. | AEMO's scenario definitions document.[12] |
| **Fuel prices** | The price of gas impacts the relative operating cost and use of GPG units. In some cases, gas supply contracts are modelled for existing units; these provide existing units with a lower fuel cost than is available to new units. | 2014 Planning Assumptions.[13] |
| **Gas Supply Agreement** | The volume of gas supply under Gas Supply Agreements and the assumed terms of those agreements, including minimum contractual quantities, can influence modelling of GPG operation in the NEM and thus projections of GPG gas consumption. | 2015 Core Energy's Eastern Gas Intelligence System |
| **Construction and maintenance costs for new technologies** | The costs to build and maintain new generation projects affect GPG gas consumption and maximum demand by either setting the economics of building new GPG units, or by incentivising investment in competing technologies. | 2014 Planning Assumptions. |
| **Electricity transmission network limitations** | Limitations on the electricity transmission network can reduce the generating unit output despite their physical availability to run. | AEMO produces these in-house to reflect normal system conditions, and adjusts them to account for committed network upgrades.[14] |
| **Generating unit technical characteristics** | The characteristics of a generating unit affect its behaviour, competitiveness, and fuel usage.<br>These parameters include capacities, marginal loss factors, minimum generation levels, forced outage rates, water storage levels, ramp rates, auxiliary load, emission factors, and thermal efficiency. | 2013 Planning Assumption.[15]<br><br>Supplemented by AEMO's annual generator survey.[16] |

[11] Available at: http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report.
[12] Available at: http://www.aemo.com.au/Electricity/Planning/Forecasting.
[13] Available at: http://www.aemo.com.au/Electricity/Planning/Related-Information/Planning-Assumptions.
[14] Available at: http://www.aemo.com.au/Electricity/Planning/Related-Information/Planning-Assumptions.
[15] Available at: http://www.aemo.com.au/Electricity/Planning/Related-Information/Planning-Assumptions.
[16] Available at: http://www.aemo.com.au/Electricity/Planning/Related-Information/Generation-Information.

### 3.3.2 Assumptions

All modelling and forecasting activities include a set of assumptions, either because some variables are unknown, or as a compromise between modelling precision and modelling practicality. The most important assumptions underpinning development of GPG gas consumption and maximum demand forecasts are outlined in Table 4.

As in the 2015 ESOO, AEMO's modelling input data reflected the latest operational consumption and maximum demand forecasts developed for the 2015 National Electricity Forecasting Report (NEFR)[17], transmission developments, committed and existing generator availabilities, as at 1 July 2015.

Note that 2015 ESOO maximum demand values were not directly comparable to 2015 NEFR maximum demand values, as ESOO values were adjusted for use in market modelling. These adjustments included removal of auxiliary loads, inclusion of some but not all non-scheduled generation, and transformation of maximum demand values into hourly profiles.

AEMO's adequacy modelling accounted for the hourly generation output of wind farms based on historical data, and included any contributions toward avoiding unserved energy (USE). However, at times of maximum demand (when the majority of USE occurs), only a percentage of wind generation is typically available. Information about projected monthly energy, utilisation of inter-regional support to meet electricity consumption, and modelled interconnector flow, is available in the regional data files on the ESOO web page[18].

The 2015 ESOO included additional commentary and analysis using AEMO's latest generator survey results and electricity consumption forecasts.

**Table 5 Key assumptions made when projecting GPG demand**

| Key assumption | Detail |
|---|---|
| **The reliability standard for electricity will be met.** | The power system reliability benchmark is set under the National Electricity Rules.<br>The maximum permissible unserved energy (USE), or the maximum allowable level of electricity at risk of not being supplied to consumers, due to insufficient generation, bulk transmission or demand-side participation (DSP) capacity, is 0.002% of the annual energy consumption for the associated region, or regions, per financial year |
| **The shape of operational consumption and wind generation are consistent with the 2009–10 reference year.** | The NEFR provides forecasts of annual electricity operational consumption, and seasonal maximum demands. These values must be translated into hourly traces for use in modelling.<br>Translation involved starting with an hourly reference shape, and adjusting it to meet the NEFR energy and maximum demand targets, while also maintaining any day-of-week effects.<br>A consistent reference year was chosen for all regional consumption and wind traces to maintain correlation.<br>AEMO currently uses 2009–10 as the reference shape due to its relatively consistent demand conditions across all regions, and relatively average capacity factors across all wind locations.<br>Contributions from rooftop solar PV and small non-scheduled generation were netted out of the reference shape, and applied separately to the final traces. This accounts for changes in the consumption shape that have been driven by these components since 2009–10. |
| **Violation penalty for not meeting the LRET is modelled** | The investment modelling applied the penalty cost for not meeting the LRET target. |
| **Generation expansion and retirement plan are consistent with AEMO's long-term electricity planning studies, such as the NTNDP.** | AEMO produced generation expansion and retirement plans as part of the NTNDP process which minimises the total cost of running the electricity system over the 25-year outlook. These are produced for planning purposes (not as an assessment of profitability). |
| **Profitability bidding** | In investment modelling, generators were assumed to be dispatched according to their underlying costs.<br>In the behavioural modelling phase, generators were allowed to change their bids to increase their business unit's total profit, taking into account the revenue from the electricity spot market and its underlying operating costs. |

[17] http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report
[18] http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportunities.

# CHAPTER 4. INDUSTRIAL – ANNUAL GAS CONSUMPTION

This chapter outlines the methodology used to develop annual gas consumption forecasts for industrial customers. Industrial consumption, also known as Tariff D consumption, is defined as consumption by network customers who are billed on a demand basis.[19] These customers typically consume more than 10 TJ per year.AEMO defined two categories of industrial customer for analysis purposes:

- Large industrial loads (LIL): consume more than 500 TJ annually at an individual site. Typically includes aluminium and steel producers, glass plants, paper and chemical producers, oil refineries and gas-powered generation (GPG) not included in GPG forecasts.[20]
- Small-to-medium industrial loads (SMIL): consume more than 10 TJ but less than 500 TJ annually at an individual site. Typically includes food manufacturing, casinos, shopping centres, hospitals, stadiums, and universities.

Industrial gas consumption has tended to be dominated by very large users, often representative of heavy manufacturing. Over the last ten to fifteen years, industrial consumption has experienced large declines in most states, and declines in heavy gas-intensive manufacturing can overwhelm the historic data that is used to forecast future consumption. Growing sectors for gas consumption, such as services and food and beverage manufacturing, represent only 17% of total annual industrial consumption across all regions.

In the 2014 NGFR, AEMO obtained large industrial load forecasts directly from gas users, and forecast the remainder using regionally-aggregated models and gas meter data that for some states only covered a short period of historical consumption.

For the 2015 NGFR, AEMO has introduced major improvements including:

- Recognising structural changes in the economy by identifying sectors exhibiting growth and modelling them separately from manufacturing sectors which have been declining over the last 20 years. This disaggregated approach mitigates the risk of downward bias which would otherwise arise due to the dominating effect of the sectors in decline. AEMO used separate models, and different macroeconomic drivers, for:
  - Growth Sectors: The primary growth sectors are food and beverage manufacturing and the services sector. The model also includes other smaller sectors which are expected to have a neutral or positive effect on gas consumption. The key drivers of the growth sectors are population growth and retail gas price.
  - Manufacturing: All other manufacturing sectors (not including food and beverage manufacturing sectors). Key drivers are input-output producer price ratio, which captures industry profitability trends; retail gas price; long-term trend variables and operational changes in large industrial loads.
- Modelling Large Industrial Loads (LIL) and Small and Medium Industrial Loads (SMIL) together, because long term trends in both LIL and SMIL are driven by macroeconomic factors.
- Using econometric modelling and economic techniques to derive a base model and adjust the model for long-term macroeconomic trend forecasts.
- For the models in Victoria and South Australia, estimating the effect on gas consumption of automotive vehicle manufacturing industry closures by 2018[21], and making a post model adjustment to account for this.

[19] Customers are charged based on their Maximum Hourly Quantity (MHQ), measured in gigajoules (GJ) per hour.
[20] This includes GPG which is not connected to the National Electricity Market (NEM), and large co-generation.
[21] Productivity Commission, "Australia's Automotive Manufacturing Industry", 2014; Productivity Commission Enquiry Report. Available: http://www.pc.gov.au/inquiries/completed/automotive/report/automotive.pdf. Viewed 23 November 2015.

- Complementing this approach by surveying and interviewing most large industrial customers, seeking advice on high certainty and near term adjustments to forecasts.
- Overcoming gas meter data limitations in some states by using available meter data with complimentary data sources, such as financial data from Australia's national accounts (Australian Bureau of Statistics) and long-term gas consumption data from the federal Bureau of Resources and Energy Economics (BREE).

## 4.1 Industrial Gas Consumption Model

Econometric modelling and economic techniques were used to derive a base model and adjust the model for long term macroeconomic trend forecasts. Additionally, a post-model adjustment was made for near-certain short-term industrial load changes that deviated from long term trends. Survey methodology was used to make this adjustment.

AEMO has modelled short-term gas consumption and long-term gas consumption separately. The short-term model captures changes in gas consumption due to weather and seasonality effects, while the long-term model accounts for structural economic changes.

### 4.1.1 Data sources

#### Gas consumption data

AEMO receives aggregated historical industrial consumption data from distribution and transmission business owners for all regions except Victoria. In Victoria, this data is obtained from AEMO's Market Management System used in market settlements.

AEMO aggregated the historical and forecast data to region level for confidentiality purposes.

#### Public Data Sources

AEMO's long-term forecast models used macro-economic variables. AEMO sourced information on these economic indicators from publically available data from Australian Bureau of Statistics (ABS), Bureau of Resource and Energy Economics (BREE).

Please see Table 32 for a list of references to datasets used.

#### Other Data Sources

Retail gas price data sources are discussed in Appendix A.

## 4.2 Methodology

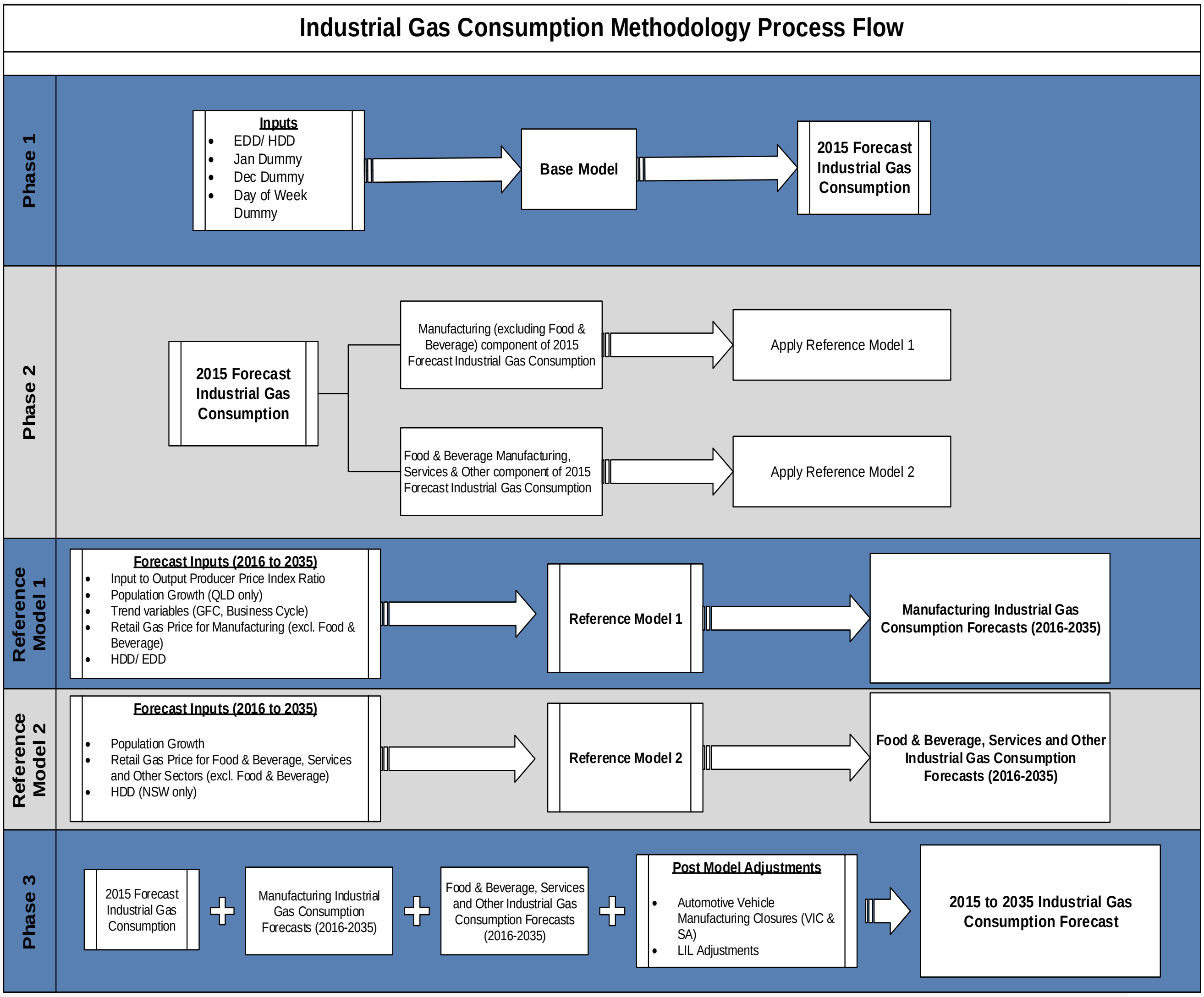
AEMO has taken a hybrid modelling approach to industrial forecasting:

- First, a base model was used to forecast 2015 annual consumption. This used a short period data to provide a tuned starting point that was not affected by historic long-run macroeconomic trends, structural economic changes and economic shocks. This base model ALSO captured large commercial[22] heating trends which have not been considered in previous models.
- The base model was then adjusted by reference models, by sector, to capture anticipated long run changes.
- Finally, post-model adjustments were made for anticipated step changes that were not captured in the models.

Figure 2 shows the steps undertaken to derive the final industrial forecast.

[22] Some large commercial consumers have big enough annual consumption to fall under the Small Industrial Load (SMIL) category. Commercial consumers' gas load tends to be sensitive to weather variations.

