Electricity Demand Forecasting Methodology

Consultation paper

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New South Wales | Queensland | South Australia | Victoria | Australian Capital Territory | Tasmania | Western Australia

Australian Energy Market Operator Ltd ABN 94 072 010 327

Explanatory statement and consultation notice

This consultation paper commences the first stage consultation conducted by AEMO to review its Electricity Demand Forecasting Methodology. This consultation is intended to satisfy AEMO's requirements to review each key component of its Forecasting Approach at least every four years, as required by the Australian Energy Regulator's (AER's) Forecasting Best Practice Guidelines (FBPG)[1] and AEMO's Reliability Forecast Guidelines (RFG)[2].

The detailed sections of this consultation paper include more information on the matters for consultation, including questions that may prompt feedback from stakeholders. Given the preliminary status of the consultation topics, AEMO is not including a draft or proposed methodology with this consultation paper. A draft methodology will be released with the draft determination, which will take into account the submissions received in this first stage of consultation. Stakeholders will be given a further opportunity to provide feedback on the draft determination and draft methodology prior to finalisation.

Consultation notice

AEMO invites written submissions from interested persons on the issues identified in this paper to energy.forecasting@aemo.com.au by 5:00 pm (Melbourne time) on 23 August 2024.

Before making a submission, please read and take note of AEMO's consultation submission guidelines, which can be found at https://aemo.com.au/consultations. Subject to those guidelines, submissions will be published on AEMO's website.

Please identify any parts of your submission that you wish to remain confidential, and explain why. AEMO may still publish that information if it does not consider it to be confidential, but will consult with you before doing so. Material identified as confidential may be given less weight in the decision-making process than material that is published.

AEMO is not obliged to consider any submission received after the closing date and time except in exceptional circumstances. Any late submissions should explain the reason for lateness and the detriment to you if AEMO does not consider your submission.

Interested persons can request a meeting with AEMO to discuss any particularly complex, sensitive or confidential matters relating to the proposal. Meeting requests must be received by the end of the submission period and include reasons for the request. We will try to accommodate reasonable meeting requests but, where appropriate, we may hold joint meetings with other stakeholders or convene a meeting with a broader industry group. Subject to confidentiality restrictions, AEMO will publish a summary of matters discussed at stakeholder meetings.

[1] At https://www.aer.gov.au/system/files/AER%20-%20Forecasting%20best%20practice%20guidelines%20-%2025%20August%202020.pdf.

[2] At https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/rsig/reliability-forecast-guidelines.pdf.

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1. Stakeholder consultation process

This consultation paper commences the first stage of consultation conducted by AEMO to review its Electricity Demand Forecasting Methodology.

The electricity demand forecasting methodology and the forecasts produced by it are key inputs into a number of AEMO's reliability processes specified in the National Electricity Rules (NER), including the Electricity Statement of Opportunities (ESOO) and its associated reliability forecast. Given the importance of the reliability forecast in potentially triggering obligations under the Retailer Reliability Obligation (RRO), AEMO strives to engage with all relevant stakeholders, to ensure the methodologies used for each component of the forecast reflect stakeholder feedback and insights.

This consultation addresses the requirements in the Australian Energy Regulator's (AER's) Forecasting Best Practice Guidelines (FBPG) and AEMO's Reliability Forecasting Guidelines (RFG), which require that AEMO review each component of its Forecasting Approach at least once every four years. The electricity demand forecasting methodology is one component of AEMO's Forecasting Approach and was last consulted on between December 2020 and May 2021.

AEMO's indicative process and timeline for this consultation are outlined below. Future dates may be adjusted and additional steps may be included if necessary, as the consultation progresses. In the event that these dates change, AEMO will clearly identify the timetable on the webpage for this consultation.

Consultation steps	Dates
Publication of consultation paper, with stakeholder consultation for this paper commencing.	26 July 2024
Submissions on consultation paper due	23 August 2024
Publication of draft determination and draft methodology, with stakeholder consultation for these papers commencing.	31 October 2024
Submissions on draft determination due	29 November 2024
Publication of final determination and final methodology to be applied in the 2025 Electricity Statement of Opportunities and other relevant forecasting and planning activiites.	29 March 2025

2. Background

2.1. Context for this consultation

AEMO's electricity demand forecasting methodology and the forecasts produced by it are key inputs into a number of AEMO reliability and planning processes in the National Electricity Market (NEM), including:

- The Medium Term Projected Assessment of System Adequacy (MT PASA).
- The ESOO and its associated reliability forecast.
- The Integrated System Plan (ISP).

AEMO is required to produce reliability forecasts in accordance with the FBPG and the RFG.

AEMO's Forecasting Approach[3] sets out the various components that contribute to the forecast of electricity demand and consumption critical to AEMO's NEM forecasting and planning publications, including the reliability forecast. The FBPG require that AEMO review its Forecasting Approach at least every four years using the consultation procedures outlined in Appendix A of the FBPG.

The electricity demand forecasting methodology is one of the methodologies within AEMO's Forecasting Approach and was last consulted on between December 2020 and May 2021. This consultation therefore intends to meet the FBPG requirement to review and consult on the components of AEMO's Forecasting Approach at least once every four years.

2.2. Consultation paper structure

Section 3 below follows the structure of AEMO's existing forecasting methodology and presents questions that stakeholders may elect to address in their written submissions to this consultation. AEMO's discussion of how its current methodology may change falls into two broad categories:

- **Proposed changes**, where AEMO has a specific proposal for how it is seeking to amend the methodology in the second stage of the consultation.
- **Potential changes**, where AEMO has noted that the existing methodology may need to be revised, but has not yet formed a specific approach that it seeking feedback on at this time.

The overview of the current approach in each section is intended to be a high level discussion of the methodology for that component of the forecast and does not contain all of the detail required for an in-depth understanding of the methodology. AEMO encourages stakeholders to read this consultation paper in conjunction with the forecasting methodology itself, which may help stakeholders respond to AEMO's suggestions, or to identify additional issues for AEMO's consideration and inform feedback provided in response to this paper.

Section 4 contains a summary of all consultation questions included throughout Section 3.

