Review of the ATA's household fuel cost models

REPORT FOR THE ALTERNATIVE TECHNOLOGY ASSOCATION (ATA)

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Executive summary

Frontier Economics was engaged to review the ATA's models used to calculate the competitiveness of household fuel options for a range of representative households across Eastern Australia (or National Electricity Market).

Our approach was to:

- Benchmark and test the ATA models against best practice processes—both in terms of incorporating the key relevant economic relationships and utilising appropriate modelling techniques; and
- Set out our findings and recommendations in a way that provides the ATA with clear opportunities to incorporate relevant best practice model design features over the short and longer-term.

A summary of our key findings and ATA's response is set out in Table 1; for more detail regarding our recommendations across the four models, see the QA log.

Our review and recommendations are based on models and associated documentation provided between January and March and has been updated to reflect the ATA's final response to our Draft Report (received 15th May 2017).[1] We have not reviewed the ATA's proposed changes as this is outside the scope of this project.

Table 1: Frontier Economics' key recommendations and potential response pathways

Principle	Frontier Economics recommendations and response pathway
Models/scenarios should reflect household consumption for the key household types in the NEM	The consumption assumptions (both total household consumption and 'end-use' appliance consumptions) are not representative of household consumption in the NEM. Over the longer term we recommend estimating consumption via a top down approach (rather than trying to build up the energy required for each end-use appliance) using actual data from publically available sources such as IPART's 2015 household survey (which contains information on the relationships between household energy consumption and key household characteristics by climate zone) and the AER's consumption benchmarks.[2] Over the short term we recommend including an estimate of the number of hours of space heating in the estimation of a household's heating load. The total energy assumed for electric space heating is materially understated when compared to actual data (see, for example, IPART's 2015 household survey).

1 Specifically the responses outlined in the ATA (2017), *Summary of Frontier recommendations and ATA response* and ATA (2017), *ATA Response to Frontier Economics' Draft Report on Household Fuel Models.*

2 While there are a number of methodological flaws in the AER's 2014 energy consumption benchmarks, the AER may address these issues in its 2017 update.

	The ATA have indicated that they will develop a heating and cooling model that uses NatHERS and E3 data along with 30-minute temperature data to determine heating and cooling energy requirements and add them to the interval data for each household type and location. The ATA is confident that their approach is robust, and that the estimates, when sense-checked against other estimates of both energy and water usage, are credible.
Models/scenarios should capture the variability in residential household consumption across the key household types in the NEM	The models would benefit from using actual consumption data (either total consumption or 'end-use' consumption) to ensure the assumed household consumption figures (both total consumption and the pattern of consumption throughout the year and day) reflect the significant diversity in consumption that exists across household types. In the short term we recommend using actual consumption data to ensure that the consumption profiles are broadly in line with actual household consumption. The ATA have indicated they believe that the consumption figures are credible. The ATA have also indicated that as they will be developing a new model, they will use new underlying consumption profiles without cooling. They will use interval data from southern Victorian households matching the household types that have gas heating, cooking and hot water and no cooling.
Models/scenarios should capture the variability in residential household consumption across the key household types in the NEM	It is not clear that the scenarios or household types capture the diversity in residential household consumption across key households (or customer archetypes) in the NEM. This diversity across the NEM occurs in terms of total consumption and end-use consumption (in annual, seasonal and hourly profiles). The diversity that currently is assumed between some scenarios is not representative of actual household consumption in the NEM or cannot be explained by the key drivers of household consumption. As shown in Figure 8 and Figure 9 the underlying consumption profiles (consumption excluding water heating, space heating and cooking) don't seem to reflect the relativities between household types. For instance, a small house has more people than a working couple (and are likely to be at home more than a working couple), yet the consumption profile is significantly lower than the working couple at all times, despite the fact that they live in the same size house. The models would benefit from using actual consumption data (either total consumption or 'end-use' consumption) to ensure the assumed household consumption figures reflect the significant diversity in consumption that exists across household types. Household scenarios would benefit from: • The inclusion of an apartment household type • Using Climate Zones to capture most material differences across household consumption driven by location. In the short term we recommend including an apartment household type and adding an additional zone in South Australia. Over the long-term we recommend using Australian climate zones as the locations in the models (rather than gas and electric zones). The ATA have indicated they have corrected the household composition information and clarified the dwelling types. They have also derived new profiles for the Large Home and New Build. The ATA considers that the inclusion of an apartment household type is impractical for the purposes of this project. The ATA have indicated that the will develop a new model that will add more granular heating and cooling loads to move accurately reflect locational differences in underling profiles and heating loads.

	However, they note that as they will calculate heating, cooling and hot water loads separately, and climate-related factors are part of the modelling approach, climate-related differences in the underlying consumption are of less significance that if the profiles were representing all consumption.
Models/scenarios should capture the seasonal nature of household consumption	The models would benefit from calculating bills on a consistent, monthly basis, as calculating some bills on a monthly basis and some on an annual basis will not capture the significant variability in household consumption across the year. In the short term we recommend using a consistent approach to calculating bills across all four models. Over the longer term we recommend integrating the four models into a single model.
	The ATA have indicated they will calculate all bills quarterly (except Victorian gas bills, calculated bi-monthly).
Models/scenarios should capture the material variability in solar PV generation across the key household types in the NEM	Models / scenarios would benefit from the option to: • have the solar PV system power a household's energy consumption regardless of the end-use driving the consumption; • incorporate different panel sizes such as 1.5 kW, 3 kW and 5kW; • the use of actual PV output data (e.g. data from IPART's household survey). In the short term we recommend incorporating different panel sizes. Over the long term, we suggest using actual PV output data and allowing the solar PV system to power a household's energy consumption regardless of the end-use driving the consumption.
	The ATA have indicated that the new model will ensure that heating, cooling and hot water will be included in solar calculations. The ATA have indicated that they have adjusted the solar modelling to use 5 kW for new systems, but 2.5 kW for existing systems. The ATA have indicated that the Sunulator accounts for solar variability and sub-optimal conditions.
Models/scenarios should capture the uncertainty in future energy tariff structures and levels over the forecast period (25 years)	The models would benefit from the use of scenarios in forecasting future tariffs given the uncertainties around the future cost of retail gas and electricity supply (incl. climate policy and fuel costs) and future tariff structures. In the short term, we recommend using publically available data to inform trends and scenarios in future energy tariffs (including AEMC price trends, and AEMO assumptions). Over the longer term we recommend considering getting specific advice around forecasting future tariff prices.
	The ATA have indicated that the index used to estimate future price changes is based on the most recent AEMO forecasts and that this approach is no less accurate than any other. ATA have indicated that they will undertake sensitivity analyses using higher and lower indexes.
Models should capture the interactions between tariff levels and	The models do not consistently calculate bills to incorporate the interactions between tariff levels and consumption and vice versa. The models would benefit from having one section/model calculate the relevant electricity and gas consumption and another section/model calculate the relevant bills, rather than having multiple models calculate household consumption and bills.