**Figure 2 Methodology Process Flow for Industrial Gas Consumption Forecasts**




### 4.2.1 Short Term Base Model (Phase 1)

A short-term model was used to create a base forecast. This component is not sensitive to macroeconomic shocks, reflects the most current business conditions, and is weather-normalised to give the most accurate forecast starting point that is tuned for current load and current consumption. The model also captured large commercial heating load, which previous industrial models have not considered.

The base model forecast 2015 annual gas consumption for industrial loads. The econometric equation is represented below[23]:

$$\widehat{Tariff}\ D_i = \beta_0 + \beta_1(HDD\ or\ EDD)_i + \beta_2 Jan_i + \beta_3 Dec_i + \beta_4 DoW_i$$

The variables were defined as shown in Table 6.

[23] Note that for Queensland the HDD variable was not significant since most of Queensland's industrial gas consumption comprises of large industrial loads that are less sensitive to weather changes. For this reason, the base model forecast for 2015 used 2014 annual consumption values, adjusted for large industrial load adjustments as a post model adjustment.

**Table 6 Base Model Variable Description**

| Variable names | ID | Units | Description |
|---|---|---|---|
| Heating Degree Days[24] or Effective Degree Days[25] | HDD or EDD | °C | HDD or EDD values were used to account for deviation in weather from normal weather standards. South Australia, Queensland and New South Wales use HDD while Victoria uses EDD.[26]. |
| January Dummy | Jan | {0,1} | A dummy for the month of January captured the ramp-up in industrial processes, and consequently gas consumption, following a major holiday period. |
| December Dummy | Dec | {0,1} | A dummy for the month of December captured the ramp-down in industrial processes, and consequently gas consumption, coming up to a major holiday period. |
| Day of Week Dummy | DoW | {0,1} | A dummy for the days of the week was used to capture the difference in gas consumption on working days from non-working days. The days of the week were grouped into Peak (Monday to Thursday), Shoulder (Friday), and Off-Peak (Saturday and Sunday) |

The base model parameters were forecast using 2014 daily data. The length of time series used was intentionally short so the parameters reflected the most current business conditions and were not biased by long-run trends resulting from policy shocks, technological changes and other macro-economic factors.

### 4.2.2 Long Term Reference Models (Phase 2)

AEMO's 2015 industrial consumption model further improved on past models by incorporating structural economic changes to more accurately reflect long-term influences on industrial business decisions and consequently on gas consumption.

Two reference models were developed, splitting the base forecast consumption by the two main sectors of the economy (see below). The reference models were then applied to the relevant sectors of the economy.

#### Sector Decomposition

Over the last couple of decades, the manufacturing sectors (excluding food and beverage manufacturing) have experienced a period of sustained decline, and conservative growth is anticipated for the long term. Meanwhile, other sectors of the economy, such as food and beverage manufacturing and services, are expected to exhibit long-term growth.

AEMO modelled gas consumption for these sectors separately, to mitigate the risk of a downward bias which would otherwise arise due to the dominating effect of the sectors in decline.

AEMO's model framework broke down the industrial users into two main categories[27]:

- Manufacturing (excluding food and beverage manufacturing).
- Food and beverage manufacturing, services and others (called 'other').

[24] HDDs are a measure of how much (in degrees) and for how long (in days) the outside air temperature is lower than a threshold temperature. Calculated as Threshold Temperature – Average Daily Temperature. If this value is negative (i.e., average daily temperature is greater than threshold temperature), HDDs are considered to be zero.

[25] EDDs are similar to HDDs but take into account wind speed, sunshine hours, and a seasonal consumer response to weather. EDDs provide a better correlation between weather and energy consumption than HDDs.

[26] EDDs are only used in Victoria as AEMO has not developed a calculation for the other states.

[27] For further details on sectors see Table 26 in Appendix D.

### Splitting industrial (Tariff D) consumption data

As AEMO's internal gas consumption data was not available at a sector-disaggregated level, AEMO used Bureau of Resource Energy Economics data[28] to calculate the sector split, and then derived a split between commercial (Tariff V) and industrial (Tariff D) consumption using ABS data[29] to estimate industrial gas consumption by sector. The sector totals were then calibrated against AEMO's total industrial consumption data.

- **Tariff D versus Tariff V split:** All manufacturing consumption was assumed to be Tariff D consumption. For 'other' customers, using ABS data, AEMO assumed businesses with annual turnover less than $200,000 fell in the category of Tariff V consumers, and businesses with annual turnover greater than $200,000 fell in the category of Tariff D consumers. The Tariff D versus Tariff V split was therefore derived by taking the ratio of the count of businesses with annual turnover greater than  $200,000 to less than $200,000.
- **Manufacturing Split:** While manufacturing did not need to be split by Tariff D versus Tariff V, the model required manufacturing consumption to be split by food and beverage manufacturing consumption and all manufacturing consumption. Bureau of Resource Energy Economics data[30] was again used to estimate this.

### Reference Model 1

This model was used to forecast long-term gas consumption behaviour for manufacturing sectors (excluding food and beverage manufacturing). It considered the key inputs that drive business decision-making for these sectors.

[28] Office of the Chief Economist (formerly Bureau of Resource Energy Economics), Australian Energy Statistics Tables, "Australian Energy Consumption by state, by industry, by fuel, energy units". Available: http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Australian-energy-statistics.aspx#. Viewed 5 November 2015.

[29] Australian Bureau of Statistics, Counts of Australian Businesses, including Entries and Exits, "Survival of Businesses by Main State by Subdivision by Turnover Size Ranges, June 2010 - June 2014". Available: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/8165.0Jun%202010%20to%20Jun%202014?OpenDocument;  Australian Bureau of Statistics, Counts of Australian Businesses, including Entries and Exits, "Survival of Businesses by Main State by Subdivision by Turnover Size Ranges, June 2007 - June 2011". Available: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/8165.0Jun%202007%20to%20Jun%202011?OpenDocument; Australian Bureau of Statistics, Counts of Australian Businesses, including Entries and Exits, "Survival of Businesses by Main State by Subdivision by Turnover Size Ranges, June 2003 - June 2007". Available: http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/3CC7EAE24A51E9A7CA2577C2000F0987?opendocument. Viewed: 5 November 2015.

[30] Office of the Chief Economist (formerly Bureau of Resource Energy Economics), Australian Energy Statistics Tables, "Australian Energy Consumption by state, by industry, by fuel, energy units". Available: http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Australian-energy-statistics.aspx#. Viewed: 5 November 2015.

### Model Development

*Inputs:*

**Table 7 Reference Model 1 Variable Description**

| Variable names | ID | Units | Description |
|---|---|---|---|
| Manufacturing Consumption | Man_C | PJ | Manufacturing consumption (excluding Food and Beverage Manufacturing). |
| Retail Price | Price | $/GJ | Retail gas price for industrial users. |
| Input Producer Price Index | I_PPI | Index | Input PPI measures the rate of change in the prices of good and services purchased as inputs by the producer. |
| Output Producer Price Index | O_PPI | Index | Output PPI measures the rate of change in the prices of goods and services purchased as inputs by the producer. Manufacturing output PPI was specifically used. |
| Input-Output Producer Price Ratio | PPI_Ratio | Index | PPI_Ratio = I_PPI/O_PPI |
| Population | POP | Persons | Population level of a state (net of deaths, births, migration). |
| GFC Dummy | GFC | {1,0} | Dummy variable to capture long term effects of the economic shock from the Global Financial Crisis. This is a binary variable that takes on the value of 1 or 0. |
| Business Cycle Dummy | BC | {1,0} | Dummy variable to capture long term effects of the economic shock from the Global Financial Crisis. This is a binary variable that takes on the value of 1 or 0. |
| Heating Degree Days or Effective Degree Days | HDD or EDD | °C | HDD or EDD values were used to account for deviation in weather from normal weather standards. South Australia, Queensland and New South Wales use HDD while Victoria uses EDD. |

*Econometric Model:*

The following econometric model was used to estimate the elasticity[31] parameters of manufacturing consumption in response to changes in other variables.

$$\ln(Man\_C) = \beta_0 + \beta_1 \ln(Price\_lagged\ 1\ Year) + \beta_2 \ln(PPI\_Ratio) + \beta_3 \ln(POP) + \delta_1 GFC + \delta_2 MB + \delta_3 \ln(HDD/EDD)$$

Where:

- The coefficient $\beta$ is interpreted as the elasticity value of manufacturing consumption to changes in the respective macroeconomic variables, when all else is held constant.
- Population is only included in the model for Queensland, but excluded in the model for other states.[32]

Global Financial Crisis (GFC) and Business Cycle trend dummy variables were also included in the model to improve model specification.[33] This is an annual model and model parameters were derived using historic data from 2000–14.[34]

[31] Elasticity is defined as the percentage change in a variable in response to a 1% change in another variable. For example, if elasticity of Manufacturing Consumption (Man_C) to Price is 2 this is interpreted as a 1% change in Price results in a 2% change in Manufacturing Consumption.

[32] POP is only statistically significant in Queensland.

[33] Model misspecification can arise when statistically significant variables are omitted from the model. This can result in the parameters, of the variables included in the model, being biased.

[34] The historic data has intentionally been restricted to the latest 14 years to reflect current businesses and business conditions and avoid biasing future estimates by historic conditions that are no longer prevalent.

**Forecast Manufacturing Consumption:**

The following steps outline how manufacturing sector consumption initial forecasts are derived.

**Step 1**: Forecast raw input data

**Step 2**: Calculate annual percentage change in inputs

**Step 3**: Calculate percentage change in manufacturing consumption in response to changes in the inputs using the elasticity parameters derived from the econometric model.

**Step 4**: Adjust the base forecast by the annual percentage changes in manufacturing for each input, derived in step 3 to get the final annual consumption.

## Reference Model 2

This model was used to forecast long-term gas consumption behaviour for 'Other' sectors (namely Food and Beverage manufacturing, Services and Other). It considered the key inputs that drive business decision-making processes for these sectors.

**Model Development**

*Inputs:*

**Table 8 Reference Model 2 Variable Description**

| Variable names | ID | Units | Description |
|---|---|---|---|
| Other Consumption | Other_C | PJ | Consumption from Food & Beverage manufacturing and non-manufacturing sectors such as Services. |
| Population | POP | Persons | Population level of a state (net of deaths, births, migration) |
| GFC Dummy | GFC | {1,0} | Dummy variable to capture long term effects of the economic shock from the Global Financial Crisis. This is a binary variable that takes on the value of 1or 0. |
| Business Cycle Dummy | BC | {1,0} | Dummy variable to capture long term effects of the business cycle variations. his is a binary variable that takes on the value of 1 or 0. |
| Heating Degree Days | HDD | °C | HDD account for deviation in weather from normal weather standards. |

*Econometric Model:*

The following econometric model was used to estimate the elasticity[35] parameters of 'Other' sector consumption in response to changes in other variables.

$$\ln(Other\_C) = \beta_0 + \beta_1 \ln(POP) + \beta_2 \ln(Price\_lagged\ 1\ Year) + \delta_1 GFC + \delta_2 BC + \delta_3 \ln(HDD)$$

Where:

- The coefficient $\beta$ is interpreted as the elasticity value of other sector gas consumption to changes in the respective macroeconomic variables, when all else is held constant.
- HDD is only included in the model for NSW, but excluded in the model for other states.

[35] Elasticity is defined as the percentage change in a variable in response to a 1% change in another variable. For example, if elasticity of Manufacturing Consumption (Man_C) to Price is 2, this is interpreted as a 1% change in Price results in a 2% change in Manufacturing Consumption.

Global Financial Crisis (GFC) and Business Cycle trend dummy variables were also included in the model to improve model specification.[36] This is an annual model and model parameters were derived using historic data from 2000–14.[37]

**Forecast Other Sector Consumption:**

The following steps outline how other sector consumption initial forecasts are derived.

**Step 1**: Forecast raw input data.

**Step 2**: Calculate annual percentage change in inputs.

**Step 3**: Calculate percentage change in manufacturing consumption in response to changes in the inputs using the elasticity parameters derived from the econometric model.

**Step 4**: Adjust the base forecast by the annual percentage changes in manufacturing for each input, derived in Step 3, to get the final annual consumption.

**Aggregating to Tariff D Forecast (pre-adjustments)**

Tariff D initial forecasts were obtained by adding together the Manufacturing sector forecast gas consumption and Other Sector forecast gas consumption. These forecasts were then adjusted by post-model adjustments to get the Tariff D final forecasts (see Phase 3).

### 4.2.3 Post Model Adjustments (Phase 3)

The reference models were used to capture long run trends in different industrial sectors. However, they did not capture significant deviations from trend, so post model adjustments were made for more likely anticipated changes. Two types of adjustments were considered:

- Automotive Vehicle Manufacturing closure adjustments (Victoria and South Australia only).
- Large Industrial Load Adjustments.

The methodology for applying the post model adjustments is detailed below.

#### Automotive Vehicle Manufacturing Closure Adjustments

With the announced closure of Toyota and Holden in 2017–18[38], the complete closure of the automotive vehicle manufacturing industry becomes a highly probable scenario. AEMO consulted Computable General Equilibrium (CGE) modelling analysis, used by the Productivity Commission[39], to estimate the impact of the automotive manufacturing industry closure on annual gas consumption. The process undertaken is outlined below.

**Analysis of CGE Modelling Results**

The CGE modelling results suggest the impact of automotive vehicle manufacturing closures are predominantly felt in Victoria and South Australia. The modelling assumes the complete closure takes place over 2017–18.

AEMO uses the CGE analysis on employment to estimate a gas consumption per employee measure. This is then used to back calculate the loss in gas consumption due to closure of the automotive vehicle manufacturing industry (see the following section).

Although the Productivity Commission has estimated that employment in the economy as a whole will return to pre-closure levels by 2025-26, given the conservative growth outlook for manufacturing, AEMO has assumed that this will occur in other sectors of the economy and not in manufacturing.

[36] Model misspecification can arise when statistically significant variables are omitted from the model. This can result in the parameters, of the variables included in the model, being biased.
[37] The historic data has intentionally been restricted to the latest 14 years to reflect current businesses and business conditions and avoid biasing future estimates by historic conditions that are no longer prevalent.
[38] ABC News, "Toyota to close: Thousands of jobs to go as carmaker closes Australian plants by 2017" (2014). Available: http://www.abc.net.au/news/2014-02-10/toyota-to-pull-out-of-australia-sources/5250114. Viewed 12 November 2015.
[39] Productivity Commission, "Australia's Automotive Manufacturing Industry", 2014; Productivity Commission Enquiry Report. Available: http://www.pc.gov.au/inquiries/completed/automotive/report/automotive.pdf. Viewed 23 November 2015.