[3] At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-approach.

3. AEMO's Electricity Demand Forecasting Methodology

This section outlines the key areas that AEMO is seeking feedback on in this consultation. The questions presented in this section are intended to prompt feedback from stakeholders, however stakeholders may provide submissions on any identified issue with the methodologies not specifically referred to in this consultation paper.

As a general observation, AEMO considers the existing methodologies to be sound and the application of the methodologies is resulting in forecasts that are consistent with the NEO and the FBPG. AEMO's Forecast Accuracy Reporting[4] provides an important check on the outcomes generated by the forecasting methodologies, by comparing AEMO's forecasts to actual observations. The accuracy of the forecasts is typically high, and where larger variances between forecasts and actuals are identified, these can often be improved via a better understanding of input data, rather than requiring a modification to the methodology.

Review of the Integrated System Plan

On 5 April 2024, the Energy and Climate Change Ministerial Council published its *Response to the Review of the Integrated System Plan*. The response outlined a range of actions that Energy Ministers have agreed to take to address the recommendations arising from the review.

AEMO notes that it may need to adapt its electricity demand forecasting methodology in light of these agreed actions for the Integrated System Plan.

AEMO is currently considering the actions and liaising with stakeholders, however at the time of publishing this document is not ready to ask specific questions regarding the implementation of the actions, or how they may be reflected in the demand forecasting methodology.

AEMO welcomes stakeholder feedback on the manner in which the electricity demand forecasting methodology may need to change to address the actions arising from the Review of the ISP. AEMO will also commence consultation explicitly on the overall ISP Methodology prior to the finalisation of this consultation.

3.1. AEMO's component based forecasing approach

The Introduction section of the electricity demand forecasting methodology provides a high level overview of:

- How the electricity demand forecasting methodology is applied.
- The forecasting principles that AEMO follows, which are in accordance with the FBPG and NER.

[4] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/forecasting-accuracy-reporting.

- Demand drivers, uncertainty and risks.
- Customer segmentation.
- Modelling customer behaviour.
- Key definitions.
- How the methodologies are maintained.

AEMO's overall approach to forecasting electricity consumption follows a component-based methodology, which allows identification and compartmentalisation of individual drivers of future electricity consumption. AEMO considers this approach to be an appropriate balance of complexity and transparency, enabling stakekholders to understand the key drivers of forecast change, while providing sufficient aggregation of sub-components to a logical and understandable driver grouping.

AEMO considers that the introduction of the methodology document adequately describes these principles and considers that this approach remains largely fit-for-purpose.

3.1.1. Customer segments within AEMO's forecasting methodology

AEMO applies a segmentation approach to forecasting electricity consumption, to ensure that the drivers that affect electricity consumption growth are tailored to each appropriate consumer cohort. AEMO's current segmentation includes:

- Residential customers.
- Business customers, including
  - Large industrial loads (LILs),
  - Hydrogen producers,
  - Liquified natural gas (LNG) producers,
  - Electric vehicles (EVs), and
  - Other business consumers, called 'business mass market'.

In the sections that follow, AEMO provides some insight as to potential changes to the segmentation approach that may be applied, however the segmentation approach concept remains reasonable in AEMO's opinion to meet the collective purposes of the electricity demand forecasting methodology.

3.1.2. Spatial forecasting

AEMO's electricity consumption, maximum demand and minimum demand forecasts are developed at the NEM region level. In applying the regional demand forecasts in planning applications, it is often appropriate to consider the location of the load within the region, and whether locations are homogenous and growing at the same pace, or if there are differences in locations (in load composition between customer segments, or growth factors). AEMO uses sub-regions in several of its planning processes, which allocate the region-level forecasts across different defined locations.

To produce demand traces at the NEM sub-regional level for the ISP, these regional forecasts are allocated to sub-regions as described in the ISP Methodology[5].

[5] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/isp-methodology-2023/isp-methodology_june-2023.pdf

Having the NEM region as the spatial dimenson for consumption and demand forecasts has benefits in terms of the number of inputs and computation time required. For example, for the five NEM regions, AEMO needs (at a high level) five sets of actual data to train models on, five sets of the various inputs (economic, energy efficiency, PV, etc.), five model runs, etc. These inputs and models then produce forecasts that can be used in AEMO's key forecasting publications.

AEMO recognises, however, that the energy transition will not necessarily occur uniformly within NEM regions. Different consumption and demand trajectories within a NEM region may be important for stakeholders to understand and act upon. AEMO is interested in stakeholder views on the benefits of more granular spatial forecasts and the appropriate methods for developing them – for example by distributing the regional forecasts between the sub-regions, or by forecasting individual sub-regions which then may be aggregated up to the regional forecast.

Questions

1. **Does a component-based forecasting approach continue to provide a fit-for-purpose method that reflects best practice for electricity demand forecasting?**
2. **Are the customer segments appropriate aggregations of electricity consumers, and do they provide sufficient capability to apply aggregate methodologies for each in order to forecast each cohort's future electricity consumption?**
3. **Do you have any comments on the benefits of AEMO developing specific sub-regional consumption and demand forecasts? Are there specific inputs and assumptions that are more likely to be important to understand on a spatial level more granular than the NEM region, or would a simpler allocation approach of the regional forecasts provide sufficient insight to inform sub-regional forecasting?**