consumption and vice versa	In the short term we recommend using the *Sunulator* and the *Gasulator* to calculate total consumption with and without solar PV (rather than calculating a household bill with and without solar PV) and calculating the household's relevant bills in the fuel cost model. In the long term we recommend consolidating the four models into one.
	The ATA have indicated that their new model will allow the Sunulator to calculate all household quarterly consumption (except for cooking, which will be added to quarterly consumption at the appropriate tariff rate) The ATA will continue to calculate gas bills in the Gasulator as it incorporates the seasonal nature of most gas tariffs.
Calculations that rely on results from other calculations should be integrated into the same model	The models would benefit from consolidation. In the short term, care should be taken to ensure that each model uses exactly the same assumptions as the other models and calculates bills in the same way across the four models. In the long term, the four models should be consolidated into one model.
	The ATA have indicated they are ensuring that assumptions and calculations are done consistently across scenarios.
General comment	The models would benefit from correcting the Vlookup formula in the ResultsSS tab in the fuel cost model as per the QA log. In the short term, correct the vlookup formula as per the QA log.
	The ATA have indicated they are implementing all the proposed changes to formulas and functions

Source: Frontier Economic

1 Background and context for the QA review

Australia's energy markets are entering a period of significant change. Increasing household choice and awareness of (increasingly affordable) energy supply options has focused attention on the competitiveness of traditional energy sources as a fuel choice for households.

In this dynamic energy market, it is important that households, governments and industry are provided with information to allow them to make informed decisions. In order to improve the community's understanding of the cost competitiveness of different fuel types, the ATA are in the process of replicating their 2014 project that estimated the up-front and running costs of efficient gas and electric appliances for a variety of uses.

To ensure that any findings are robust (in terms of the use of best practice modelling and assumptions) and realistic (in terms of reflecting the way households use energy and the diversity between households), Frontier Economics was engaged by the ATA to verify the modelling done for this project. Given time and budgetary constraints, this review focuses on the overarching processes and assumptions for the models.[3]

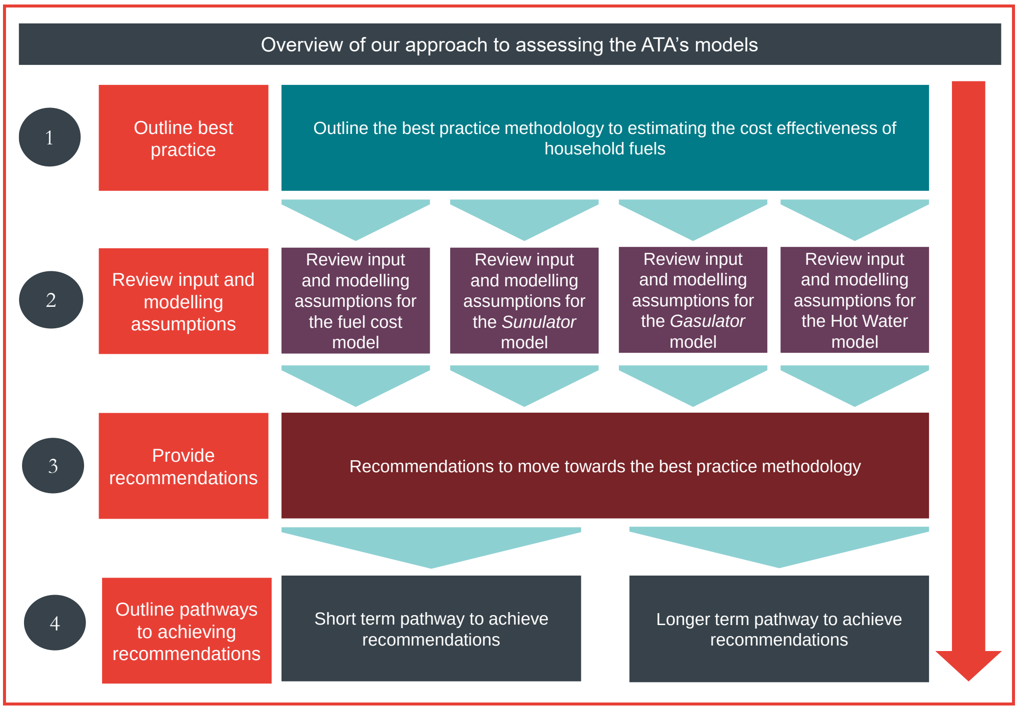
1.1 Our approach to the review and the structure of this report

To ensure that our assessment of the ATA's models is robust and objective, we have adopted the following four step process (as outlined in Figure 1):

1. Outline the best practice process to estimating the cost-effectiveness of household fuels;
2. Assess the fuel costs model, the *Sunulator* solar generation model, the *Gasulator* gas bill model and the hot water model against the best practice methodology and document the findings;
3. Recommend changes required to address any shortcomings of the models; and
4. Outline a short-term and long-term pathway to achieving these recommended changes.