Given that assumption, AEMO has used the CGE modelling results to estimate a permanent loss of consumption in manufacturing attributed to closures in the automotive vehicle manufacturing industry.

#### Estimating gas consumption impacts

To estimate the total gas consumption impact of automotive vehicle manufacturing industry closures, AEMO:

- Estimated gas consumption per employee, by estimating the gas input into the manufacturing process and spreading this across the number of employees.
- Aggregated this by projections from the Productivity Commission.

To estimate the gas per employee measure, AEMO first estimated historic total gas use in the industry. The Input-Output tables published by the ABS[40] contain dollar value estimates of inputs used in the production process for the supply of an output good, on an industry basis.

AEMO used this dataset to: first, estimate the direct and indirect[41] gas consumption into the automotive vehicle manufacturing industry in dollars; then, using a composite price ($/GJ) value, back-derive gas consumption in that year.

Then, using the CGE analysis results and the ABS data for total employment, AEMO scaled gas consumption to derive the total gas consumed by employees, in the industry, in Victoria and South Australia, then apportion this consumption by region.

After deriving the gas consumption values using public data sources, AEMO validated the results through consultation with major automotive vehicle manufacturing industrial loads. After the validation process, AEMO used these calculations to adjust the final forecasts.

#### Adjusting annual gas consumption forecast

The final forecasts for industrial consumption in Victoria and South Australia were adjusted by a permanent decline due to the automotive vehicle manufacturing industry closure, having a cumulative effect of 2.3 PJ and 0.48 PJ respectively.

### Large Industrial Load Adjustments

AEMO has modelled all industrial gas consumption in aggregate using econometric analysis. In addition, AEMO interviewed and surveyed LILs to gather data for the forecasts. Where the survey forecasts significantly deviated from the model results, the survey data was used to adjust the industrial gas consumption forecast.

#### LIL Data Sources

AEMO used the following data sources when developing LIL consumption forecasts:

- LIL questionnaire responses.
- Detailed discussion with LILs.
- Publicly available information and announcements.
- Historical data from AEMO's Market Management System.
- Historical data from AEMO's service provider for the Gas Retail Market Systems (GRMS).

The survey methodology and limitations are discussed in detail below.

[40] Australian Bureau of Statistics, Australian National Accounts: Input-Output Tables, 2012-13, "Table 2:Use Table- Input by Industry and Final Use Category and Supply by Product Group"". Available: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5209.0.55.0012012-13?OpenDocument. Viewed 14 December 2015.

[41] Gas consumed by other inputs used in the production process for automotive vehicle manufacturing.

**LIL Survey Methodology**

While major changes to LIL operations are relatively infrequent, when they do occur they have a significant impact on regional forecasts. AEMO surveyed and interviewed a range of LILs. This structured survey approach is well-suited to understanding how these customers are likely to respond to changing market dynamics (such as manufacturing competitiveness and gas prices), and analysing the effect of these responses on gas consumption.

**LIL Survey Process**

*Step 1: Initial survey*

AEMO distributed a survey to all identified LILs requesting historical and forecast gas consumption information.

The survey requested annual gas consumption and site maximum demand forecasts for three scenarios:

- Medium – reflecting the most likely forecast levels based on their current understanding and expectations about key drivers such as gas prices, commodity prices, economic growth, and exchange rates.
- High – reflecting higher production and gas consumption from the network under more favourable economic conditions than in the medium scenario, such as higher GDP growth and commodity prices, and lower gas prices and exchange rates.
- Low[42] – reflecting lower production and gas consumption from the network under less favourable economic conditions than in the medium scenario, such as lower GDP growth and commodity price or higher gas price and exchange rate.

*Step 2: Detailed interviews*

Following the survey[43], AEMO contacted each customer directly[44] to review and discuss the responses. This typically included discussions about:

- Key gas consumption drivers, such as exchange rates, commodity pricing, availability of feedstock, current and potential plant capacity, mine life, and cogeneration.
- Currently contracted gas prices and contract expiry dates.
- Gas prices the LILs forecast over the medium and long term (per scenario), and possible impacts on profitability and operations.
- Potential drivers of major change in gas consumption (e.g., expansion, reductions, cogeneration, fuel substitution) including “break-even” gas pricing[45] and timing.
- Different assumptions between the high, medium, and low scenarios.

### 4.2.4 High and Low Scenarios

High and low scenarios were constructed by first using 10% POE and 90% POE benchmarks to adjust the standard deviation of the parameters of the reference models. Some of these parameters were then further tuned to reflect the risks and opportunities that have historically been observed. For example, in the manufacturing sector, periods of weak business conditions have seen significant reductions, but returns to good business conditions haven’t seen a bounce back in manufacturing. For this reason, the elasticity parameters for retail gas price and PPI ratio were tuned further to reflect greater downside risk than upside opportunity.

[42] AEMO also adopted assumptions for aluminium smelters which were consistent with those in the low scenario of the 2015 NEFR.
[43] Or in some cases, prior to receiving responses.
[44] Apart from some smaller LILs whose responses were straightforward.
[45] This is the point of balance between profit and loss.

Note that this method was only applied to the reference model to obtain the high and low scenario forecasts for the long term trend. The high and low scenarios for the LIL surveys did not follow this methodology. For further details on LIL survey methodology, see previous page.

## 4.3 Tasmania – industrial consumption model development and analysis

Tasmania's gas network only started operation in 2004, and SMIL consumption growth since then has reflected the progressive connection of industrial energy users for whom converting to gas has proved economical. It is therefore reasonable to expect that SMIL consumption from 2004 to 2014 would not relate to economic factors as it does in other regions, although it could in future.

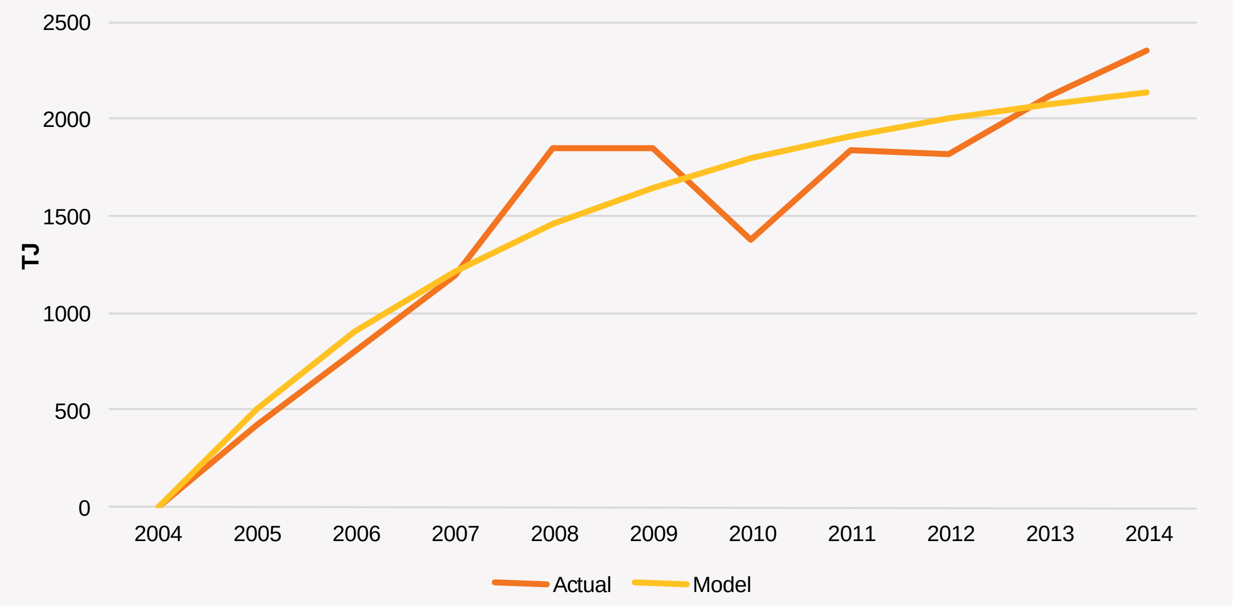
AEMO's Tasmanian SMIL model captured the concept of this progressive conversion by assuming there is a considerable amount of potential conversion available, and that historical conversion occurred as a constant percentage of the remaining potential. While further potential can be created by network growth, growth in Tasmania has been limited in recent years, so this factor was excluded.

### 4.3.1 Data analysis

The chosen model is illustrated in Figure 13. The total potential consumption estimate is 2.35 PJ by 2015.

High and low scenarios were specified as 10% and 90% POE, using the standard deviation in the model.

**Figure 3 Small to Medium Industrial Load chosen model for Tasmania**



# CHAPTER 5. RESIDENTIAL AND COMMERCIAL–ANNUAL GAS CONSUMPTION

Residential and commercial consumption, also known as Tariff V consumption, is defined as consumption by network customers who are billed on a volume basis. These customers typically consume less than 10 TJ/year.

AEMO has used econometric models to develop forecasts for the established networks of Victoria, South Australia, New South Wales (including Australian Capital Territory) and Queensland. For Tasmania, which only started connecting residential and commercial customers in 2004, AEMO applied a network development model.

In the 2015 NGFR, AEMO has:

- Disaggregated models to a finer level of detail than in 2014 to further investigate energy efficiency, gas to electric fuel switching, and the impact of dwelling preferences and price response.
- Used a reference-model approach to overcome data limitations in some states, to produce a base-year forecast calibrated to local conditions. Reference models were then used to adjust the base forecast for key long-term trends such as energy efficiency, gas to electric fuel switching, and price response.
- Separately modelled heating and non-heating load, new versus older homes, and detached versus multi-unit homes, calibrated with actual meter data trends down to postcode level, and adjusting for the effects of the mid-2000s drought, as well as the 2008–09 global financial crisis.

## 5.1 Definitions

Tariff V customers are small gas customers consuming less than 10 TJ of gas per annum, or customers with a basic meter.

Victoria has the highest consumption and greatest number of gas customers of all the eastern and south-eastern states. Approximately 97% Victorian Tariff V customers are residential.

Growth in both Tariff V residential and Tariff V commercial consumption can be attributed to similar key drivers including weather, gas price, energy efficiency measures, and growth in connections.

## 5.2 Forecast number of connections

The number of Tariff V customers connected to the gas network showed a steady increase between 2010 to 2014, with growth rates varying from region to region. The forecast future number of Tariff V customers was estimated using a model that linked the number of new connections per year to key demographic drivers. These drivers were the increase in dwelling stock and the number of new connections to the gas network of already existing buildings (“electricity-to-gas” conversions). This is an improvement of the model compared to the 2014 NGFR, which used the historical average number of new connections as the best indicator of future additions.

### 5.2.1 Data sources

AEMO used a diverse set of sources to forecast of the number of connections. The distribution businesses (DBs) provided detailed records of the historical number of Tariff V connections in their network. Depending on the network zone, the data provided cover different time ranges, with the most recent starting point being 2009 for Queensland. AEMO also asked the DBs about the numbers of new connections registered in pre-existing buildings. In some regions, DBs were not able to provide such information. For this reason, AEMO assumes a low rate of new connections in existing buildings on the basis that the gas market in these regions (except for Tasmania) are stable and therefore little growth in new connections will arise in from fuel switching in existing buildings.[46]

Historical and forecast figures for the growth of dwelling stock in each region were provided by the Housing Institute of Australia (HIA). HIA split its data set into two main dwelling categories: single detached houses and multi-unit dwellings. These forecasts are based on demographics and economic forecasts, as well as surveys to key participants of the construction market. The HIA forecasts extend until 2025. After that date, AEMO estimated the growth of dwelling stock using population growth rates[47] from the Australian Bureau of Statistics (ABS). To ensure a smooth transition between these two sources, the growth rates of the HIA forecasts were made to converge gradually to the population growth rates from ABS.

### 5.2.2 Model description

The model considered two main sources of the growth of the number of connections:

- Conversions of already existing buildings (including areas recently reached by expansions of the gas reticulation).
- The natural increase of the housing stock, a fraction of which will get connected. The likelihood of a house being connected to the network depends on both the region (regions like Victoria and the ACT exhibit a proportionately larger penetration of gas appliances compared to Queensland) and the type of dwelling (apartments in high-rise towers are more likely to be completely electricity-fuelled).

Parameter estimates were obtained from a linear regression of the following model:

$$N_t = \alpha \cdot S_t + \beta \cdot M_t + EG_t$$

Where

- $N_t$ is the net change to the number of Tariff V connections in the region considered at year t.
- $S_t$ and $M_t$ indicate the annual net growth of dwelling stock for single detached houses and multi-unit dwellings, respectively.
- α indicates the fraction of new single detached houses that are connected to the gas network.
- β is the fraction of new multi-unit dwellings connected to the gas network.
- $EG_t$ refers to the number of electricity-to-gas conversions in year t.

The parameters α and β were estimated by means of a linear regression, and it was assumed that the parameters of the model are constant over time. This assumption was approximately satisfied by restricting the data set used in the regression to the period 2009–14, when conditions were stable. In contrast to the 2014 NGFR, the modelling has been run separately for the NSW and ACT regions, taking into account the significantly different level of gas penetration in the two areas.

The forecast of the number of connections was computed by plugging the construction projections from HIA in the model, using the parameters α and β estimated from the historical values. The future values of the EGt term were assumed to be constant and equal to the 2014 figures.

### 5.2.3 Inclusion of small networks

In some regions considered by the NGFR, small distribution businesses contribute, with the main DBs, to total gas reticulation. In many cases, only limited data for these small networks is available, therefore AEMO has considered the total number of connections by means of post-model adjustments. Based on the available historical data, AEMO has related the ratio of Tariff V customers in the small networks to

[46] Dedicated tests were carried out in order to assess the robustness of the methodology under different assumptions for the electricity-to-gas conversions. The change in the final forecast was always within the range spanned by the high and low scenarios

[47] Australian Bureau of Statistics 2013, Population Projections, Australia, 2012 (base) to 2101, cat. no. 3222.0; the reference scenario used by AEMO corresponds to the Scenario B of the ABS projections.

the number of customers of the main DBs, then rescaled forecasts upwards by this relative ratio, assuming that the relationship does not change over time.

In Victoria, the number of connections has been increased by 0.6% in order to account for the customers in the Grampians and South Gippsland networks. The Mildura region is accounted for by increasing the number of connections in South Australia by 2%. The connections in the Bairnsdale and Nowra regions amount to approximately 0.6% of the NSW total. The growth in number of connections in the Wagga Wagga region was assumed to grow at the same rate as the major cities in New South Wales. For Queensland, with no data available for the Dalby Town region, AEMO followed the methodology used in the 2014 NGFR and accounted for the Dalby Town network by rescaling the total number of connections in Queensland by 2%.