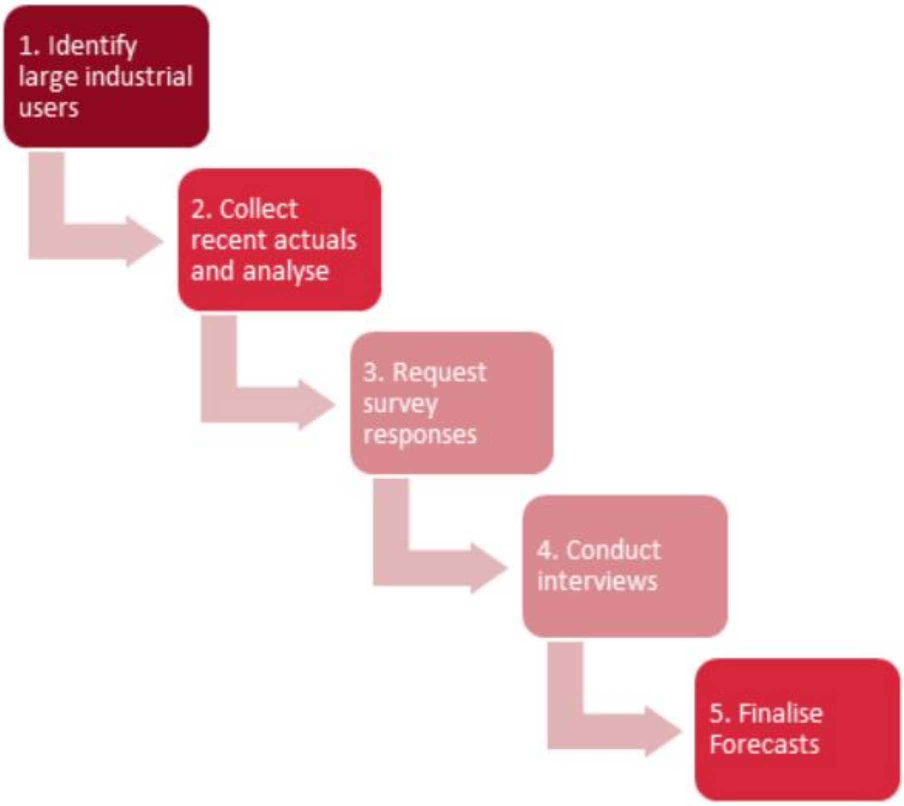
3.2. Business annual consumption

3.2.1. Large industrial load consumption forecasting

Current approach

The electricity demand forecasting methodology sets out five general steps that AEMO undertakes when forecasting LILs. These steps are summarised in Figure 7 of the methodology, which is reproduced below in Figure 1.

Figure 1 Steps for large industrial load survey process



The current process aggregates survey responses from LILs, and may adjust the forecast to account for various growth drivers, including economic, across the scenarios. AEMO considers that the current process for identifying LILs, gathering the data and forecasting LIL demand is generally sound, however, some changes may be appropriate.

Proposed changes

Under the current methodology, new LILs enter the forecast at their maximum consumption in a single year. AEMO is considering that some loads may more likely ramp up consumption over a period of time (for example, several years). AEMO is considering changes to the surveys it provides to capture greater information regarding the ramp up in consumption to support this adjustment.

Potential changes

One area of the process that AEMO is seeking stakeholder views on is the manner in which NEM LILs are evaluated for inclusion in the single scenario which is used in the ESOO's reliability forecast. The electricity demand forecasting methodology currently requires AEMO to include a LIL in the single scenario if all three of the following criteria are met:

- The project has obtained the required environmental approvals.
- The project has obtained approvals from the network service provider to connect to their system.
- The project proponent has publicly announced that it has taken a positive Final Investment Decision (FID) and/or the project has commenced construction.

These criteria are broadly consistent with the criteria that AEMO applied to supply developments in the ESOO[6] when the last forecasting approach review was conducted, of only including existing and committed generators. Since then, AEMO consulted on an amended approach with stakeholders to include anticipated generation developments, and to recognise generation commissioning delays for generation projects that are yet to be commissioned that may occur, given evidence of historical generation project delays. Retaining the existing LIL criteria for the single scenario may introduce a level of inconsistency between the commitment criteria for load growth affecting LILs, and the commitment criteria affecting supply capacity growth.

AEMO is interested in stakeholder feedback on the benefits, or otherwise, of retaining the existing criteria for industrial load developments, and whether the methodology should include new LILs that meet a similar level of certainty as the 'anticipated' generator developments.

AEMO recognises that industrial developments may be more likely to meet these criteria in the short term, but longer term growth forecasts may need to based on a different set of commitment, or forecasting approach, reflecting the scenarios that are being forecast. AEMO is interested in stakeholder views on whether the long-term approach for industrial load forecasting should differ versus shorter term forecasting.

Questions

4. **Do you have any views on whether the existing commitment criteria for LIL inclusion in the single scenario forecast should be expanded to include a similar level of certainty as the 'anticipated' generator developments?**
5. **Do you have any comments on if the forecasting approach should apply criteria differently across the short and long term?**

3.2.2. Hydrogen sector consumption forecasting

Current approach

Section 2.2 of the electricity demand forecasting methodology sets out AEMO's approach to hydrogen forecasting. The current approach captures all grid-supplied electricity consumption forecasted to be used by electrolysers to produce hydrogen in the Australian economy and is separated into two segments:

- Flexible location hydrogen production, which relates to hydrogen production to be consumed by new industrial processes or export industries, where there is no fixed existing location
- Location bound hydrogen production, which refers to hydrogen produced for existing industrial processes that are connected to existing infrastructure, particularly the gas distribution systems.

Due to the emerging nature of the hydrogen industry, AEMO includes hydrogen production as a parameter in its scenario design, which is then converted into electricity consumption for each scenario's forecast, based on an assumed conversion factor.

[6] AEMO (2023), *ESOO and Reliability Forecast Methodology Document,* version 10, p. 14.

Potential changes

AEMO is considering expanding the hydrogen component to include green commodities including steel, iron, ammonia and aluminium.

Feedback has been received from stakeholders on the assumptions used to model hydrogen storage. This aspect is modelled with the PLEXOS market model, and is covered by the ISP Methodology. The ISP Methodology will be the subject of a separate two stage consultation process prior to this consultation concluding and stakeholders will be able to provide formal feedback on hydrogen storage assumptions during that process.

Questions
6. Are there any other changes that AEMO should consider to the methodology for developing hydrogen forecasts, beyond expanding its use into other green commodities?

3.2.3. Liquefied natural gas (LNG) consumption forecasting

Current approach

Section 2.3 of the electricity demand forecasting methodology notes that AEMO's short- to medium-term forecasts for LNG are based on survey data provided by LNG producers, similar to the approach for LILs. The longer-term forecast is developed by extending the surveyed trend across the scenario collection, applying assumed global trends for each scenario.