3 More specifically, we have not checked each line of code and all the calculations involved in the ATA's modelling, but have checked the logic and assumptions of the processes by which the results were obtained.

Figure 1: Overview of our approach to assessing the ATA's models



Source: Frontier Economics

In particular, our approach to this QA is structured around answering several broad questions:

- Do the models accurately estimate household consumption? For example:
  - Do the models capture the variability in household consumption across key households types in the NEM in terms of characteristics such as dwelling type, household size, location and appliance use;
  - Do the models capture the seasonal nature of household consumption; and
  - Do the models capture the variability in solar photovoltaic (PV) generation across household archetypes in the NEM?
- Do the models accurately capture the household appliance switching process?
  - Do the models capture the variability and changing nature of the household appliance stock and the options available to households; and
  - Do the models capture differences in the way gas and electric appliances are used?
- Do the models accurately estimate current and future household bills? For example:
  - Do the models capture the interactions between tariff levels and consumption, and vice versa; and

- Do the models capture the uncertainty in future energy tariff structures and levels over the forecast period (25 years)?

The remainder of the report is structured as follows:

- Section 2 provides an overview of the ATA's fuel cost models including their underlying assumptions and how they interact with each other;
- Section 3 outlines the best practice methodology for estimating the cost effectiveness of household fuels;
- Section 4 provides a summary of our findings and assessment of the models; and
- Section 5 outlines our recommendations and the proposed pathways to achieving these recommendations.

2 The ATA's fuel cost models

This section provides an overview of the models used by the ATA to estimate the competitiveness of household fuels. In particular:

- Section 2.1 provides an overview of the household types, scenarios and locations used in the analysis;
- Section 2.2 provides an overview of the interaction between the models; and
- Sections 2.3 to 2.6 provide overviews of the Fuel cost, *Sunulator, Gasulator* and the Hot Water model, respectively.

2.1 Overview of household types, scenarios and locations

The 2017 project expands on the 2014 project through the utilisation of the *Sunulator*, *Gasulator* and Hot water models. Compared to the 2014 project, the 2017 project utilises a reduced number of dwelling types, while increasing the complexity of the individual scenarios modelled.

Household types

The household types modelled in the 2017 project are comprised of:

1. **A large house** comprised of two adults and two children living in a free-standing dwelling;
2. **A small house** comprised of two adults and two children living in a free-standing dwelling;
3. **A stay at home** family comprised of two adults and one child living in a free-standing dwelling;
4. **A working couple** comprised of two adults living in a free-standing dwelling; and
5. **A new build** comprised of two adults and two children living in a five-star rated, free-standing dwelling.

Household scenarios

Household types one to four are modelled under several scenarios in which a decision is made to replace one or more existing appliances at the point where it needs to be replaced, or it is highly likely to require replacement within five years. Scenarios include:

- Switching a gas appliance to electricity within five years of the end of life of the asset and staying on the gas network;

- Switching one gas appliance, of any age, to electricity and disconnecting from the gas network;
- Switching two gas appliances to electricity, at least one within five years of end of life, and disconnecting from the gas network; and
- All gas appliances are switched to electricity, where one appliance is within five years of the end of asset life.

For the new build household type the cost of installing new electric appliances is compared to the base case of having no electric space heating, water heating or cooking appliances.

Locations

Each household type and scenario is evaluated for each of the gas zones of Eastern Australia, which comprises seven Victorian gas zones, five NSW zones; two South-East Queensland zones; and one zone each for South Australia (Adelaide),[4] ACT (Canberra) and Tasmania (Hobart).

2.2 Overview and interaction between the models

In a residential setting, the primary use of reticulated (mains) gas occurs across three main end uses: space heating, water heating and cooking. As summarised in Figure 2, four models are utilised to calculate the competitiveness of household fuels across these three end uses for the various household types, scenarios and locations. In particular:

- **Model 1: Fuel cost comparison model:** calculates the competitiveness of household fuels for a number of household types and scenarios for each gas zone in Eastern Australia, using findings from the *Sunulator*, the *Gasulator* and Hot Water models.
- **Model 2: *Sunulator* model:** Calculates annual residual[5] and hot water electricity bills across household types, scenarios and locations, with and without PV;
- **Model 3: *Gasulator* model:** Calculates monthly gas bills across the household types, scenarios and locations.
- **Model 4: Hot water model:** Calculates the energy consumed in heating water per day across the household types, scenarios and locations.