### 5.2.4 Fuel Substitution

Behavioural and economic changes can affect the number of connections, introducing deviations from the historical trends. The model used in the 2015 NGFR accounted for these effects in two different ways:

- First, a structural change in Australian dwelling stock was observed in the past few years, with an increased number of apartments and multi-unit dwellings. While single detached houses remain the most common, the fraction of new dwellings in medium- and high-rise buildings is expected to grow in future years. Given the lower penetration of gas in the multi-unit sector, the result is a slowdown of the growth in connections compared to past trends. This trend is embedded in the NGFR via the dwelling forecasts, which predict an increasing fraction of high-rise dwellings.
- A second important mechanism involved a shift of preferences in favour of electricity. Factors driving this trend include fuel prices, cost and efficiency of alternative technologies (reverse-cycled air conditioners, solar hot water systems, and induction cooktops, for example), the removal of the carbon price, and other environmental regulations. Fully-electric systems are expected to take over faster in high-rise apartments compared to other dwelling types. To model this feature, the $\beta$ parameter for high-rise new dwellings was decreased by 80% of the baseline value.

The progressive shift towards fully-electric systems could have been incorporated in the model by allowing the parameters $\alpha$, $\beta$ and $EG_t$ to decrease over time. However, this change is relatively recent, and the available historical series do not provide clear indications of such a trend in the number of connections.

In the absence of quantitative indications that could guide the modelling, AEMO decided not to attempt to include these effects in the number of connections forecast, leaving the parameters constant. A more accurate model of these processes was left for future studies, when more data is available.

## 5.3 Forecasts Annual Consumption Methodology - Victoria

The model involved the following key steps.

### 5.3.1 Data Sources

**Historical Tariff V daily consumption and customer numbers**

Daily consumption data is:

- Obtained from distributors (except for Victoria – see below), and exclusive of gas losses (UAFG).
- Aggregated for each region, exclusive of UAFG.
- Available for 5–15 years.

Victorian data is sourced from AEMO’s settlements database.

Historical month end total Tariff V customer numbers are available for each region for four to 10 years. However, the data is not broken down by residential and small commercial categories.

**Victoria Declared Transmission System (DTS) Tariff V meter data (bi-monthly bill consumption)**

Most Tariff V customers in Victoria are billed bi-monthly. Bi-monthly meter data is only available for Victorian second-tier customers[48] for 2005–14.

**Forecast Number of Connections**

See section 5.2 for details.

**Weather Data**

Tariff V consumption (except in Queensland) is highly sensitive to weather conditions. In Victoria, Tariff V annual consumption can vary by 10 PJ or more between years, due to different weather conditions in those years.

See Appendix Bfor more detail on weather correction methodology.

**Other input data**

Sections 5.2 and Appendix B give detail on input data for residential and commercial consumption related to number of connections and weather.

Price data is an input for multiple sectors, and is detailed in Appendix A.

Other key input data included:

- Historical residential gas price indices from ABS.
- Forecast residential gas tariffs.

### 5.3.2 Analyse average annual consumption per Tariff V connection

The objectives of this step were to:

- Analyse the historical trend in Tariff V annual heating and non-heating consumption per connection. Annual heating consumption was normalised to the pre-defined weather standard, to enable accurate assessment of the underlying change (growth) in Tariff V annual consumption not associated with annual weather variations.
- Determine the weather-normalised Tariff V annual consumption for 2015, the base year of the forecasts.

In this paper, non-heating consumption is sometimes referred to as base load or hot water load (implicitly including small cooking consumption).

The following regression model was fitted to Tariff V monthly demand:

$$Y_{i,t} = c_{1,i} + c_{2,i} * edd_{i,t}$$

Where

$Y_{i,t}$ = average consumption/Tariff V connection/day for month (t), t = 1,2,..,12 and iteration i.

$edd_{i,t}$ = average daily EDD month (t), t = 1, 2, …12 and for iteration i.

$c_{1,i}$ = intercept of the model to estimate the average daily base load/connection for iteration i.

$c_{2,i}$ = Coefficient of the slope to estimate heating load/connection/EDD for iteration i.

[48] Customers who are not supplied by an assigned host retailer in the relevant supply area.

The above regression model was applied to each selected rolling 12 month period (t = 1,2,..,12) and was repeated on a rolling monthly basis (iteration i=1,2,.., n).

AEMO used the model coefficients of each iterative regression model to estimate, for each iteration i:

- The annual base load/Tariff V connection (= c1,i * 365 days).
- The annual weather-normalised heating/Tariff V connection (= c2,i * 1,304 EDD).

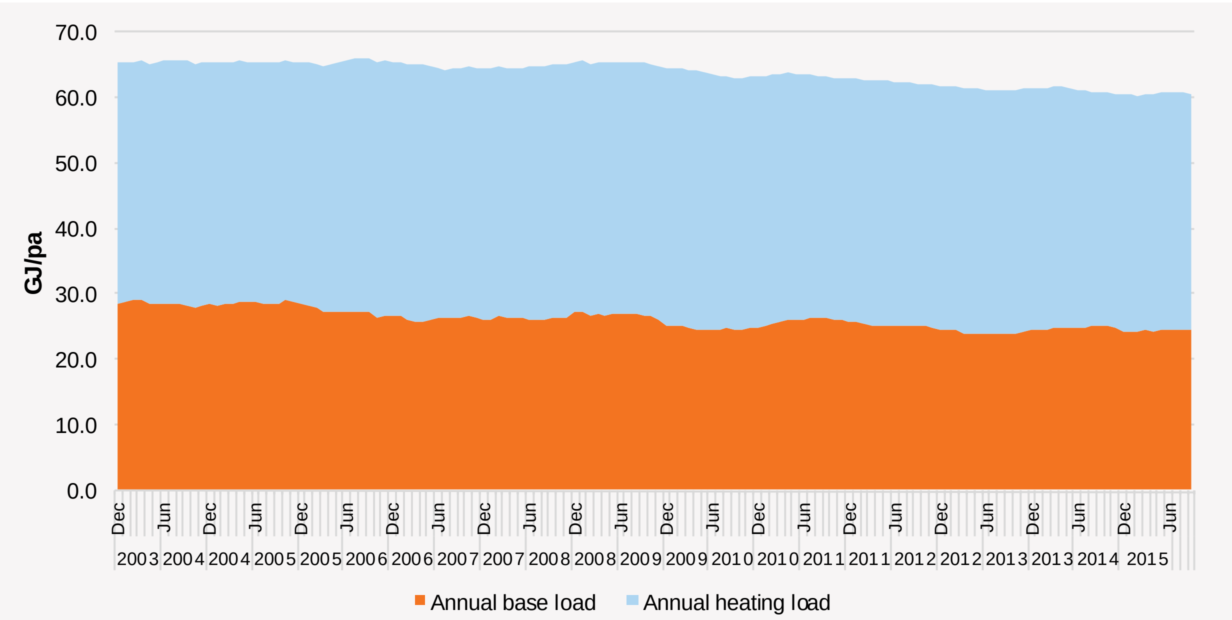
The results are summarised in the following table, and show that:

- Average annual consumption per Tariff V connection has fallen from 65.3 GJ in 2003 to 60.6 GJ at 0.6% pa since 2003, and more in base load then heating load.
- Between 2005–10:
  - Tariff V heating load increased by 4%, driven by increased penetration of central heaters.
  - Tariff V base load decreased by 13%, due to the prolonged drought in 2006-07 and the subsequent introduction of water conservation measures reducing water consumption.
- Between 2010–15:
  - Tariff V heating consumption fell by 5% as a result of the Commonwealth Government's home insulation initiative.
  - Tariff V base load continued to fall at a slower rate.

**Table 9 5 to 10 Years Historical Growth in Residential Heating and Non-Heating Load**

| Period | Heating load | Base load | Total |
|---|---|---|---|
| 2005–10 | 4% | -13% | -3% |
| 2010–15 | -5% | -2% | -4% |
| 2005–15 | -2% | -15% | -7% |

**Figure 4 Rolling 12 Month Average Annual Consumption per Tariff V Customer**



### 5.3.3 Analyse residential customer appliance annual consumption

The objectives of this step were to:

- Analyse average annual consumption of gas cooker, hot water and heater in residential new and existing homes, using Tariff V customer (basic meter) bill information stored in AEMO's retail database.
- Determine the trend in historical appliance annual consumption, to use for forecasting residential consumption.

AEMO's retail database contains retail customers' billed consumption for over 1 million second-tier small Tariff V customers 2006–14 (customers who have changed retailers at least once).

For each year, AEMO analysed each individual second-tier gas customer's bi-monthly billed consumption (5–6 bills a year) against weather (sum of daily EDD over the billing period).

The regression model structure was:

$$Y_{i,j,k} = c1_{j,k} + c2_{j,k} * edd_{i,j.}$$

$Y_{i,j,k}$ = average daily consumption for billing period i, year j and customer k.

$edd_{i,j}$ = average daily EDD for billing period i and year j.

$c1_{j,k}$ = average daily base load for year j and customer k.

$c2_{j,k}$ = average daily heating load/EDD for year j and customer k.

i = 1, 2…6 if 6 bills.

j = 2004, 2005…2014.

AEMO used the relevant regression parameters to calculate for each customer k and each year j their annual base load and heating load (= $c1_{j,k}$ * 365 + $c2_{j,k}$ * 1,304 EDD).

### 5.3.4 Estimate average appliance consumption by postcode, existing and new homes and suburb types

Customers can be grouped by geographical locations (postcodes), type of suburbs (inner, middle, outer and regional), and existing and new homes. New homes are second-tier greenfield sites connected to the DTS since 2004.

The analysis excluded small Tariff V commercial and industrial customers with annual consumption above the critical thresholds.[49]

Historical appliance consumption statistics (average, median and standard deviation) can be derived from the distribution of customer appliance consumption distributions.

The charts below compare historical average annual base load and heating load (weather-normalised) for existing homes and new homes 2005–2013 and by suburb type.

**Inner suburbs**: postcodes within 10 km of Melbourne CBD.

**Middle suburbs**: postcodes between 10 km and 20 km of Melbourne CBD.

**Outer suburbs**: postcodes between 20 km and 50 km of Melbourne CBD.

**Regional suburbs**: All other postcodes in Victoria.

[49] Annual consumption threshold is 50GJ pa for base load and 100GJ for heating load.

**Figure 5 Average annual consumption in existing residential home**

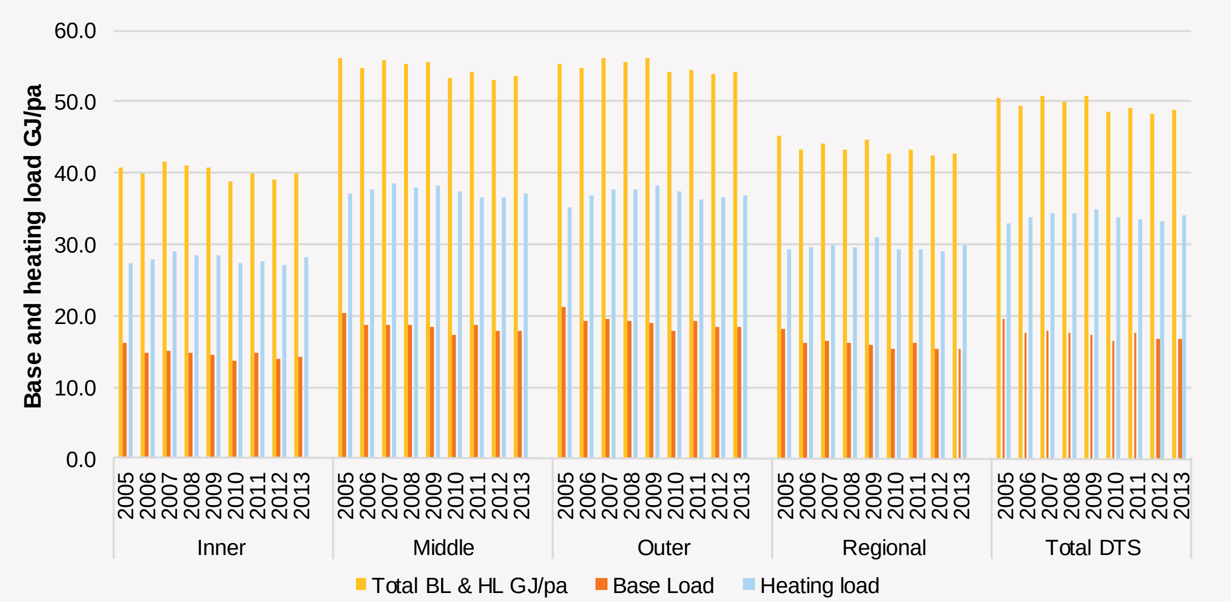
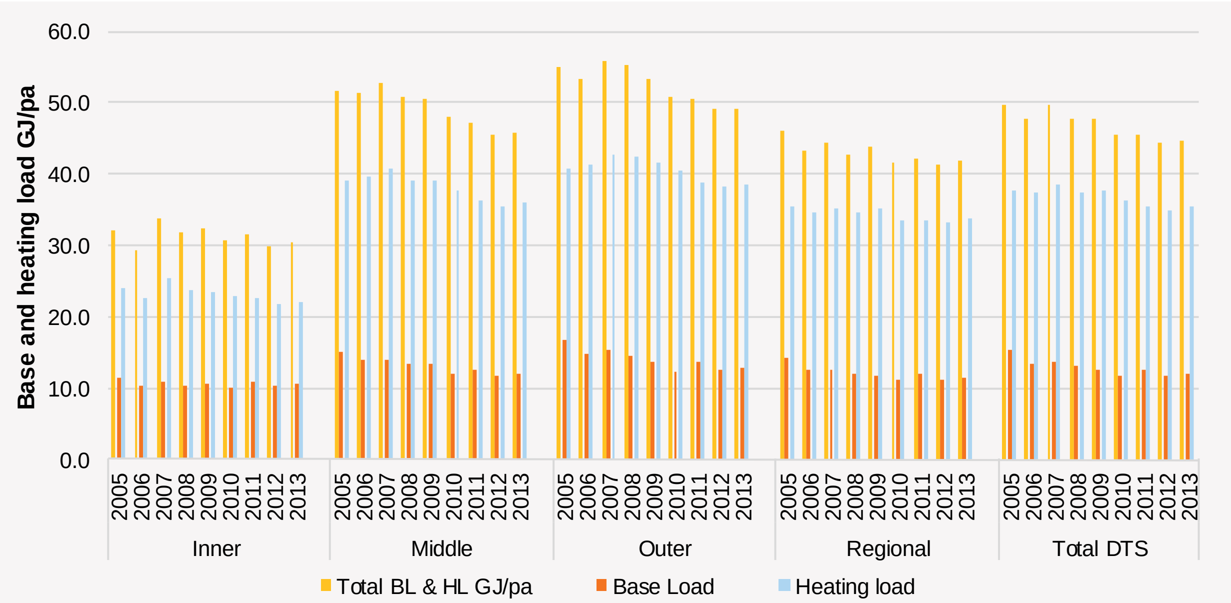



**Figure 6 Average annual consumption in new residential home**




The results of the analysis are summarised below.