Potential changes

AEMO is not considering any changes to the existing LNG consumption forecasting methodology.

3.2.4. Business mass market consumption forecasting

Current approach

Section 2.4 of the electricity demand forecasting methodology sets out AEMO's approach to forecasting consumption for the business mass market (BMM) customer segment.

At a high level, the BMM consumption forecast is derived from a combination of a short-term time-series model and a long-term causal model. The short-term model is a linear regression model which uses 60 months of historical data and decomposes the BMM load into a trend, weather-driven seasonality, and a residual. Dummy variables are used to capture structural shocks, where applicable.

The long-term model estimates the impact that the following factors will have on future BMM consumption:

- Economic factors.
- Electricity price changes.
- Electrification (not related to energy efficiency).
- Energy efficiency.
- Climate change.

The short-term and long-term models are combined by weighting the forecasts more heavily towards the short-term model in the earlier years of the forecast and gradually changing the weighting towards the long-term model outcomes, such that by year six of the forecast, the short-term model weighting has reached 0%.

To the above forecast is added the impact on BMM consumption of business-related consumer energy resources (CER), namely rooftop photovoltaic (PV) generation, EVs and losses arising from the operation of behind-the-meter batteries.

Potential changes from accuracy assessments and other general improvements

As noted in the 2023 Forecast Accuracy Report (FAR)[7], AEMO considers that its consumption models have performed reasonably well. Figure 6 and Table 8 in the 2023 FAR indicate that AEMO's one-year ahead forecast accuracy is typically within ±3%. Further, the short- to medium-term central forecasts have not changed significantly from forecast publication to forecast publication, indicating that the models are producing stable and accurate forecasts over that time period. The longer term accuracy of the forecasts is by its nature difficult to measure, but AEMO welcomes feedback from stakeholders on its approach to transitioning from short term to long term forecasts for all forecasting components.

One exception to the above was the short-term consumption model for Tasmania. AEMO has committed in the 2024 Forecast Improvement Plan[8] to expanding its review of that region's growth trends.

AEMO also notes its ongoing work in better understanding business consumption at the sectoral level, as outlined in the 2023 Forecast Improvement Plan and presented to the Forecasting Reference Group (FRG)[9] in April 2024. AEMO is considering ways in which the insights gained from its analysis of sectoral consumption may feed into the BMM model.

Potential additional customer segment – Data Centres

AEMO is considering one change that may need to be made to potentially both the short-term and the long-term model, which is specifically related to emerging commercial loads such as data centres. While many data centres will be captured in AEMO's LIL survey process, there is the potential for some data centres to not meet the LIL threshold. In the aggregate, these data centres may have a significant impact on BMM consumption. AEMO considers that there is potential value in considering data centres as a separate group within the BMM model with its own forecast, or a separate business segmentation (similar to hydrogen and LNG facilities). Either approach may improve the (aggregate, or residual) BMM and also provide more transparency about AEMO's assumptions of this increasingly important commercial sector.

In developing a bespoke data centre methodology, consideration must be given to the appropriate infrastructure required of data centres, influencing the location of these potential loads. Low data latency (i.e. high data transfer speeds) is a key pre-requisite for many data centre applications that seek to provide near real-time digital services. This may require data centres locating in strong parts of Australia's fibre network and geographically near to the customers that will use the services (i.e. in or near the capital cities). However new infrastructure to deliver improved data latency in other locations, including via coordinated development of electricity infrastructure and fibre infrastructure, may provide broader opportunities for these emerging loads to locate in other areas.

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[7] AEMO (2024), *Forecast Accuracy Report*, version 1, pp.24-26.

[8] Which is included in the FAR.

[9] See https://aemo.com.au/en/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/forecasting-reference-group-frg for FRG meeting materials, including presentations and minutes.

Questions

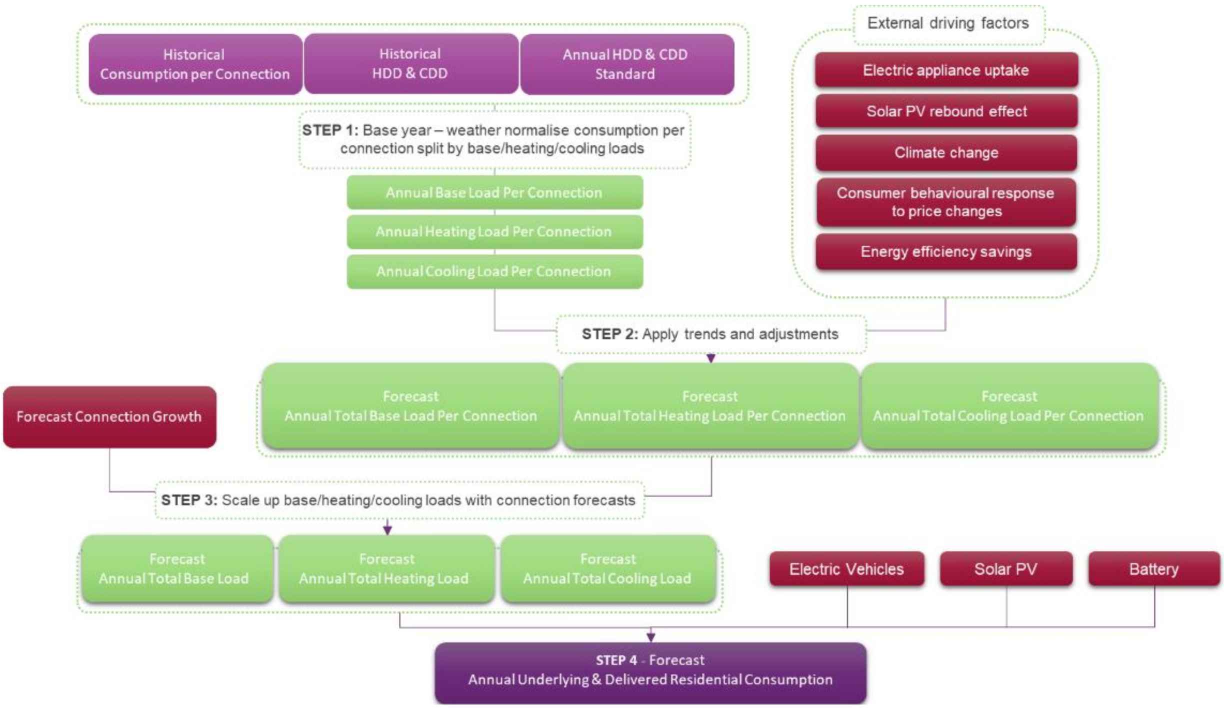
7. **Should AEMO create a separate customer segmentation for data centres, removing them from the LIL and BMM segments? Would the preferred approach apply a survey-driven forecast, observations from international trends, or another technique?**
8. **Are there other sectors which should have their own category within the BMM model?**