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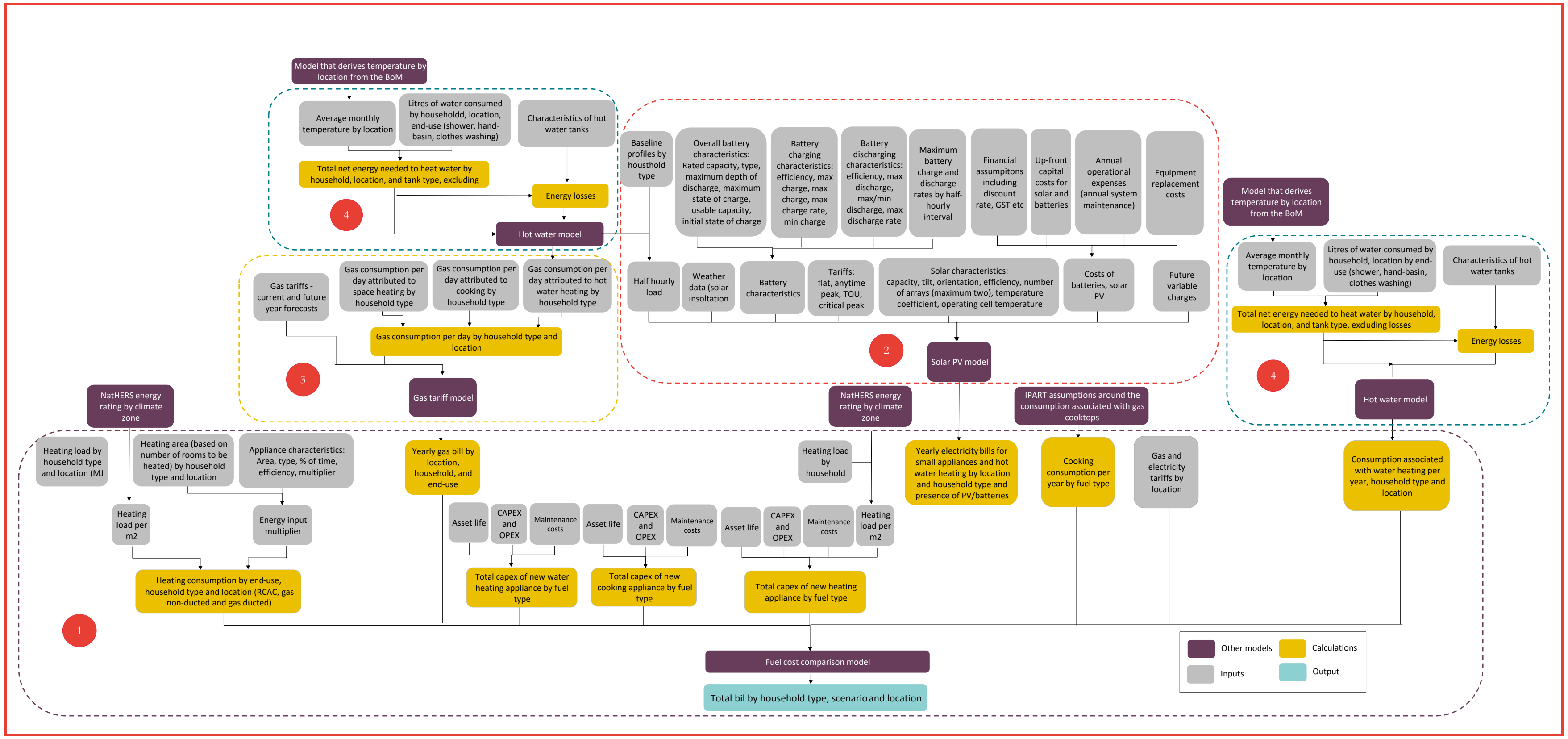
4 Although South Australia has five gas zones, there is very little tariff variation between zones; hence only one zone was considered.

5 Electricity consumption that is not associated with hot water, space heating and cooking.

Figure 2: Calculating the competitiveness of household fuels: The interaction between the 4 models



Source: Frontier Economics

2.3 Model 1: Fuel cost comparison model

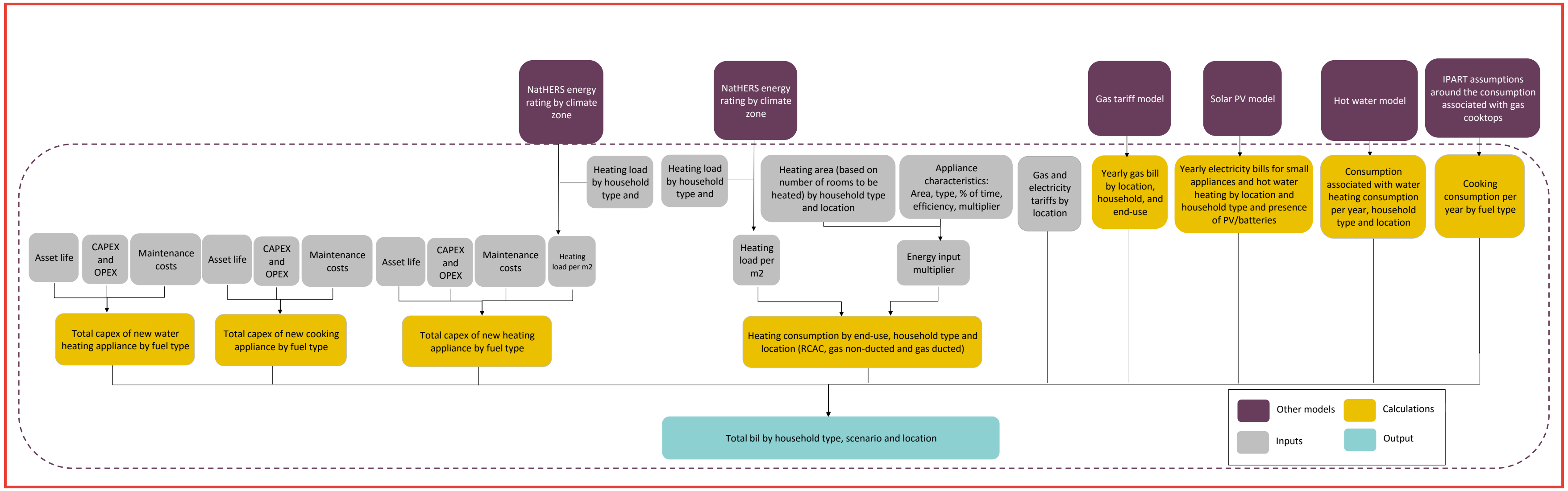
As summarised in Figure 3, the fuel cost comparison model is designed to calculate the competitiveness of household fuels for a number of household types across Eastern Australia. In particular, the model uses findings from the *Sunulator*, *Gasulator* and Hot Water models to estimate the costs of switching hot water, heating and/or cooking appliances from gas to electricity, as well as estimating the impact of installing solar panels. Key inputs of the model include:

- An estimate of household gas bills for the current year by household type, location and end-use as estimated in the *Gasulator;*
- An estimate of household yearly electricity bills for small appliances (not space heating or cooking) and water heating by household type, location and presence of solar PV as estimated in the *Sunulator*;
- An estimate of household gas consumption associated with gas water heating per year by household type and location as estimated in the Hot Water model;[6]
- An estimate of household cooking consumption per year by fuel type;
- An estimate of household space heating consumption per year by fuel type, location and household type calculated using an estimated of the household type's relevant heating load;
- Relevant current and future gas and electricity tariffs; and
- Relevant information on the costs of replacing electric appliances, including asset life, capex and opex and maintenance costs.