Hot water consumption (base load) has been falling across the DTS since 2005, more rapidly in new homes than existing homes driven by mandatory installation of solar hot water heaters in 5 and 6 star new homes. The decline was steeper between 2005–08 driven by consumers' changing water usage behaviours in response to water consumption conservation measures (for example, water-efficient shower heads) at that time.

Over the period 2005–13, hot water consumption in existing homes was 25% lower than in new homes.

Heating consumption increased during 2005–08 (in new homes) and 2010 (in existing homes) driven by increased penetration of central heaters. Annual heating consumption has been falling since that time, due to better home insulation (the Commonwealth Government pink batt scheme).

Over the period 2005–13, heating consumption in new homes was about 9% higher compared to existing homes, despite mandatory 5 and 6 star building shells. This was due to the increased building size in new homes and building design in favour of full length glass windows, offsetting potential energy savings from improved home insultation.

Comparing hot water and heating consumption by geographical locations, inner suburbs had the lowest annual hot water and heating consumption in both new and existing homes, because of smaller house sizes in these suburbs. Over the period 2005–13, hot water and heating consumption in new homes in innner suburbs was 18% and 40% lower respectively, compared to the Victorian DTS average.

By contrast, existing and new homes in outer suburbs had the highest hot water and heating consumption of all suburbs (10% higher than the Victorian DTS average), due to the larger home sizes. These suburbs also showed the fastest rate of decline in appliance consumption.

### 5.3.5 Analyse impact of gas price and energy efficiency on hot water and heating consumption

The objectives of this analysis were to:

- Analyse the impact of gas price and energy efficiency of historical hot water and heater consumption in existing and new homes.
- Use the model results to forecast the impact of these drivers on future residential appliance consumption.

The analysis was conducted separately for existing and new homes.

To overcome the problem of insufficient historical data, the analysis used pooled appliance consumption data to include inner, middle, outer, regional suburbs and total DTS.

A log linear model was fitted to both historical median and average hot water and heating consumption obtained from the analysis of estimating average appliance consumption by postcode, existing and new homes and suburb types. In general, more robust regression results are obtained from models using the median values of appliance consumption distributions.

#### Hot water annual consumption model

$$\mathrm{Ln}\,(Y_{HW,i,j}) = c_{1,HW} + c_{2,HW} * \ln(P_{i-1}) + c_{3,HW} * \ln(T_{HW,i}) + c_{4,HW} * I_{HW,i} + c_{5,HW} * M_{HW,i} + c_{6,HW} * O_{HW,i} + c_{7,HW} * R_{HW,i}$$

$Y_{HW,i,j}$ = hot water average (or median) annual consumption for year i, suburb type j (j=1 for total DTS, 2 for inner suburbs, 3 for middle suburbs, 4 for outer suburbs, 5 for regional suburbs).

$P_{i-1}$ = 1 year lagged load-weighted price for year i.

$T_{HW,i}$ = time trend for year i (= 1, 2, …,10 1=2005 and 9 = 2013) was used to model trend in penetration of high energy efficiency rating hot water heaters.

$I_{HW,i}$ = dummy variable for inner suburb for year i (= 1 if inner suburbs, = 0 otherwise).

$M_{HW,i}$ = dummy variable for middle suburbs for year i (= 1 if middle suburbs, = 0 otherwise).

$O_{HW,i}$ = dummy variable for outer suburbs for year i (= 1 if outer suburbs, = 0 otherwise).

$R_{HW,i}$ = dummy variable for regional suburbs for year i (= 1 if regional suburbs, = 0 otherwise).

$c_{1,HW}$ = average annual hot water load for total DTS (not impacted by gas price and energy efficiency).

$c_{2,HW}$ = Price elasticity for hot water consumption.

$c_{3,HW}$ = hot water consumption energy efficiency elasticity.

$c_{4,HW}$ = change to inner suburb average annual base load relative to DTS average.

$c_{5,HW}$ = change to middle suburb average annual base load relative to DTS average.

$c_{6,HW}$ = change to outer suburb average annual base load relative to DTS average.

$c_{7,\,HW}$ = change to regional suburb average annual base load relative to DTS average.

The model coefficients presented in the following tables relate to models using the median values of the relevant appliance consumption distributions.

**Table 10 Model Parameters for Annual Hot Water Gas Consumption**

| | | Intercept | Price | Time trend | Inner | Middle | Outer | Regional | R-Square |
|---|---|---|---|---|---|---|---|---|---|
| | | $c_{1,\,HW}$ | $c_{2,\,HW}$ | $c_{3,\,HW}$ | $c_{4,\,HW}$ | $c_{5,\,HW}$ | $c_{6,\,HW}$ | $c_{7,\,HW}$ | |
| Existing homes | Coefficient | 0.200 | -0.066 | -0.034 | -0.204 | 0.068 | 0.096 | -0.109 | 97% |
| | Standard error | 0.319 | 0.076 | 0.017 | 0.012 | 0.012 | 0.012 | 0.012 | |
| New homes | Coefficient | 0.631 | -0.162 | -0.085 | -0.260 | 0.030 | 0.109 | -0.095 | 92% |
| | Standard error | 0.610 | 0.145 | 0.033 | 0.023 | 0.023 | 0.023 | 0.023 | |

## Heater annual consumption model

$$\ln(Y_{HT,i,j}) = c_{1,\,HT} + c_{2,\,HT} * \ln(P_{i-1}) + c_{3,\,HT} * \ln(T_{1\,HT,i}) + c_{4,\,HT} * \ln(T_{2\,HT,i}) + c_{5,\,HT} * I_{HT,i} + c_{6,\,HT} * M_{HT,i} + c_{7,\,HT} * O_{HT,i} + c_{8,\,HT} * R_{HT,i}$$

$Y_{HT,i,j}$ = average (or median) annual heating consumption for year i, suburb type j.

$P_{i-1}$ = 1 year lagged load weighted price for year i (based on ABS residential price indices).

$T_{1\,HT,i}$ = Time trend for year i (= 1, 2,3 1 for 2011). This variable was used to model the observed decreasing trend in average gas heating consumption since 2011.

$T_{2\,HT,i}$ = Time trend for year i (= 1, 2, …6, 1 for 2005 and 6 for all years from 2010). This variable was used to model the increase in average annual heating consumption in this period driven by increased penetration of gas central heaters.

$I_{HT,i}$ = dummy variable for inner suburbs for year i (= 1 if inner suburbs, = 0 otherwise).

$M_{HT,i}$ = dummy variable for middle suburbs for year i (= 1 if middle suburbs, = 0 otherwise).

$O_{HT,i}$ = dummy variable for outer suburbs for year i (= 1 if outer suburbs, = 0 otherwise).

$R_{HT,i}$ = dummy variable for regional suburbs for year i (= 1 if regional suburbs, = 0 otherwise).

$c_{1,\,HT}$ = average annual heating load for total DTS (not impacted by gas price and energy efficiency).

$c_{2,\,HT}$ = Price elasticity for heating consumption.

$c_{3,\,HT}$ = energy savings elasticity post 2010.

$c_{4,\,HT}$ = annual % increase in annual gas heating consumption before 2010.

$c_{5,\,HT}$ = change to inner suburb average annual base load relative to DTS average.

$c_{6,\,HT}$ = change to middle suburb average annual base load relative to DTS average.

$c_{7,\,HT}$ = change to outer suburb average annual base load relative to DTS average.

$c_{8,\,HT}$ = change to regional suburb average annual base load relative to DTS average.

The model coefficients presented in the following tables relate to models using the median values of the relevant appliance consumption distributions.

**Table 11 Model Parameters for Annual Heating Consumption**

| | | Intercept | Price | Time trend | Time trend 2 | Inner | Middle | Outer | Regional | R-Square |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $c_{1,\,HT}$ | $c_{2,\,HT}$ | $c_{3,\,HT}$ | $c_{4,\,HT}$ | $c_{5,\,HT}$ | $c_{6,\,HT}$ | $c_{7,\,HT}$ | $c_{8,\,HT}$ | |
| | Coefficient | 0.89 | -0.20 | -0.004 | 0.04 | -0.35 | 0.15 | 0.13 | -0.18 | 99% |

| | | Intercept | Price | Time trend | Time trend 2 | Inner | Middle | Outer | Regional | R-Square |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $C_{1, HT}$ | $C_{2, HT}$ | $C_{3, HT}$ | $C_{4, HT}$ | $C_{5, HT}$ | $C_{6, HT}$ | $C_{7, HT}$ | $C_{8, HT}$ | |
| Existing homes | Standard error | 0.49 | 0.11 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | |
| New homes | Coefficient | 1.47 | -0.33 | -0.07 | 0.04 | -1.24 | 0.04 | 0.11 | -0.09 | 99% |
| | Standard error | 1.37 | 0.31 | 0.05 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | |

### 5.3.6 Forecast impact of fuel switching

Impact of fuel switching was estimated based on the following assumptions:

Hot water consumption:

- Existing home gas hot water units were assumed be replaced within the next 10 years with solar hot water units or heat pumps, reducing the forecast difference between existing and new home average annual hot water consumption by 80% within the next 10 years.[50] A quadratic model was used to model the load reduction. In the absence of new energy policies from both the Commonwealth and State governments, the impact of fuel switching was forecast to plateau after the initial period.
- Fuel switching in new homes was assumed to be driven by a slow rate of change over of existing gas hot water units to electric appliances driven by a forecast 2% decline of gas hot water penetration over 2015–35.

Heating consumption:

- Heating units in existing homes was assumed be replaced within the next 20 years by with either smaller gas space heaters, or smaller gas space heater units combined with reverse cycle air conditioners (RCAC), or RCAC only.[51] This is modelled to reduce the forecast difference between existing and new home average annual gas heating consumption by 50% in the next 20 years.
- It was also assumed that 40% of the forecast reduced gas heating consumption in existing homes is due to improved building shell fabric (5 star or 6 star building shell upgrades). As such, an estimated load reduction was reallocated from fuel switching impact to energy efficiency impact. In the absence of new energy policies from both the Commonwealth and State governnents, the impact of fuel switching was forecast to plateau after the initial period.
- Fuel switching for new home heating appliances was assumed to be insignificant.

### 5.3.7 Forecast total load reduction per existing and new residential connection

Forecast total load reduction per existing and new connection for each year is the sum of the load reductions due to the impact of forecast gas prices, energy efficiency savings and fuel switching. These are denoted as $R_{E,i}$ and $R_{N,i}$ for existing homes E and new homes N for year i.

### 5.3.8 Forecast total annual residential load reduction

Using the results from the analysis described above in "Forecast total load reduction per existing and new residential connection", AEMO forecast total reduction in Tariff V base (hot water) and heating load.

$$R_{HW,i} = R_{E,Hw,i} * E + R_{N,HW,i} * N_{i.}$$

$$R_{HT,i} = R_{E,HT,i} * E + R_{N,HT,i} * N_{i.}$$

[50] The average life of a gas hot water unit is between eight and 12 years.
[51] The average life of a gas heating unit is between 18 and 22 years.

$R_{HW,i}$ and $R_{HT,i}$ refer to total DTS annual hot water and heating load reduction for forecast year i respectively.

$R_{E,HW,i}$ and $R_{E,HT,i}$ refer to forecast hot water and heating load reduction per connection for existing homes E and new homes N in year i.

$R_{N,HW,i}$ and $R_{N,,HT,i}$ refer to forecast hot water and heating load reduction per connection for new homes E and new homes in year i.

E = Stock of existing homes.

$N_i$ = forecast total new connections in year i since 2004.

### 5.3.9 Forecast total Tariff V annual consumption

Forecast total Tariff V annual consumption for each year i was derived by subtracting the forecast total load reduction for that year from the estimated actual 2015 Tariff V annual demand $D_{v,2015}$.

$F_{v,HW,i} = D_{v,HW,2015} - R_{HW,i}$.

$F_{v,HT,i} = D_{v,HT,2015} - R_{HT,i}$.

## 5.4 Forecast Annual Consumption Methodology – New South Wales, South Australia and Queensland

Forecasting Tariff V annual consumption for the above regions made use of the modelling results of the analysis of Victorian meter data and analysis of historical tariff V annual consumption per connection in that region. The methodology is summarised in the following steps.

### 5.4.1 Analyse average regional annual consumption per Tariff V connection

Tariff V daily demand is only available for 2010−14. Regression analysis of historical daily demand (winter May-Sep) 2010−14 was conducted to determine annual base load and weather-normalised heating load per Tariff V connection for each region.

The model structure used is:

$$Y_{i,j,k} = c_{1,j,k} + c_{2,j,k} * HDD_{i,j,k} + c_{3,j,k} * Sat_k + c_{4,j,k} * Sun_k$$

$Y_{i,j,k}$ = Tariff V weekday consumption for day i and year j.

$HDD_{i,j,k}$ = daily HDD for day i and year j.

$Sat_k$ = Saturday dummy variable (=1 if Saturday and 0 otherwise) for region k.

$Sun_k$ = Sunday dummy variable (=1 if Sunday and 0 otherwise) for region k.

$c_{1,j,k}$ = average daily base load for year j and region k.

$c_{2,j,k}$ = average daily heating load/HDD for year j (= 2000, …2014) and region k.

$c_{3,j,k}$ estimates the load decrease on Saturday relative to winter weekdays Mondays-Fridays for year j and region k.

$c_{4,j,k}$ estimates the load decrease on Sunday relative to winter weekdays Mondays-Thursdays for year j and region k.

### 5.4.2 Estimate 2015 Tariff V annual consumption

Tariff V annual consumption for 2015 was estimated using 2014 model parameters and the estimated total Tariff V connections and the regional weather standards in the following table.