3.3. Residential annual consumption

Current approach

Section 3 of the electricity demand forecasting methodology sets out the methodology AEMO uses to forecast residential annual electricity consumption. The approach is summarised on page 29 of the forecasting methodology and presented diagrammatically in Figure 13, which is reproduced below.

Figure 2 Process flow for residential consumption forecasts



Potential changes

As noted above in section 3.2.4, AEMO's consumption models have been found in the FAR to have performed reasonably well and to produce relatively stable forecasts year-on-year. On this basis, AEMO has not identified any material issues relating to its residential consumption forecasting methodology.

AEMO is interested in whether it should be considering different external drivers of consumption (refer Figure 2), or on how it is currently estimating the impact of these drivers.

For example, at the May 2024 FRG meeting, several stakeholders commented on AEMO's approach to calculating the 'solar rebound' effect. Currently, AEMO applies a rebound of energy consumption of

20% to base load, heating load and cooling load for customers who install rooftop PV. AEMO is considering whether it should amend its methodology to treat these types of load (base, cooling, heating) differently when it comes to the solar rebound effect, and the magnitude of the rebound itself, should adequate evidence exist to make this distinction.

Questions
9. Do you think AEMO should be considering any other external drivers of energy consumption when developing its residential consumption forecasts? **10. Should AEMO's approach to the solar rebound effect take into account differences in the impacts on base load, cooling load and heating load? What data sources exist that may help to estimate these impacts?**

3.4. Small non-scheduled generation, losses and auxiliary loads

Current approach

Section 4.1 of the electricity demand forecasting methodology sets out AEMO's approach for forecasting two categories of small non-scheduled generation: PV non-scheduled generation (PVNSG) and other non-scheduled generation (ONSG). PVNSG is calculated by multiplying the forecast of 100 kW to 30 MW PV systems (sourced from a consultant) by a normalised generation trace. The ONSG forecast is based on information about committed or retiring generators (using AEMO's Generation Information data) and trends in historical capacity additions. This forecast capacity is converted into annual energy generation projections, based on historical, or estimated, capacity factors for the relevant technologies in each region.

Section 4.2 of the methodology describes AEMO's approach for forecasting distribution and transmission losses. Forecast distribution and transmission losses are based on the most recent year of actual losses and these values are carried forward unchanged into the forecast years.

Section 4.3 of the methodology explains AEMO's approach for estimating and forecasting auxiliary loads. Historical auxiliary load is estimated by multiplying the metered generation for an individual generating unit by using an estimated auxiliary percentage, which is published in the IASR. Future auxiliary calculations rely upon the auxiliary factors for existing and new generation technologies published in the IASR, and relying on a future generation forecast (for example from a draft or final ISP) to apply these auxiliary factors to.

Potential changes

AEMO considers that its approaches for forecasting ONSG, losses and auxiliary loads are generally fit-for-purpose, being based on reasonable assumptions and the latest available data.

Regarding PVNSG generation profiles, AEMO notes increased availability of large data samples of such sites, and proposes to adopt them as the source of historical generation profiles, replacing the current solar data-based approach. Relative to the current solar data-based approach, the structure of such sample site data is more efficiently used in forecasting. The solar irradiance data-based approach is currently also used for large-scale PV sites, which AEMO may consider reviewing if there is similar availability of high quality historical information across AEMO's reference year collection, in line with the new proposed approach for PVNSG, and for large-scale wind generation.

Regarding ONSG, AEMO considers there may be potential for more information from LIL and other business segment surveys to inform the development potential of ONSG, to augment the existing approach. Such an approach would improve the connection of embedded generation that supports business activity within the forecast.

Regarding distribution and transmission losses, AEMO considers it reasonable to apply the existing approach, but acknowledges that transmission flows in particular are likely to change with the transition from coal generation to firmed renewable generation, which may impact on the volume of energy transmitted through existing transmission flow paths, affecting transmission losses.

It may be a reasonable alternative to the existing approach to utilise the most recent AEMO forecast of network utilisation, from the most recent draft or final ISP forecast for example, to inform the forecast losses.

AEMO would welcome alternative views, or support for the existing approach.

Question
11. What data sources can stakeholders recommend that provide additional visibility or insights on non-scheduled generators?

3.5. Maximum and minimum demand

Current approach

The electricity demand forecasting methodology sets out the key steps and definitions underpinning AEMO's maximum and minimum demand forecasts. As demand is dependant on both structural and random drivers, in particular weather conditions, seasonal effects and other 'random' factors, AEMO's approach is probabilistic rather than deterministic, and the forecasts produced reflect 'probabilities of exceedence' targets (for example, 10% probability of exceedence, meaning likely to only be exceeded one year out of every 10).

Some of the key features of AEMO's maximum and minimum demand forecasts are:

- Forecasts are unconstrained, that is, they are not adjusted for subregional network constraints, generation outages, or market levers such as demand side participation or battery VPP, or any off-market interventions (such as Reliability and Emergency Reserve Trader (RERT), or any government interventions requesting consumers to reduce demand).
- Maximum demand is forecast on an 'operational sent out' (OPSO) basis, which can be converted to an 'operational as generated' (OPGEN) forecast using estimates of auxiliary load.
- To provide the ability to forecast each season wholistically, the NEM forecasts are based on a Season Year which spans 1 September to 30 August, thereby including all of the winter and summer season. A financial year approach would mean that the winter season straddled both ends of the forecast horizon.