For more detail regarding model processes and inputs see the QA log.

6 While consumption associated with water heating is calculated in the Hot Water model, consumption associated with space heating and cooking is calculated within the Fuel cost model.

Figure 3: Overview of the fuel cost comparison model:



Source: Frontier Economics

2.4 Model 2: *Sunulator*

As summarised in Figure 3, the fuel cost comparison model requires an estimate of the household electricity bills associated with different end uses by location to calculate the relative competiveness of household fuels. The household's initial (prior to switching) electricity bill is calculated in the *Sunulator* model. The *Sunulator* also calculates the value of solar PV for each relevant scenario and a household's subsequent electricity bill after switching. As shown in Figure 4, key inputs of the model include:

- 19 years (1994-2013) of solar insolation data from the BOM to help estimate generation.
- Consumption profiles for electricity consumption that is not associated with space heating, cooking or water heating. This is referred to as residual or underlying load.
- Relevant information on 5kW solar panels and batteries, such as capital costs;
- Total electricity consumed to heat water per day by household type, location and tank type (excluding losses) from the Hot Water model;
- Relevant current and future tariffs by location (including flat, anytime, peak, time-of-use and critical peak demand tariffs);

The model is restricted to 5kW solar PV systems, and assumes that any existing or new solar PV system will only power (in part) the residual and hot water load[7] (and thus space heating and cooking electrical loads are entirely powered from the grid). For the scenarios with solar PV, the energy required to heat water (as estimated in the Hot Water model) is added to the underlying electrical load profile for that household type. The combined profile is then modelled on a 30-minute basis to understand exactly how much of the total electrical load the solar PV system will serve over the course of a year.

Customer electricity bills by household type and location are then calculated by 'netting off' generation versus consumption specific to that location and user profile, for each 30 minute interval over a full year.

For more detail regarding model processes and inputs see the QA log.

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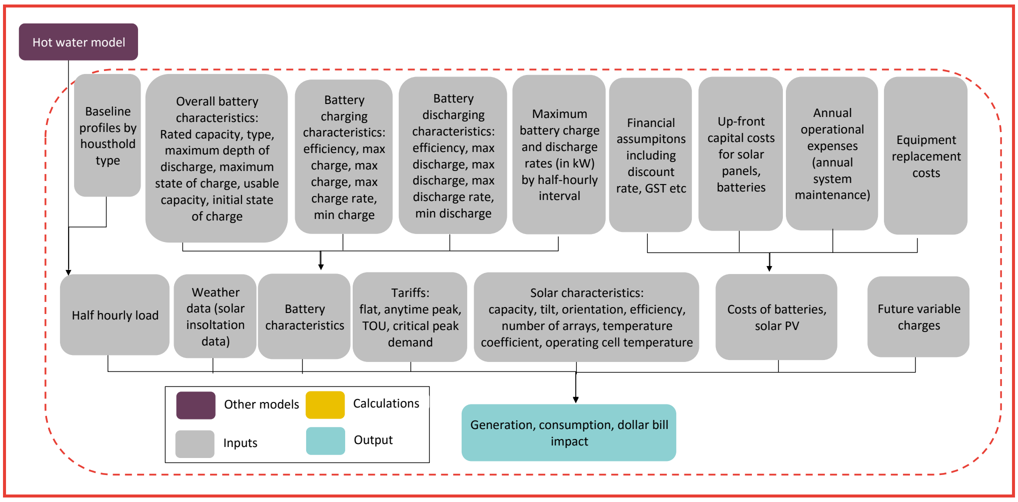
7 This is different to the documentation provided on the Sunulator which states that solar power will only power the hot water load.

Figure 4: Overview of the *Sunulator* model:



Source: Frontier Economics

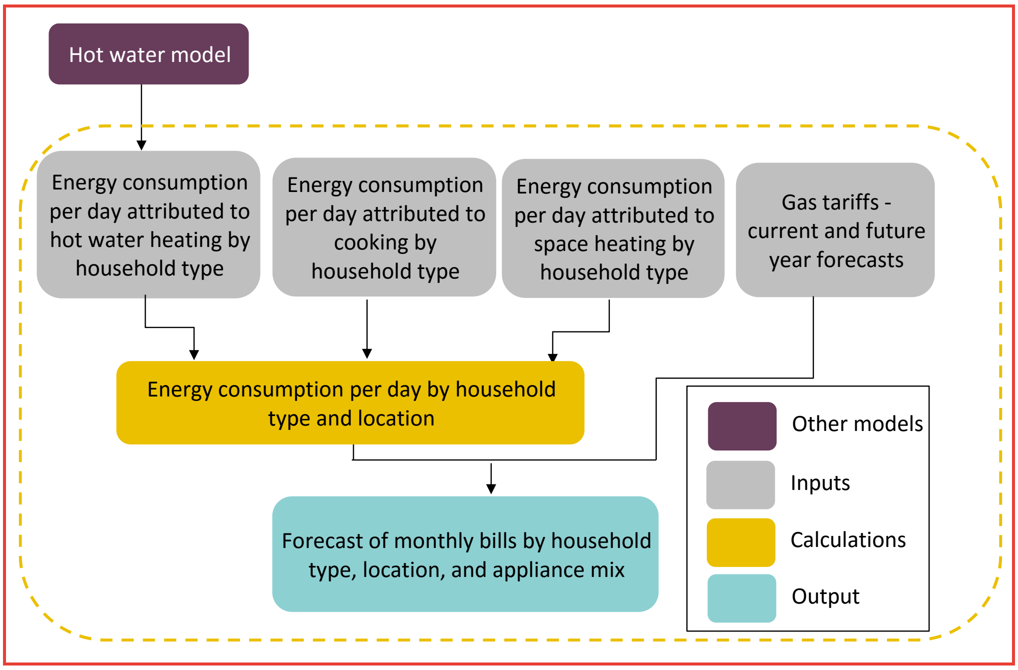
2.5 Model 3: *Gasulator*

As summarised in Figure 3, the fuel cost comparison model requires an estimate of the gas consumption associated with different end uses by household type and location to calculate the relative competiveness of household fuels. The household's initial (prior to switching) gas bill is calculated in the *Gasulator*. In particular, the *Gasulator* calculates a household's relevant gas bill by household type, location and appliance mix. As shown in Figure 5, key inputs of the model include:

- Total gas consumed to heat water per day by household, location and tank type (excluding losses) from the Hot Water model;
- Total gas consumed per day attributed to gas cooking by household type;
- Total gas consumed per day attributed to gas space heating by household type and location; and
- Relevant current and future gas tariffs by location (including block, peak and off-peak tariffs).

For more detail regarding model processes and inputs see the QA log.

Figure 5: Overview of the *Gasulator model*



Source: Frontier Economics

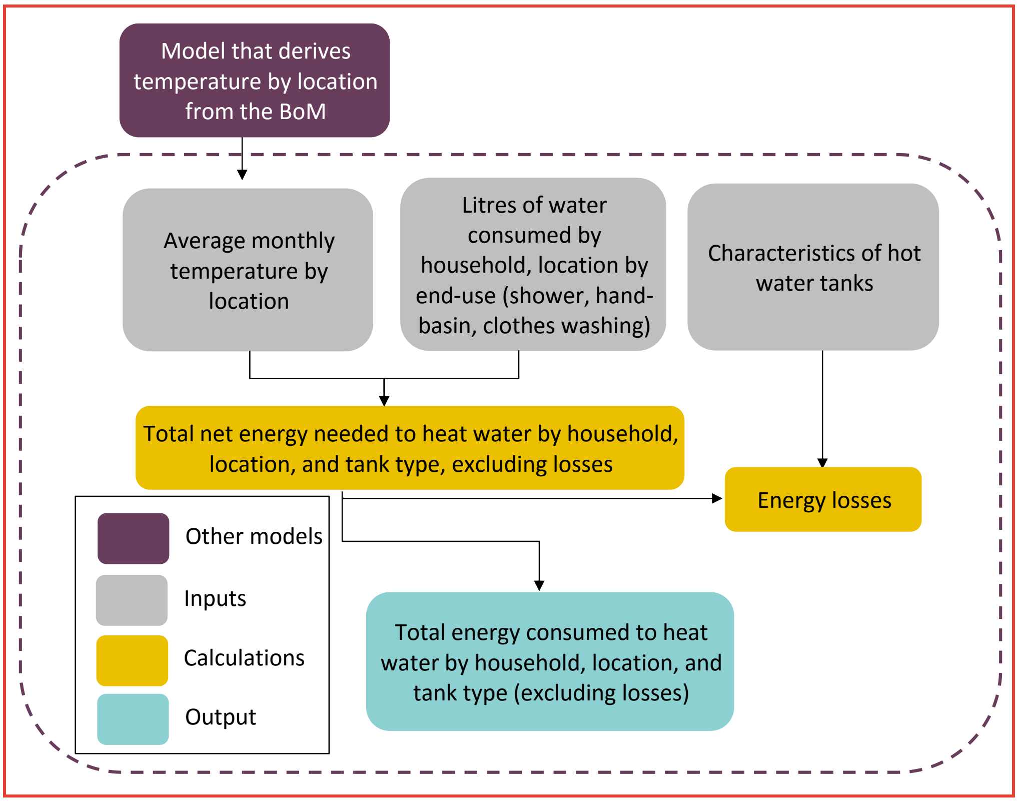
2.6 Model 4: Hot Water model

As summarised in Figure 2, the other models require an estimate of hot water consumption by fuel type, household type and location. The hot water model is an "engineering" model of hot water consumption for each household type for a variety of locations around Australia. The Hot Water model constructs half hourly electrical and gas hot water loads based on:

- Bureau of Meteorology (BoM) ambient temperature by location data;
- Hot water demand from various uses within the home, including the use of showers, hand basins, dishwashers and washing machines;
- The required water storage (as relevant) and delivery temperature;
- Standing losses(as relevant); and
- Information on the gas storage appliances used to heat and store (as relevant) and deliver the hot water, and the efficiency of that hot water appliance (all households are assumed to have the same hot water tank).

For more detail regarding model processes and inputs see the QA log.

Figure 6: Overview of the Hot Water model



Source: Frontier Economics

3 Best practice processes

Estimating the cost-effectiveness of household fuels is not a simple exercise, with the respective costs of gas and electricity consumption depending significantly on various, interrelated factors, which must be taken into account to ensure a robust estimation of the upfront and ongoing cost of various household fuels.

For instance, work by Frontier Economics analysing the results of the 2015 IPART Household Survey[8] outlined the need to account for several key factors when seeking to understand the impacts that changes in energy sources and energy consumption may have on household energy bills, including that:

- There is significant diversity in NSW household energy consumption, even within regions, with a household's specific consumption pattern being a key determinant of the competitiveness of energy sources;
- There is a relationship between household energy usage and the incremental cost of using energy (as a result of the structure of electricity and gas tariffs), which can dampen or exacerbate the impact on bills from changes to consumption; and
- There is significant uncertainty related to future changes to retail electricity and gas prices (both the level and structure of tariffs).

These factors are not mutually exclusive and may involve complex trade-offs and interactions. As such, any model comparing the cost effectiveness of household fuels must account for each of these factors and the relationship between the factors.