**Table 12 Model parameters for 2014**

| | Intercept | HDD | Sat | Sun | RSquare |
|---|---|---|---|---|---|
| | $c_{1,j,k}$ | $c_{2,j,k}$ | $c_{3,j,k}$ | $c_{4,j,k}$ | |
| New South Wales | 63.6 | 6.2 | -10.5 | -11.9 | 95% |
| | 1.4 | 0.1 | 1.5 | 1.5 | |
| Queensland | 78.1 | 8.8 | -13.0 | -12.0 | 58% |
| | 0.8 | 0.4 | 1.7 | 1.7 | |
| South Australia | 37.5 | 6.1 | -3.5 | -6.4 | 94% |
| | 1.4 | 0.1 | 1.5 | 1.5 | |

### 5.4.3 Forecast impact of gas price, energy efficiency and fuel switching

For each region, forecast impact of gas prices on appliance consumption was determined using the relevant regional forecast prices and Victorian price elasticity.

Forecast impact of energy efficiency on hot water and heater consumption in each region required existing and new home appliance average annual consumption for the base year 2015 This information was not available and had to be derived from:

- Each region's average annual base load and heating load per Tariff V connection for 2015.
- Assuming that the relationship between average annual base load and heating load per Tariff V connection and per residential existing and new home connection in Victoria also applied to other regions. Due to limited historical connection information, all connections since 2010 were defined as new homes.

The derived existing and new home appliance average annual consumption for each of this reqgion was then used to forecast the impact of energy efficiency and fuel switching on each region's residential appliance consumption in the same manner as for Victoria described in Section 5.5 above.

Forecasting fuel switching followed the same approach as for Victoria.

## 5.5 Forecast Annual Consumption Methodology – Tasmania

The Tasmanian gas network began operation in 2004, and subsequent residential and commercial consumption growth reflects the progressive connection of existing houses to the network.

The model used in the 2015 NGFR is largely unchanged from the 2014 NGFR. The main differences are:

- The number of connections has been estimated from basic building forecasts, as described in Section 5.3.
- The total number of connections was split into a residential and commercial component based on the observed historical values. Figure 15 shows the fraction of connections associated to residential customers, and highlights that this fraction is relatively stable over the past four years. For the forecast, AEMO used a constant split fraction equal to the value reported in 2014 (0.933).
- The average consumption per connection has been updated to the values of 29.9 GJ per annum (residential connections) and 458.0 GJ[52] per annum (commercial connections). Figure 16 and Figure 17 show the historical annual average consumption for the two categories of connections.

52 Following the 2014 NGFR methodology, the average consumption per commercial connection has been calculated over the period 2011–14.

Figure 7 Fraction of residential connections

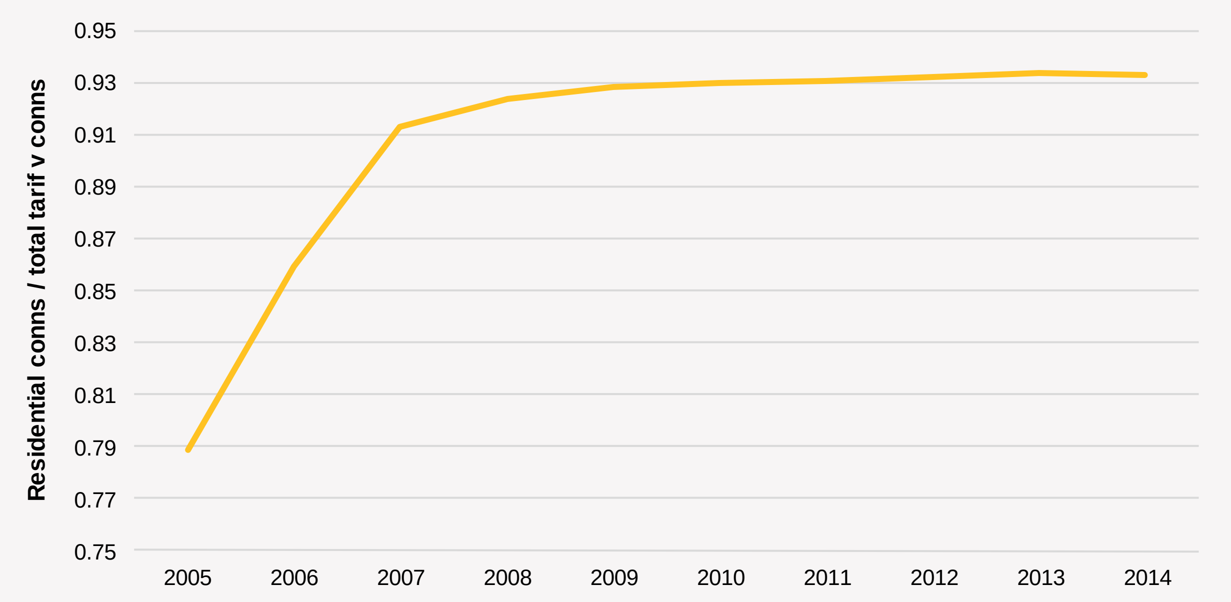



Figure 8 Average annual residential consumption

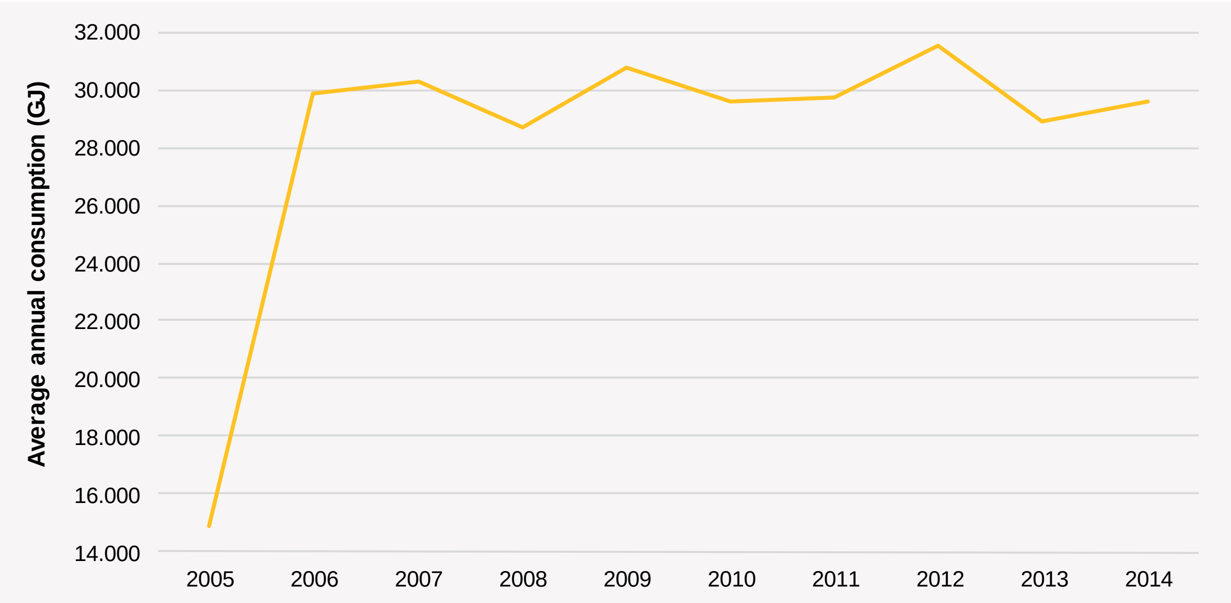
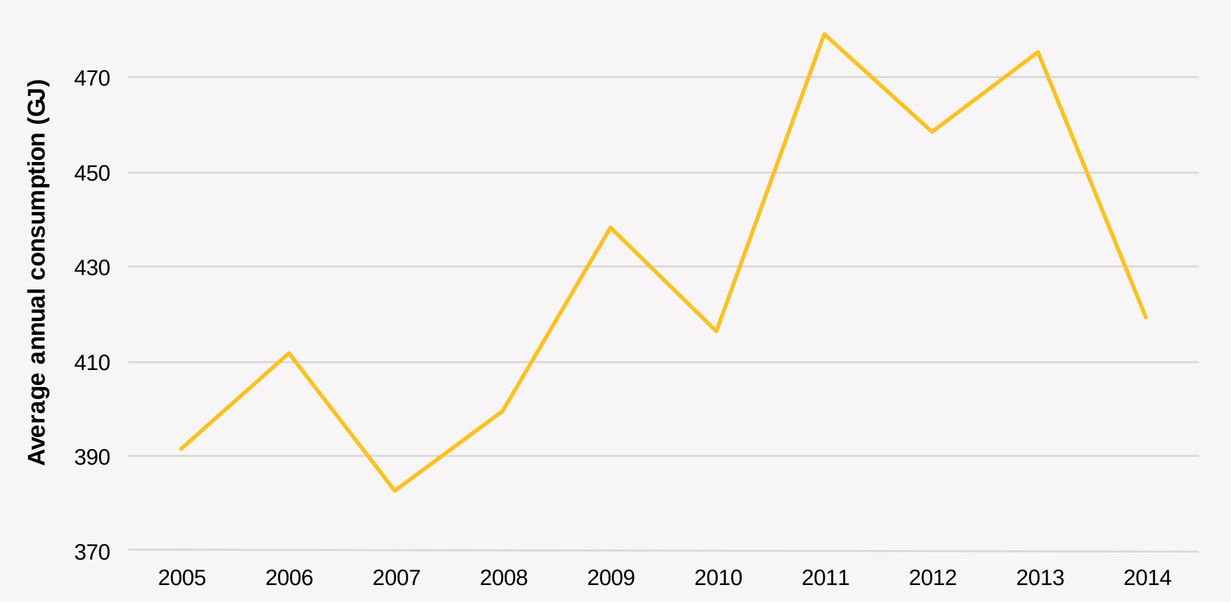


**Figure 9 Average annual commercial consumption**




The price elasticity has been left unchanged to −0.2 for both residential and commercial. The average consumption was forecast according to the following relationship:

$$AFC = AHC * \left(\frac{Price\ Forecast}{RefPrice}\right)^{-0.2}$$

where AFC indicates the average forecast consumption and AHC is the average historical consumption. The total Tariff V consumption was then calculated as the sum of the total residential and commercial forecast consumption:

$$Tariff\ V\ forecast = AFC_{Res} * \ Connections_{Res} + \ AFC_{Comm} * \ Connections_{Comm}$$

# CHAPTER 6. MAXIMUM DEMAND

This chapter outlines the methodology used to develop forecasts of maximum daily demand for each year in the 20-year forecast horizon.

AEMO has updated its forecasting methodology for the 2015 NGFR to better account for long-run weather trends, appliance-based influences on demand and to provide more detailed information on fuel switching, energy efficiency and price response. Winter maximum demand models are aligned with the new annual consumption models.

Forecasts of daily maximum demand are used to assess the adequacy of infrastructure supply capacity, as well as to inform commercial and operational decisions that are dependent on the potential consumption range of demand over time. Variations in domestic gas consumption are mostly driven by heating demand and GPG. For all states except Queensland, this means maximum daily demand occurs during the winter heating season.

In Queensland, due to climate factors, maximum demand normally occurs during the summer. However with the commencement of LNG exports, it is expected that from 2015 in Queensland, maximum demand will occur during winter. AEMO assumes liquefaction processing efficiency is lower in winter, introducing seasonality in gas usage for liquefaction, and a consequentially a winter peak.

Forecasts of maximum daily demand for each region are estimated as the sum of the following:

1. Residential, commercial and industrial maximum demand on day of system peak.
2. GPG on day of system peak.
3. LNG on day of system peak.

## Phase 1: Tune daily models for the most recent winter heating season

Short term econometric forecasting models were developed for Tariff V (residential and commercial) and Tariff D (industrial) gas consumption using daily data. The models:

- Captured current customer behaviour, including the current appliance mix of households and operational practices of industry.
- Excluded the longer-term effects of price response, energy efficiency trends and fuel switching trends. These effects were added back in phase 3.

Since gas consumption is winter peaking, the short-term models were developed for the winter heating period.[53] The most recent year of data available was used to develop the model parameters, to capture the most current heating trends and consumer behaviour.[54]

The formulation of the models is shown below. The process separately treated the heating and non-heating components of the respective Tariff V and D models. This recognises that, on a peak day, the heating component is comparatively larger as a proportion of total consumption than in the annual consumption forecast. This method also enabled separate heating and non-heating adjustments for fuel switching and energy efficiency, again, having different proportions on a peak day compared to an annual period.

[53] AEMO defines the winter heating period as 1 May to 30 September in all states except for Victoria. In Victoria the heating period is defined as 1 April to 30 September. For 2015 NGFR, the most recent dataset available was for 2015 in VIC and 2014 in all other states.

[54] Residential, commercial and industrial gas consumption values are exclusive of losses. For industrial consumption in Victoria, the load has been adjusted for anticipated industrial reductions.