The steps involved in the forecasting process are summarised below:

- Data preparation, including half hourly demand, weather and other inputs such as estimated PV generation.

- Exploratory data analysis to detect outliers, identify demand drivers and selecting an appropriate time span for model training.
- Model development and selection, which is used to produce the minimum and maximum demand in the first year of the forecast by simulation.
- Extrapolation of the base year to future years in the forecast using the same long-term indices as the annual consumption forecasts, while distinguishing between baseload, heating load and cooling load, to inform the seasonal and temporal impacts on demand.
- Adjustments for several components that are modelled separate to the above process, including losses, ONSG, LILs, auxiliary loads, electrification and corrdinated EV charging. These components do not typically have an appropriate load shape or utlisation to incorporate within the probabilistic simulation.

Potential changes

The above process reflects the maximum and minimum demand forecasting model improvements presented to the FRG in April and June 2023. As noted in those presentations, the new model had a significant improvement in accuracy compared to the existing model[10]. Another recent presentation to the FRG in April 2024 noted that the actual summer demand outcomes aligned well with the model's predictions.

On the basis of these accuracy metrics, AEMO is not proposing any changes to its minimum and maximum demand forecast methodology.

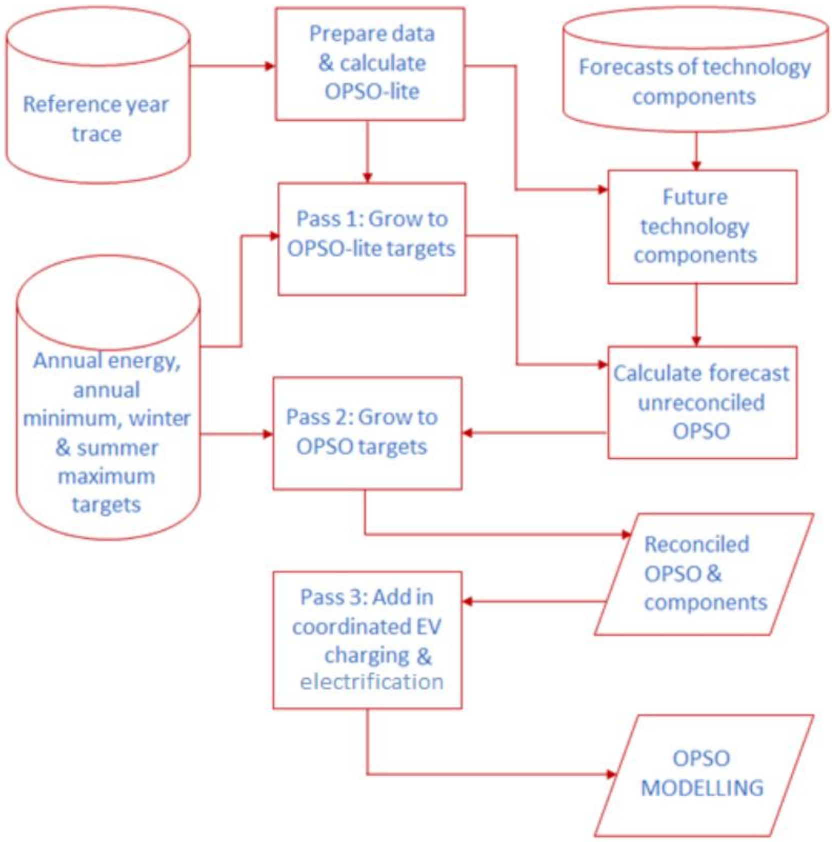
3.6. Half-hourly demand traces

Current approach

AEMO's half-hourly demand traces convert AEMO's annual consumption, maximum demand and minimum demand forecasts into a projection of 30-minute demand over a forecast period, such as 10 to 30 years. The process to produce these traces is set out in Section 6 of the electricity demand forecasting methodology. Figure 22 from the methodology summarises the process, and is reproduced below.

[10] Measured by the Mean Average Percentage Error (MAPE), the new model had a MAPE of 1.88% compared to 3.60% for the existing model.

Figure 3 Demand trace development process flow diagram



In summary, AEMO's approach to producing half-hourly traces is to start with actual 30-minute demands from a series of reference years, then grow and shape those 30-minute profiles to meet the annual consumption, maximum demand and minimum demand forecasts produced by the methodologies referred to in sections 3.2 to 3.5. Separate half-hourly traces for PV generation, battery storage, electrification, EVs and LNG are also prepared and added back to the traces.

Potential changes

AEMO is investigating options to improve its development of demand traces. These potential improvements were discussed at the April 2023 FRG and are also discussed in AEMO's 2024 Forecast Improvement Plan[11]. While these approaches do not significantly deviate from the current overall methodology, they may provide material improvements to the half-hourly trace development process with minimal actual change to the overall methodology. The potential improvements include:

- Creating 'synthetic' weather years, which represent potential weather outcomes within the estimated distribution of possible weather outcomes today and in future forecast years. These synthetic weather years could be included alongside, or replace, the reference years which are currently used
- Distinguishing between LIL and non-LIL components when scaling the traces to meet annual energy, maximum and minimum demand targets. The current approach does not differentiate between these categories, despite LIL having a very different load shape (much flatter) than the average load

[11] AEMO (2024), *Forecast Accuracy Report*, version 1, p.95.

profile. Scaling LIL and non-LIL sectors separately is expected to improve the accuracy of the 30-minute traces

- Improving the trace scaling algorithm itself. Currently, the reference years are scaled to meet the maximum demand, minimum demand and energy targets of a given forecast year. This can produce distorted traces in the event that a mild reference year is scaled up to meet a given target. AEMO intends to develop traces that maintain the actual weather conditions in the reference year (which may be a synthetic weather year). Further, the trace will better reflect the reference year's demand profile by scaling demand across the entire year, as opposed to prioritising maximum demand and minimum demand periods in order to achieve the maximum and minimum targets for future years. This will address the issue of distorted forecast load shapes which can arise under the current approach when energy consumption targets are scaled to subsequent to maximum and minimum demand targets. When combined with synthetic traces for variable renewable energy (wind and solar), the new traces will produce a more consistent and robust view of the likely supply side and demand side traces in a given year.