In order to ensure that the findings from ATA's models are robust and defensible, step one of our quality assurance process involves developing a clear methodology to underpin our systematic assessment of ATA's models, informed by our experience. Table 2 and Table 3 provide an overview of the best practice approach to modelling residential household fuel competitiveness.

8 Frontier Economics (2016), *Determinants of Household Energy Consumption: A Report Prepared for the Independent Pricing and Regulatory Tribunal.*

Table 2: The best practice approach to modelling household fuel competiveness (economic relationships)

Principle	Why
Economic relationships	
Assumptions about total and end-use consumptions should reflect the key household types in the NEM	Household consumption is a material driver of the competitiveness of different fuel types Household consumption (including take-up, use of, and performance of appliances) varies significantly between households – driven by climate, income, household type and size. The temporal nature of these relationships is summarised in Table 5
Models should capture the seasonal nature of household consumption	Household energy bills are typically calculated quarterly, and household consumption can vary significantly by season – particularly for those climates with more extreme winters/summers and for those households with extensive space heating/cooling requirements
Models/scenarios should capture the differences in the way gas and electric appliances are used	Households using gas appliances will consume energy differently to those using electric appliances as a result of customer preferences and appliance performance i.e. it is not a simple 'like for like' substitute
Models/scenarios should capture the material variability in solar PV generation across the key household types in the NEM	The quantum and profile of solar PV generation has a significant effect on billed electricity consumption However, the effect of solar generation on household consumption varies significantly with location-specific variables such as size of the panels, the panel location and the tile and potential coverage of the household roof
Models should capture the interactions between tariff levels and consumption	Household consumption levels determine the incremental cost of using electricity or gas due to the declining or inclining block structure of most network and retail tariffs. That is, the incremental cost of an additional hour of heating/cooling will not be the same for each customer (as it will depend on the total amount of energy used by other appliances in the household) Similarly, tariff levels (and the incremental cost of operating an appliance) will influence consumption (i.e. there is an elasticity response), although some household or appliance consumption is more influenced by price than others
Models/scenarios should capture the uncertainty in future energy tariff structures and levels over the forecast period (25 years)	Household energy tariff structures and levels are material drivers of the competitiveness of different fuel types

	Future household energy tariff levels are highly uncertain and likely to be driven by future climate policy, mix of energy generation (distributed and non-distributed), fuel costs (incl. coal and gas) and demand across the NEM Future household energy tariff structures are also uncertain and influenced by technology (such as metering), government policy and customer preferences
Models/scenarios should capture the variability in household appliance stocks and the options available to households	Household choice of appliance stock has a material impact on energy consumption and thus household bills

Source: Frontier Economics

Table 3: The best practice approach to modelling household fuel competiveness (modelling techniques and practices)

Principle	Why
Modelling techniques and practices	
Calculations should be done in a way to allow others to use or QA the model easily	Designing the model so that calculations are transparent facilitates any use or review of the model, which will assist in ensuring robust estimates
Calculations that rely on results from other models should be integrated into the same model, or should be dynamically linked	Utilising subsidiary models to calculate inputs for other models and hard-coding the results from one model in another, makes it difficult to check any results and increases the risk of failing to update the full model when inputs are updated (i.e. user error).
Tabs and cells should be colour-coded to indicate whether they contain inputs or calculations, and they should only contain inputs or calculations (not both)	Designing the model so that calculations are transparent facilitates any use or review of the model, which will assist in ensuring robust estimates
Cells should (where relevant) reference named ranges, rather than cells	Designing the model so that calculations are transparent facilitates the use and review of the model, which will assist in ensuring robust estimates
Any assumptions should be correctly documented	To develop transparent and robust estimation process, any assumptions used should be documented to allow others to check the process
The models should only include information relevant to the calculation process	Irrelevant information complicates use or review of the model

Source: Frontier Economics

4 Summary of our findings and assessment

In order to ensure that the findings from the ATA's models are robust and defensible, steps two and three of our QA process involves ensuring that the ATA's fuel cost, *Sunulator*, *Gasulator* and Water Heating models are consistent with best practice (see the criteria in Section 3), and outlining any opportunities to incorporate best practice model design into the models.

The following sections provide an overview of the findings from our quality assurance process and a summary of the ATA's response (the blue boxes). In general, the first column of each table in each section highlights the relevant best practice principle, while the second column provides a summary of our relevant findings and recommendations and the ATA's response using a "traffic-light" system to provide an indication of its relative materiality. In particular,

- Red boxes indicate findings that require ATA's immediate attention;
- Orange boxes indicate findings that are not in line with best practice, but may not require immediate attention; and
- Green boxes indicate that we agree with the methodology and/or assumptions used.

For more detail regarding our findings, see the QA log.

4.1 Overarching findings

Given many of the models rely on the same underlying assumptions and methodology, Table 4 provides an overview of some of our general findings on the ATA's modelling process and their response. The subsequent sections address issues specific to the individual models that have not been previously discussed in Table 4. For more detail regarding our overarching findings, see the QA log.

Table 4: Overall modelling approach: Frontier Economics' key findings

Principle	Frontier Economics findings and recommendations
Economic relationships	
Assumptions about total and end-use consumptions should reflect the consumption of the key household types in the NEM	The consumption assumptions (both total household consumption and 'end-use' appliance consumption) are not representative of household consumption in the NEM. As shown in Figure 8 and Figure 9, the underlying consumption profiles (consumption excluding water heating, space heating and cooking) don't seem to reflect the relativities between household types. For example, as shown in Figure 9, the models assume working couple households in Sydney have electricity consumption of over 9,000kWh; however, results of the IPART 2015 household survey suggest that the average electricity consumption across all