### Residential and commercial model (Tariff V)

$$Tariff\ V\ Consumption = f(HDD/EDD, Month\_Dummy, Saturday\_Dummy, Sunday\_Dummy, Trend\ Variable)$$

**Table 13 State Specific Residential and Commercial Model (Tariff V)**

| Region | Econometric Model |
|---|---|
| New South Wales | $TV\ per\ connection = \beta_0 + \beta_1 HDD + \beta_2 May + \beta_3 Sat + \beta_4 Sun + \beta_5 Trend\ Variable$ |
| Queensland | $TV\ per\ connection = \beta_0 + \beta_1 HDD + \beta_2 Jul + \beta_3 Sat + \beta_4 Sun + \beta_5 Trend\ Variable$ |
| Victoria | $TV\ per\ connection = \beta_0 + \beta_1 EDD + \beta_2 Apr + \beta_3 Sep + \beta_4 Sat + \beta_5 Sun + \beta_6 Trend\ Variable$ |
| South Australia | $TV\ per\ connection = \beta_0 + \beta_1 HDD + \beta_2 Sat + \beta_3 Sun + \beta_4 Trend\ Variable$ |

The trend variables for each region (shown below) captured seasonality in consumption in the regions that use the HDD weather variable. It captured some non-linearity in consumption due to weather.

| Region | Trend Variable |
|---|---|
| New South Wales | $Trend\ Variable = -0.002 * (trend_{num})sqr + 0.264 * (trend_{num}) - 6.1849$ |
| Queensland | $Trend\ Variable = -0.0016 * (trend_{num})sqr + 0.2098 * (trend_{num}) - 4.9908$ |
| South Australia | $Trend\ Variable = -0.005 * (trend_{num})sqr + 0.6671 * (trend_{num}) - 15.64$ |
| | Where $(trend_{num})$ =Calendar year day number minus 120, calculated for each gas day that has a calendar year day number >120, measured during the modelled heating season (so on 1 May 2014:$(trend_{num}) = 1$). |

### Industrial model (Tariff D)

$$Tariff\ D\ Consumption = f(HDD/EDD, Month\_Dummy, Monday\_Dummy, Friday\_Dummy, Saturday\_Dummy, Sunday\_Dummy,)$$

**Table 14 State Specific Industrial Model (Tariff D)**

| Region | Econometric Model |
|---|---|
| New South Wales | $TD = \beta_0 + \beta_1 HDD + \beta_2 Aug + \beta_3 Mon + \beta_4 Fri + \beta_5 Sat + \beta_6 Sun$ |
| Queensland | $TD = \beta_0 + \beta_1 HDD + \beta_2 May + \beta_3 Sep + \beta_4 Fri + \beta_5 Sat + \beta_6 Sun$ |
| Victoria | $TD = \beta_0 + \beta_1 EDD + \beta_2 Apr + \beta_3 Sep + \beta_4 Mon + \beta_5 Fri + \beta_6 Sat + \beta_7 Sun$ |
| South Australia | $TD = \beta_0 + \beta_1 HDD + \beta_2 Fri + \beta_3 Sat + \beta_4 Sun$ |

**Table 15 Residential and commercial model (Tariff V)**

| Variables | NSW_Model | QLD_Model | SA_Model | VIC_Model |
|---|---|---|---|---|
| Constant | 88.34 | 95.92 | 61.12 | 0.12 |
| HDD/EDD | 8.71 | 2.15 | 7.25 | 0.02 |
| May | -6.44 | - | - | - |
| Apr | - | - | - | -0.03 |
| Jul | - | 7.59 | - | - |
| Sep | - | - | - | -0.03 |
| Sat | -9.59 | -17.54 | -4.64 | -0.01 |
| Sun | -10.27 | -15.73 | -10.23 | -0.02 |
| Trend Variable | 1.74 | 1.48 | 1.23 | - |

**Table 16 Industrial model (Tariff D)**

| Variables | NSW_Model | QLD_Model | SA_Model | VIC_Model |
|---|---|---|---|---|
| Constant | 188.59 | 303.13 | 76.15 | 225.63 |
| HDD/EDD | 0.90 | 2.47 | 0.38 | 2.94 |
| May | - | -10.03 | - | - |
| Apr | - | - | - | -14.22 |
| Aug | 6.51 | - | - | - |
| Sep | - | -11.95 | - | -11.90 |
| Mon | -5.79 | - | - | -5.65 |
| Fri | -12.24 | -6.08 | -2.50 | -19.54 |
| Sat | -44.27 | -13.97 | -11.47 | -61.14 |
| Sun | -45.03 | -14.14 | -12.82 | -60.56 |

### Phase 2: Determine base-year residential, commercial and industrial maximum demand

The estimated maximum demand in 2015 for both Tariff V and D was modelled by means of a simulation of the weather conditions, based on historical data. The maximum demand in 2015 was then used as base year for a subsequent forecast.

The daily EDD/HDD values were calculated for all days between 1 January 1980 and 30 September 2015. For dates before 1 January 2000, the EDD/HDD was adjusted to take into account structural changes in the climate data. In place of the actual EDD/HDD, a climate-normalised factor was used with the following formulation:

$$EDD/HDD_d = EDD/HDD_{Actual} * \frac{POE50\ forecast\ annual\ EDD/HDD}{Total\ annual\ EDD/HDD}$$

The POE50 forecast annual EDD/HDD is provided below. Total annual EDD/HDD refers to the 365-day sum of actual daily EDD/HDD, summed to September 30 each year.

In the simulation process, the EDD/HDD for a given day was randomly drawn from the pool of historical values covering the period 1 January 1980 to 30 September 2015. Approximately one million random days were drawn. The randomly drawn data was then passed into the short term Tariff V and Tariff D models, as described in Phase 1.

From each simulated heating season (1980 to 2015), the maximum daily demand for Tariff V and D was recorded. The 50% POE was calculated taking the median of the statistical distribution of the simulated maximum demands. In a similar fashion, the 5% POE was computed by identifying the 5% quantile of the simulated distribution.

For all regions except Victoria, the parameters of the model were estimated using the 2014 data. The estimated maximum demand for Tariff D in 2015 was obtained by further adjusting the 50% and 5% POE for large load adjustments between 2014 and 2015. As described in Phase 1, the Tariff V model computed the average demand per connection. In order to obtain the total maximum demand for the base year, the average maximum demand was multiplied by the forecast number of Tariff V connections in 2015.

## Phase 3: Determine residential, commercial and industrial MD for the forecast horizon

Annual consumption forecasts were used with the base year maximum demand forecast as the means for determining the maximum demand forecast. The growth rates of the heat and non-heat sensitive components were evaluated independently in the annual consumption forecast and applied to the base-year values of the maximum demand. This approach adjusts for the higher proportion of heating demand on a peak day, and therefore also enabled a more accurate forecast of energy efficiency and fuel-switching.

### Residential and commercial

(1) $$Heating\ Load = (POE50\ \ or\ POE5\ of\ Avg\ Tariff\ V\ Heating\ MD\ in\ 2015) * (No.of\ conns\ in\ 2015) * \frac{Ann.\ Heating\ Load(forecast)}{Ann.\ Heating\ Load\ 2015}$$

(2) $$NonHeating\ Load = (Avg\ Tariff\ V\ NonHeating\ MD\ in\ 2015) * (No.of\ conns\ in\ 2015) * \frac{Ann.\ NonHeating\ Load\ (forecast)}{Ann.\ NonHeating\ Load\ 2015}$$

### Industrial

(3) $$Heating\ Load = (POE50\ or\ POE5\ of\ Avg\ Tariff\ D\ Heating\ MD\ in\ 2015) * (No.of\ conns\ in\ 2015) * \frac{Ann.\ Heating\ Load\ (forecast)}{Ann.\ Heating\ Load\ 2015}$$

(4) $$NonHeating\ Load = (Avg\ Tariff\ D\ NonHeating\ MD\ in\ 2015) * (No.of\ conns\ in\ 2015) * \frac{Ann.\ NonHeating\ Load\ (forecast)}{Ann.\ NonHeating\ Load\ 2015}$$

The overall Tariff V and D forecast maximum demands were computed by summing together the heating and non-heating components.

## Phase 4: Determine system peak forecast for all sectors

To obtain the system peak forecast for all sectors, AEMO aggregated the maximum demand for the residential, commercial and industrial sectors (obtained in Phase 3) with LNG maximum demand[55] and an estimated average GPG.[56] The reasoning for using an average GPG is because the system peak normally occurs on a cold winter day, and that is typically otherwise unexceptional for GPG.

GPG maximum demand data and methodology is outlined in Chapter 3.

[55] This is assumed to be the LNG maximum demand estimate for July in Queensland.
[56] This is the 50% POE maximum demand winter average GPG consumption for Monday to Thursday over the winter period.

# APPENDIX A. GAS RETAIL PRICING

Price data was a key input in forecast models across multiple sectors.

The gas retail price projections used in the 2015 NGFR are bottom up projections based on separate projections of the various components of retail prices. Separate prices have been prepared for four markets (residential, business, small industrial and large industrial) in four states (New South Wales, Victoria, South Australia and Queensland). The prices are intended to represent those paid by the average or typical user in each market, located in a distribution zone in the capital city.

## A.1 Price components

Gas retail prices typically include the wholesale market price, peak gas supply cost, transmission cost, distribution cost, retail cost of service, retail margin and cost of carbon-equivalent emissions.

### A.1.1 Wholesale market price (baseload gas supply)

Wholesale market price projections were prepared by CORE Energy Group. The projections represent contract prices paid by retailers. The estimates were based on existing contracts up to 2016 or 2017 (depending on location), and from 2017 onwards assumed that contract prices are linked to oil prices.

CORE Energy projections were under three scenarios: reference case, high case, and low case. In all scenarios the wholesale price escalates materially in 2017 and 2018 as existing contracts are replaced by oil-linked contracts. AEMO understands that these escalations have already been locked into some new contracts scheduled to start in 2017 and 2018.

AEMO's discussions with industrial consumers suggested prices in Queensland will be $1–2/GJ higher than elsewhere, rather than similar as projected by CORE Energy. Accordingly, for Queensland, a further $1.50/GJ has been added to the reference case values, and $1/GJ to the low case and $2/GJ to the high case.

### A.1.2 Peak gas supply cost

Contract prices reflect gas supplied at load factors that are higher than most demand market load factors. The load factor gap is met by peak gas supply from underground storages, pipeline line-pack services (such as park and loan), and wellhead peak contracts.

The costs of peak gas were calculated using a cost of peaking capacity, set in $/GJ/day/year, and applying it to the peak supply required for each market per GJ of annual demand.

Peak supply required = 1/(365*market load factor) – 1/(365*wholesale contract load factor)

For the projections, it was assumed to be constant in real terms, and as other parameters are also constant, the projected peak supply costs are constant in real terms.

For some industrial markets the market load factor was higher than the contract load factor, so no peak supply was required.

Note that peak supply charges are derived based on contractual agreement rather than regulated. Therefore they may vary over time and across participants. Market participants have also noted that flexibility in wholesale contracts is changing and load factors are increasing.

### A.1.3 Transmission cost

The majority of transmission pipelines charge for service on the basis of both capacity reserved and throughput. For retail pricing purposes it was assumed that each market is charged for capacity on a stand-alone basis, with capacity requirements per GJ of annual demand given by:

Transmission capacity required = 1/(365*market load factor)

Pipeline charges were based on 2015–16 tariffs for the following pipelines:

- NSW – Moomba Sydney Pipeline.
- Victoria – Victorian Transmission System.
- South Australia – Moomba Adelaide Pipeline.
- Queensland – Roma Brisbane Pipeline.
- Tasmania –Tasmanian Gas Pipeline.

Tariffs for competing pipelines serving some markets were assumed to be similar to those selected.

For the projections, it was assumed that all charges are constant in real terms, and as other parameters are also constant the projected transmission costs are constant in real terms. Victorian and Queensland pipeline tariffs are regulated but New South Wales and South Australia are not.

### A.1.4 Distribution cost

Distribution costs are determined by distribution tariffs, which are regulated by the Australian Energy Regulator (AER). Costs were based on 2015–16 tariffs (or the average of 2015 and 2016 calendar year tariffs) and escalated according to the most recent AER decision. From the end of the current tariff period, tariffs were assumed to be constant in real terms, though recently the AER has made a revenue determination resulting in significant tariff declines in New South Wales (Jemena Gas Networks).

The tariffs used are listed below. Note that it is assumed that large industrial consumers take supply directly from transmission pipelines and do not pay distribution charges.

**Table 17 Network tariffs used**

| Region | Residential | Business | Small Industrial |
|---|---|---|---|
| **New South Wales** | Jemena Volume Individual – Coastal | Jemena Volume Individual – Coastal | Jemena Demand Tariff DC–3 |
| **Queensland** | Australian Gas Networks Tariff R Brisbane | Australian Gas Networks Tariff C Brisbane | Australian Gas Networks Tariff D Brisbane |
| **South Australia** | Australian Gas Networks Tariff R Adelaide | Australian Gas Networks Tariff C Adelaide | Australian Gas Networks Tariff D Adelaide |
| **Victoria** | Multinet Tariff V Residential | Multinet Tariff V Business | Multinet Tariff L Non-residential |
| **Tasmania** | Included source of network tariff assumption from the price forecast spreadsheet | Not modelled | Not modelled |

### A.1.5 Retail cost of service

Retail cost of service was assumed to be a fixed annual cost per customer in each customer category. The cost per GJ was the fixed cost divided by the customer annual consumption, which varies from state to state.

### A.1.6 Retail margin

Retail margins are set in a competitive market environment. Margins were estimated by calibrating components to current retail prices, from which future margins can be projected using a number of alternative methods: at a constant real rate per GJ, or as a constant % of controllable costs (all other costs except regulated distribution costs).

## A.2 Price calibration

### A.2.1 Industrial

For industrial users there are no standing offer retail tariffs, so there were no initial values to calibrate against.

AEMO's discussions with industrial users suggested that the wholesale components of their prices are higher than the $4.20–$4.25/GJ in current contracts, and that they are already paying for some or most of the escalation projected in 2017 and 2018. Further, margins for industrial users are relatively small because many have direct access to the wholesale market.

The 2015–16 prices therefore assume that 67% of the projected wholesale price change from 2015 to 2018 has already been passed on and that margins are fixed at 5% of controllable costs.

### A.2.2 Residential and commercial

As far as possible, the initial (2015–16) retail prices were tied back to actual prices paid. For residential and commercial prices, this meant:

- Calculating the retail price under a current standing offer retail tariff.
- Applying a typical market discount to the standing offer price.
- Adjusting the retail margin so the sum of the 2015–16 price components matched the discounted price (in a deregulated retail market the margin is effectively determined by the discount).

This ensured projected changes in the sectors linked back consistently to current and historical prices.

The retail standing tariffs used for calibration are listed below. They were chosen to be consistent with the network tariffs.

**Table 18 Retail standing tariffs used**

| Region | Residential | Business |
|---|---|---|
| New South Wales | AGL Residential | AGL Business Standard |
| Queensland | Origin Residential AGN Brisbane | Origin QLD Small Business AGN Brisbane |
| South Australia | Origin Residential Adelaide | Origin SA Small Business |
| Victoria | Origin Multinet Main 1 | Origin Multinet Main 1 Small Business Tariff 13/21 |
| Tasmania | See retail price forecast spreadsheet | Not modelled |

Typically customers do not pay a standing tariff, but obtain a discount under a competitive offer. AEMO takes an assumed discount rate based on Origin Energy's reported discounts[57]. These assumptions are considered sound as they result in similar estimates of retail margins as expected.

[57] Improving Returns in Energy Markets, Origin Energy, 10 June 2015. Available https://www.originenergy.com.au/content/dam/origin/about/investors-media/docs/improving-returns-in-energy-markets-presentation-2015.PDFViewed:17th December 2015[57]

**Table 19 Tariff discounts assumed**

| Region | Residential | Business |
|---|---|---|
| New South Wales | 10% | 10% |
| Queensland | 5% | 12.5% |
| South Australia | 12.5% | 12.5% |
| Victoria | 15% | 15% |

It is important to note that the calibrations have significant impacts on the price projections:

- For residential and commercial, the full change in wholesale prices between 2015 and 2018 has still to flow through to retail prices.
- For industrial, this is already 67% accomplished, so the future impact is diminished.