Questions
12. Do you have any comments on AEMO's potential improvements to developing demand traces?

3.7. Appendices

3.7.1. Retail electricity prices

Current approach

Section A1 of the electricity demand forecasting methodology describes AEMO's approach to forecasting retail electricity prices, which is based on a bottom-up forecast of the individual components of the retail price, namely:

- Wholesale costs.
- Network costs.
- Environmental costs.
- Retail costs and margin.

Potential changes

AEMO considers that the bottom-up approach remains valid and that the sources relied upon for these components, as described in the methodology, remain the best available sources. Therefore, AEMO is not considering any material changes to the manner in which it forecasts retail electricity prices.

3.7.2. Weather and climate

Current approach

AEMO uses Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) in its consumption forecasts, with Section A2.1 of the electricity demand forecasting methodology setting out the critical temperatures and formulae used in the calculation of those metrics. Section A2.2 notes that daily observations back to 1 January 2000 are used to determine the median weather standard (that is, the HDD and CDD values which are applied to consumption forecasts).

The manner in which the methodology accounts for climate change is described in Section A2.3 of the methodology. The approach, involving collaboration between AEMO, CSIRO and the Bureau of Meteorology (BoM), adopts a quantile-to-quantile matching algorithm to statistically scale publicly available daily minimum, mean and maximum temperature data out to 20 to 50 years. The approach ensures the historical weather variability is maintained within each climate scenario modelled.

Potential changes

Currently, AEMO uses one weather station per region when gathering daily weather observations for the purpose of calculating HDDs and CDDs. AEMO is considering whether to expand the number of weather stations used, to better inform the diversity of weather within a NEM region. The choice of weather stations is an input, rather than a methodology, therefore the methodology itself would be unaffected by this potential change, and AEMO would continue to consult on the relevant list of weather stations within the IASR and associated consultation.

AEMO is considering whether using weather data as far back as 2000 is still appropriate. A median weather standard based on a shorter and more recent dataset may be more reflective of short- to medium-term weather outcomes, however this has the disadvantage of potentially removing relevant years from the analysis.

AEMO considers that the climate change adjustments to annual consumption and maximum demand are still fit-for-purpose and is not considering any changes to the existing approach.

Question
13. Should AEMO continue to use weather data back to the year 2000 when determining the median weather standard? If not, what time period do you consider appropriate?
14. Are the weather variables (average 30-minute temperature compared to critical temperatures) used in AEMO's weather standards still appropriate?
15. Are the adjustments for the impact of climate change on consumption and demand appropriate? If not, how might they be improved?

3.7.3. Rooftop PV and energy storage

Current approach

Appendix A3 of the electricity demand forecasting methodology sets out the approach to forecasting Rooftop PV and energy storage. AEMO currently obtains PV and energy storage capacity forecasts from one or more appropriately skilled consultants each year, and the methodology notes a range of key drivers, including:

- Financial incentives, including state-funded rebate schemes.
- Installation costs.
- Payback periods, considering retail electricity prices and feed-in tariffs.
- Population growth.

- Uptake of complementary technologies, such as batteries and EVs.

AEMO's PV generation profiles are based on solar irradiance data from satellite and ground observations. This generaion profile is multiplied by the rooftop PV capacity forecasts to produce a forecast of rooftop PV generation.

Energy storage charge and discharge profiles are currently provided by the same consultant(s) that provides the capacity forecast. Profiles are based on historical solar irradiance and apply various battery operating strategies to, for example, minimise customer bills, or reduce overall system costs (by being operated as a virtual power plant).

Electrical losses associated with storage systems' charging and discharging cycles are accounted for in residential and BMM energy consumption.

Proposed changes

AEMO recognises that, following the early wave of PV adoption, many PV owners are now considering PV retirements, upgrades and/or replacement. AEMO considers it appropriate, where suitable data exists, to incorporate these dynamics into the forecasts.

AEMO considers the drivers for rooftop PV uptake used in the current approach to be sufficient, but recognises that the explainability of the forecasts may be improved. AEMO seeks stakeholder input on whether the existing methodology (including consultancy reports that describe the methodologies deployed) adequately provides suitable explainability?

Regarding PV generation profiles, AEMO is considering whether additional data sources may be appropriate to improve the calibration of generation profiles developed using solar irradiance estimates to site measurements (potentially via a sampling approach). Such an approach may enable broader consideration of factors such as export limits, panel and inverter performance.

Regarding energy storage, AEMO is considering expanding the description of energy storage losses to add an explanation of how losses may be included in both half hourly traces and annual consumption forecasts.

Potential changes

AEMO is seeking stakeholder views on whether additional clarity may be provided in the methodology, including greater description on the approach and transparency for CER forecasting interpendency, and the impacts of CER on peak demand and minimum demand forecasts. This would also be the case if AEMO developed models to supplement/replace the consultant forecasts which are a current feature of the methodology.

Question
16. Do stakeholders consider that the current collection of methodologies, published by AEMO and/or its consultants, provide sufficient transparency on its approach to forecasting PV, battery and VPP uptake and operation?

3.7.4. Electric vehicles

Current approach

Section A4 of the electricity demand forecasting methodology sets out AEMO's approach for forecasting EVs.

The EV uptake forecasts considers sales data, government and state policies, relative prices between alternate vehicle types, payback period, vehicle purchasing trends, utilisation rate, battery and technology improvements, and decarbonisation targets.

The EV charging profiles are data-driven, and change day to day and over the longer term as infrastructure, charging technologies and tariffs adapt to the emerging sector.

The EV consumption forecast allows for the availability, popularity and technical charcateristics of home, business and public charging facilities, evolving vehicle mix, utilisation rate, varying travelling distances and market share of short- and long-range vehicles.

Proposed changes

AEMO recognises that the current methodology describes specific charging concepts. While it is appropriate to include descriptions of general charging behaviour concepts, AEMO considers that the forecasts should have flexibility to apply charging behaviours independent of specific charging concepts described in the methodology. As such, AEMO considers that charging behaviours described in the methodology be described as non-exhaustive and examples, and for the charge profiles to be described and consulted on in the normal IASR consultation process for this key input.

Question
17. Do you support AEMO's proposal to remove specific references to the types of charging behaviours adopted in its EV forecast methodology and instead include these in the IASR?

3.7.5. Connections and uptake of electric appliances

Current approach

Section A5.1 of the electricity demand forecasting methodology sets out AEMO's approach for forecasting connections, which combines actual electricity connections (sourced from AEMO's role as retail market operator) and a residential building stock model that combines electricity connection growth rates and Australian Bureau of Statistics (ABS) household projections. The spread between scenarios is informed by AEMO's economic consultant's economic and population forecasts.

Section A5.2 of the methodology provides detail on AEMO's appliance stock model and how it influences AEMO's annual energy consumption forecast. Appliance data from the Residential Baseline Study (RBS)[12] is converted into a growth index per household for each of heating load, cooling load and base load, with the each index comprising appliances relevant to those types of loads. These growth indices are then applied to the reference year of the forecast (that is, the year before the first forecast year).

[12] DISER, 2021 Residential Baseline Study for Australia and New Zealand for 2000 – 2040, at https://www.energyrating.gov.au/industryinformation/publications/report-2021-residential-baseline-study-australia-and-new-zealand-2000-2040.

Proposed changes

To the extent possible, AEMO would prefer that the electricity demand forecasting methodology removes references to specific *inputs* to the methodology, as these may change over time as better data sources become available. Changes to inputs are more appropriately described in documents such as the *Inputs, Assumptions and Scenarios Report*, or a *Forecasting Assumptions Update*. AEMO proposes to update the methodology to refer to the RBS as one of the data sources that AEMO may consider when forecasting the impact of the take-up of different appliances.

Potential changes

AEMO considers that its connections model is reasonably sound and fit for purpose, notwithstanding the most recent year which was over-forecast due to explainable variances in various inputs.

One emerging challenge is forecasting the impact of embedded networks. These embedded networks are largely invisible to AEMO (being 'hidden' behind a single National Metering Identifier (NMI)) and can lead to distortions in the estimates of consumption per connection. AEMO is seeking stakeholder views on the role, scale, impact and data sources for embedded networks.

Question
18. Can you suggest data sources that would assist AEMO's investigation of the impact of embedded networks on consumption forecasts?

3.7.6. Residential/business segmentation

Current approach

Section A6 of the electricity demand forecasting methodology sets out AEMO's approach to separating historical consumption into the residential and business customer segments. This is required because the historical consumption data that AEMO uses in its forecasting is not split between these two customer groups.

AEMO has two approaches for this segmentation exercise. The first approach uses a representative sample of smart meter data to calculate average residential consumption per household for customers with and without rooftop PV. In regions without sufficient smart meter data, AEMO relies on a second approach, which uses data from the AER's Economic Benchmarking Regulatory Information Notice (RIN), together with rooftop PV data from the Clean Energy Regulator.

Once the residential consumption per connection has been calculated via one of the two above approaches, AEMO scales this to regional consumption by multiplying the value by the number of residential connections in that region. Finally, business consumption is calculated by deducting the residential annual consumption from the total distribution-connected delivered consumption (that is, business consumption is the balancing item between total grid consumption and the calculated consumption for residential customers).

Potential changes

AEMO considers that its residential-business segmentation process is sound and fit-for-purpose.

4. Summary of issues for consultation

Submissions may be made on any matter relating to the electricity demand forecasting methodology discussed in this consultation paper. AEMO would welcome in particular comments and feedback on the following questions. AEMO would also welcome additional feedback on relevant and material issues not described in this consultation paper.

Details on how to submit to this consultation, including the key milestones, are included in Section 1.

Summary of Questions presented in this Consultation Paper

1. Does a component-based forecasting approach continue to provide a fit-for-purpose method that reflects best practice for electricity demand forecasting?
2. Are the customer segments appropriate aggregations of electricity consumers, and do they provide sufficient capability to apply aggregate methodologies for each in order to forecast each cohort's future electricity consumption?
3. Do you have any comments on the benefits of AEMO developing specific sub-regional consumption and demand forecasts? Are there specific inputs and assumptions that are more likely to be important to understand on a spatial level more granular than the NEM region, or would a simpler allocation approach of the regional forecasts provide sufficient insight to inform sub-regional forecasting?
4. Do you have any views on whether the existing commitment criteria for LIL inclusion in the single scenario forecast should be expanded to include a similar level of certainty as the 'anticipated' generator developments?
5. Do you have any comments on if the forecasting approach should apply criteria differently across the short and long term?
6. Are there any other changes that AEMO should consider to the methodology for developing hydrogen forecasts, beyond expanding its use into other green commodities?
7. Should AEMO create a separate customer segmentation for data centres, removing them from the LIL and BMM segments? Would the preferred approach apply a survey-driven forecast, observations from international trends, or another technique?
8. Are there other sectors which should have their own category within the BMM model?
9. Do you think AEMO should be considering any other external drivers of energy consumption when developing its residential consumption forecasts?
10. Should AEMO's approach to the solar rebound effect take into account differences in the impacts on base load, cooling load and heating load? What data sources exist that may help to estimate these impacts?
11. What data sources can stakeholders recommend that provide additional visibility or insights on non-scheduled generators?
12. Do you have any comments on AEMO's potential improvements to developing demand traces?
13. Should AEMO continue to use weather data back to the year 2000 when determining the median weather standard? If not, what time period do you consider appropriate?
14. Are the weather variables (average 30-minute temperature compared to critical temperatures) used in AEMO's weather standards still appropriate?
15. Are the adjustments for the impact of climate change on consumption and demand appropriate? If not, how might they be improved?
16. Do stakeholders consider that the current collection of methodologies, published by AEMO and/or its consultants, provide sufficient transparency on its approach to forecasting PV, battery and VPP uptake and operation?
17. Do you support AEMO's proposal to remove specific references to the types of charging behaviours adopted in its EV forecast methodology and instead include these in the IASR?
18. Can you suggest data sources that would assist AEMO's investigation of the impact of embedded networks on consumption forecasts?