# APPENDIX B. WEATHER STANDARDS

## B.1 Heating Degree Days (HDD)

HDD is a measure of heating demand, defined by differencing air temperature from a threshold temperature of 18 degrees[58]. The formula for HDD[59] is:

$$HDD = \quad Max(0, \overline{T} - 18)$$

where $\overline{T}$ is average daily temperature on a 6:00 PM to 6:00 PM basis.

HDD was used in modelling and forecasting of Tariff D and V consumption and maximum demand for New South Wales, Queensland and South Australia. This was calculated at the weather station level, taking a weighted average of the stations in the region to get regional HDD.

The weather station temperature data was sourced from the Bureau of Meteorology[60] and the stations used are given below.

**Table 20 Weather stations used for HDD**

| Region | Station Name |
|---|---|
| New South Wales | Sydney (Observatory Hill) |
| New South Wales | Bankstown Airport |
| New South Wales | Wagga Wagga |
| Queensland | Archerfield |
| Queensland | Rockhampton |
| Queensland | Townsville |
| South Australia | Edinburgh RAAF |
| South Australia | Adelaide (Kent Town) |
| Tasmania | Hobart Airport |
| Tasmania | Hobart (Ellerslie Road) |

## B.2 Effective Degree Days (EDD)

For Victoria, EDD is an index that has been developed to quantify the impact of temperature, wind speed and sunshine hours on gas consumption and maximum demand.

EDD312 (2012) is the index used by AEMO for modelling Victorian medium-to-long term gas demand. The 2015 National Gas Forecasting report (NGFR) uses this EDD standard. EDD312 indicates observations between 3.00 am of the current calendar day to 12.00 am of the following calendar day.

The formula to calculate EDD312 is:

$$EDD_{312} = f(Temperature, Wind\ Chill, Seasonality, Isolation)$$

$$= \max(0, DD_{312} + 0.037 * DD_{312} * 0.604 * W_{312} + 0.144 * Sunshine\ Hours + 2 * Cosine\left(2 * Pi * \frac{Day - 190}{365}\right))$$

The following sections outline how each of the components were calculated.

58 18 degrees C represents a threshold temperature for residential gas heating.
59 All the HDDs in a year are aggregated to obtain the *annual* HDD.
60 Bureau of Meteorology Climate Data, http://www.bom.gov.au/climate/data/ Viewed: 14th December 2015.

### Temperature ($T_{312}$) & Degree Days ($DD_{312}$)

This is the average of the eight three-hourly Melbourne temperature readings (in degree Celsius) from 3 am to 12 am the following day, inclusive.

For the period of 1 January 2015 to 5 January 2015, while the Melbourne Regional Office Weather station was active:

$$T_{312} = * (T3AM + T6AM + T9AM + T12PM + T3PM + T6PM + T9PM + T12AM)/8$$

From the period of 6 January 2015, using Melbourne Olympic Park Weather Station[61] :

$T_{312} = 1.028 * (T3AM + T6AM + T9AM + T12PM + T3PM + T6PM + T9PM + T12AM)/8$This is used to derive the degree days ($DD_{312}$), the number of degree days per quarter, above a threshold temperature of 18 degrees.[62] The mathematical formula is as follows:

$$DD_{312} = \sum Max(0, T_{312} - 18)$$

The weather station temperature data is sourced from the Bureau of Meteorology. Melbourne Regional office weather station data was used until it closed on 6 January 2015. From then the Melbourne Olympic park weather station data was used, as shown below.

**Table 21 Weather stations used for EDD**

| Region | Station Name |
|---|---|
| Victoria | Melbourne Regional Office (until 5 January 2015)[63] |
| Victoria | Melbourne (Olympic Park) (from 6 January 2015) |

### Wind Speed ($W_{312}$)

This is the average of the eight three-hourly Melbourne wind observations (measured in knots) from 3.00 am to 12.00 am the following day, inclusive.

i.e. $W_{312} = (W3AM + W6AM + W9AM + W12PM + W3PM + W6PM + W9PM + W12AM)/8$

This was calculated at the weather station level and a weighted average of the stations in the region is taken to get regional wind speed. The weather station temperature data is sourced from the Bureau of Meteorology and the stations used are given below.

**Table 22 Weather stations used for wind speed**

| Region | Station Name |
|---|---|
| Victoria | Laverton RAAF |
| Victoria | Moorabbin Airport |

A localisation factor was applied to account for the shift from the Melbourne wind station (closed in 1999) to the average of Laverton and Moorabbin wind stations, in order to align them with the Melbourne wind station reading. This factor is highlighted in red in the formula.

[61] An adjustment factor is applied to align the Melbourne Olympic Park weather station with historic data
[62] 18 degrees C represents a threshold temperature for residential gas heating.
[63] Melbourne Regional Office weather station closed at the beginning of January 2015. After this point Melbourne (Olympic Park) weather station observations were used.

### Sunshine Hours

This is number of hours of sunshine above a standard intensity, as measured by the Bureau of Meteorology at the weather station listed below.

**Table 23 Weather stations used for sunshine hours**

| Region | Station Name |
|---|---|
| Victoria | Melbourne Airport |

### Seasonal Factor (COSINE function)

This factor modelled seasonality in consumer response to different weather. It indicates that residential consumers more readily turn on heaters, adjust heaters higher, or leave heaters on longer in winter than in shoulder seasons for the same weather or change in weather conditions. For example, central heaters are often programmed once cold weather sets in resulting in more regular use.

This change in behaviour was captured by the Cosine term in the EDD formula, which implies that for the same weather conditions, heating demand is higher in the winter periods than the shoulder seasons or in summer.

## B.3 Determining HDD & EDD Standards

Analysis of historic 365-day rolling HDD and EDD data indicated that warming trends across regions have stabilised since the early 2000s. For this reason, the 2015 NGFR used data from 2000 to 2014 to derive a median weather trend. The 2015 NGFR also departed from the 2014 NGFR by using a longer historic period to calculate the median weather standard (2000–14), where the 2014 NGFR used a more recent period.

While the warming trend has stabilised, it is not possible to determine the direction of the warming trend going forward. Therefore, AEMO used the derived median weather standard for future EDD/HDD projections.

The differences in HDD/EDD from 2014 NGFR forecasts to 2015 NGFR forecasts are shown below.

**Table 24 Annual HDD and EDD (2014 NGFR & 2015 NGFR)**

| Region | NGFR 2014 | NGFR 2015 |
|---|---|---|
| New South Wales | 1,181 | 1,070 |
| Queensland | 389 | 210 |
| South Australia | 1,055 | 1,070 |
| Tasmania | 1,864 | 1,860 |
| Victoria | 1308 | 1,340 |

# APPENDIX C. DISTRIBUTION AND TRANSMISSION LOSSES

Gas is transported through high-pressure transmission pipelines to lower-pressure distribution networks before it is used.[64] During this process, some gas is unaccounted for and some used for operational purposes. This gas is collectively referred to as “total losses” in this document.

In the distribution networks, losses are typically a result of gas leaks and metering uncertainties. These losses are also known as unaccounted for gas (UAFG).

Transmission pipeline losses are mainly gas used by compressors and heaters in support of normal pipeline operation. UAFG also occurs along high-pressure pipelines, but in smaller quantities.

## C.1 Annual consumption

AEMO obtained historical losses from the sources listed in Table 32.

Historical data is normalised before being used in the forecasts. In particular, transmission losses are expressed as a percentage of total gas consumption by residential and commercial users, industrial users, gas-powered generators and distribution losses. Distribution losses are expressed as a percentage of total gas consumed by residential, commercial and distribution-connected industrial users.

In consultation with transmission and distribution businesses, AEMO produced regional total loss forecasts based on one of the following approaches:

1. Continue an observed historical trend.
2. Hold the loss level constant at a recently observed level.
3. Apply historical averages.

AEMO forecast transmission and distribution separately due to different underlying drivers, but aggregated them in the final forecasts. Transmission losses are primarily driven by operational losses, while distribution losses are driven by UAFG.

Regional transmission losses are forecast to range from 0.7% to 1.2% of total consumption, while distribution losses vary between 1.1% and 5.3%. These variations arise from differences in the number, size, and type of users, age of assets, network upgrades and total gas demand.

## C.2 Maximum demand

Losses during times of maximum demand were forecast in a similar way to annual consumption losses. It was assumed the normalised losses (transmission or distribution) during times of maximum demand are similar to those on an average day.

[64] Many commercial and Industrial gas consumers also take gas directly from high-pressure pipelines.

# APPENDIX D. DATA AND RECONCILIATION

**Table 25 Historical data sources**

| Demand component | Data source for all regions except for Vic | Data source for Vic |
|---|---|---|
| Residential and commercial | Distribution businesses | AEMO's internal database |
| Industrial | 1. Distribution businesses (for all Tariff D customers, aggregated on a network basis)<br>2. Direct surveys (for specific large industrial customers) | AEMO's internal database |
| Transmission losses | Transmission businesses | AEMO's internal database |
| Distribution losses | Distribution businesses | 1. Distribution businesses<br>2. AEMO's internal database |
| Gas-powered generation | 1. Transmission businesses where permission has been granted<br>2. AEMO's internal database | AEMO's internal database |

**Table 26 ANZSIC Code Mapping for Industrial Sector Disaggregation**

| ANZSIC Division ID | ANZSIC Division Name | AEMO Sector Category |
|---|---|---|
| A | Agriculture, Forestry and Fishing | Other |
| B | Mining | Other |
| C | Manufacturing | 1. Food Product Manufacturing (ANZSIC Code: 11) & Beverage and Tobacco Manufacturing (ANZSIC Code: 12) are categorised as 'Other'<br>2. All other manufacturing sub sectors are categorised under manufacturing |
| D | Electricity, Gas, Water and Waste Services | Other |
| E | Construction | Other |
| F | Wholesale Trade | Other |
| G | Retail Trade | Other |
| H | Accommodation and Food Services | Other |
| I | Transport, Postal and Warehousing | Other |
| J | Information Media and Telecommunications | Other |
| K | Financial and Insurance Services | Other |
| L | Rental, Hiring and Real Estate Services | Other |
| M | Professional, Scientific and Technical Services | Other |
| N | Administrative and Support Services | Other |
| O | Public Administration and Safety | Other |
| P | Education and Training | Other |
| Q | Health Care and Social Assistance | Other |
| R | Arts and Recreation Services | Other |
| S | Other Services | Other |

**Table 27 Public Datasets**

| Indicator | Description | Units | Source |
|---|---|---|---|
| Gas Consumption Data | Gas consumption data for 'other' sector industries and manufacturing sector consumption; For the manufacturing sector (excluding food and beverage manufacturing) this dataset is only used to derive the manufacturing to other sector Tariff D consumption split. GVA data is used as a proxy for historic manufacturing sector gas consumption. | PJ | Bureau of Resource Energy Economics, Australian Energy Stastics Tables; Table F.Australian energy consumption, by state, by industry, by fuel, energy units |
| Onput Producer Price Index | "An onput PPI measures the rate of change in the prices of good and services purchased as inputs by the producer" | Index | ABS Table 12 Output of the Manufacturing industries, division, subdivision, group and class index numbers (64720.0); **Series Title:** Index Numbers; Manufacturing Division; **Series ID:** A2305166A |
| Iutput Producer Price Index | "An iutput PPI measures the rate of change in the prices of goods and services purchased as inputs by the producer." | Index | ABS Table 11 Input to the Manufacturing industries, division and selected industries, index numbers and percentage changes (64720.0) ; **Series Title:** Index Numbers; Manufacturing Division; **Series ID:** A2309054F |
| CPI Index by City | CPI Index is used to convert I_PPI and O_PPI values for the respective city to 2014 Real terms. | Index | ABS Table 5 CPI: Groups, Index Numbers by Capital City (6401); **Series Title:** Index Numbers ; All groups CPI ; Sydney ; Adelaide ; Brisbane; Melbourne; **Series ID:** A2325806K; A2325821J; A2325816R; A2325811C |
| Price Deflator | Used to adjust GVA and GSP values to 2014 real terms | Index | ABS Table 5 Expenditure on Gross Domestic Product (GDP), Implicit price deflators (5206) ; **Series Title:** GROSS DOMESTIC PRODUCT ; **Series ID:** A2303730T |
| Gross Value Added | Gross Value Added (2000-2014) data for manufacturing sector, by region (excluding food and beverage manufacturing) is used as a proxy variable to capture historic gas consumption trends in the manufacturing sector. | $ ('Mill) | ABS Table 2. Expenditure, Income and Industry Components of Gross State Product, New South Wales, Chain volume measures and current prices (5220.0) ; ABS Table 3. Expenditure, Income and Industry Components of Gross State Product, Victoria, Chain volume measures and current prices (5220.0) ; ABS Table 4. Expenditure, Income and Industry Components of Gross State Product, Queensland, Chain volume measures and current prices (5220.0) ; ABS Table 5. Expenditure, Income and Industry Components of Gross State Product, South Australia, Chain volume measures and current prices (5220.0); ABS Table 9. Expenditure, Income and Industry Components of Gross State Product, Australian Capital Territory, Chain volume measures and current prices (5220.0) ; |
| Population | Population (net of births, deaths and migration) | No. of persons | ABS Table A1.Population projections, By age and sex, New South Wales - Series A (3222.0); ABS Table A2.Population projections, By age and sex,Victoria - Series A (3222.0); ABS Table A3.Population projections, By age and sex, Queensland - Series A (3222.0); ABS Table A4.Population projections, By age and sex, South Australia - Series A (3222.0); ABS Table A6.Population projections, By age and sex, Tasmania - Series A (3222.0); ABS Table A8.Population projections, By age and sex, Australian Captial Territory- Series A (3222.0); |
| Business Count Data | Counts of Australian Businesses by Annual Turnover rate was used to estimate a split between Industrial (Tariff D) and Residential & Commericial (Tariff V) consumption. | No. of busines ses | ABS Businesses by Main State by Industry Class by Turnover Size Ranges, June 2014 and June 2013 (8165.0)<br>ABS Businesses by Industry Class by Main State by Turnover Size Ranges, June 2007 - June 2011 (8165.0)<br>Businesses by Industry Class by Main State by Annual Turnover Size Ranges, June 2003 – June 2007 (8165.0) |