	households in Sydney was only 7,788 kWh. A small house has more people than a working couple (and is more likely to have people at home than a working couple), yet the consumption profile is significantly lower than the working couple, despite the fact that they live in the same size house It is likely that during the day, a working couple's consumption more closely reflects the consumption of a small house (as neither have members of the household at home for long periods of time during the day), while during the morning and evening a small house and a stay at home family will have similar profiles The models would benefit from: • including an estimate of the number of hours of space heating in the estimation of a household's heating load. The total energy assumed for electric space heating is materially understated when compared to actual data (say IPART's 2015 household survey) • "engineering" estimates of the energy required for each end-use appliance should be replaced by, or calibrated against, actual consumption data from publically available sources such as IPART's 2015 household survey (which contains information on the relationships between household energy consumption and key household characteristics by climate zone) and the AER's consumption benchmarks.[9]
	The ATA have indicated they have corrected the demographic descriptions of household types and that they will build a heating and cooling model to determine heating and cooling requirements. This will enable the ATA to add daily heating loads to the *Gasulator* and 30-minute heating and cooling loads to the *Sunulator* in order to most accurately model heating and cooling energy usage.
The models should capture the variability in household consumption	Figure 7 shows that the assumed underlying consumption profiles (consumption excluding water heating, space heating and cooking) seem to have unusual patterns of peaks and troughs. Given they represent electricity consumption associated with appliances other than water heating, space heating and cooking it is unlikely that they would be as variable throughout the year The models would benefit from the use of actual consumption data to sense check the results.
	The ATA have indicated that the underling consumption profiles are derived from actual data of households without electric space heating, hot water and cooking, and with cooling absent or removed. They note that variability is found in all profiles and reflects variable behaviour with all other appliances, incidental use of supplementary heating and cooling, irregularities in time spent in the dwelling, and so on.

9 While there are a number of methodological flaws in the AER's 2014 energy consumption benchmarks, the AER may address these issues in its 2017 update.

The selection of household types should be representative of the households in the NEM	As shown in Section 4.1.1, the models and scenarios are unlikely to accurately capture the variability in residential household consumption across household types and locations in the NEM. The selection of household types and regions would benefit from: • The inclusion of an apartment household type • Using Climate Zones (rather than numerous existing gas/electricity zones) to capture most material differences across household consumption driven by location.
	The ATA note that "apartment" was omitted because fuel and fixed appliance choice is typically more constrained and thus the results will not be applicable to apartment dwellers The ATA have indicated that the new model will add location specific cooling loads to the underlying consumption profiles to improve their representativeness
Models/scenarios should capture the seasonal nature of household consumption	As shown in Figure 10 and Figure 11, household consumption varies significantly by season. As such, the models should estimate bills on a quarterly basis to reflect the seasonal nature of consumption. However, some models calculate bills on an annual basis The models would benefit from consistently calculating bills on a quarterly basis
	The ATA have indicated they will calculate all bills quarterly (except Victorian gas bills, calculated every two months)
Models/scenarios should capture the differences in the way gas and electric appliances are used	The models assume that a household with gas will use an electric appliance the same way as a household with electricity would use that appliance (i.e. households use the appliance in the same way regardless of what other appliances they may have) The models would benefit from further consultation with the reference group to ensure that they accurately capture differences in the use of electric and gas appliances
	The ATA agrees that incorporating the different ways households use different types of appliances would improve the robustness of the model, but the task is beyond the ATA's resources They note that their approach does not predict exact outcomes, but still provides useful information for households facing fuel choice decisions
Models/scenarios should capture the uncertainty in future energy tariff structures and levels over the forecast period (25 years)	The *Gasulator* assume a 3% increase in gas tariff levels each year regardless of tariff type and location. As shown in Section 4.1.2, given the significant uncertainty around future tariffs, this is unlikely to be representative of tariff levels into the future (for example, in the medium term it does not account for changes in network tariffs following recent AER's decisions) The models would benefit from the use of alternative scenarios for future tariffs

	The ATA have indicated that the index used to estimate future price changes is based on the most recent AEMO forecasts and that this approach is no less accurate than any other The ATA have indicated that they will undertake sensitivity analyses using higher and lower indexes
Models should capture the interactions between tariff levels and consumption	The model does not accurately capture the relationship between consumption and tariff levels, nor the significant uncertainty in forecasting future tariff levels (for more detail see Section 4.1.3) The models would benefit from having one section calculate the relevant electricity and gas consumption and another section calculate the relevant bills, rather than having multiple models calculate household consumption and bills
	The ATA agree that calculating partial bills in the *Sunulator* and adding cooking and heating costs at the marginal tariff rate risks missing the impact of block tariffs. The ATA have indicated that the new heating/cooling model means that the *Sunulator* will calculate all household quarterly consumption (except for cooking, which will be added to quarterly consumption at the appropriate tariff rate) The ATA note that the *Gasulator* is needed to calculate gas bills because it incorporates the seasonal nature of most gas tariffs and they will continue to calculate gas bills in the *Gasulator*
Modelling techniques and practices	
Calculations that rely on results from other models should be integrated into the same model, or should be dynamically linked	Utilising different models to calculate inputs for other models and hard-coding the results from one model in another makes it difficult to check any results and increases the risk of failing to update the model with the correct inputs. It also makes it difficult to ensure that the models account for all the factors influencing household energy bills, such as the interactions between tariff levels and consumption. The models would benefit from consolidating the four models into one model, or to link the models dynamically so that they can be easily updated
	The ATA have indicated that they will ensure that hard-coded results are entered accurately and will integrate the models as part of any future reiteration of the project.
Tabs and cells should be colour-coded to indicate whether they contain inputs or calculations, and they should only contain inputs or calculations (not both)	Tabs that contain both assumptions and calculations make it harder for another person to QA. Across the models, many tabs have a mixture of assumptions and calculations without any indication of whether the cell contains a calculation or an assumption. Designing the model in a way that makes it easy to QA will assist in ensuring a robust, defensible estimate.
	The ATA have indicated that they will address this in future versions of the model
	In order to ensure a robust, defensible estimate, any assumptions used should be documented to allow others to check the process

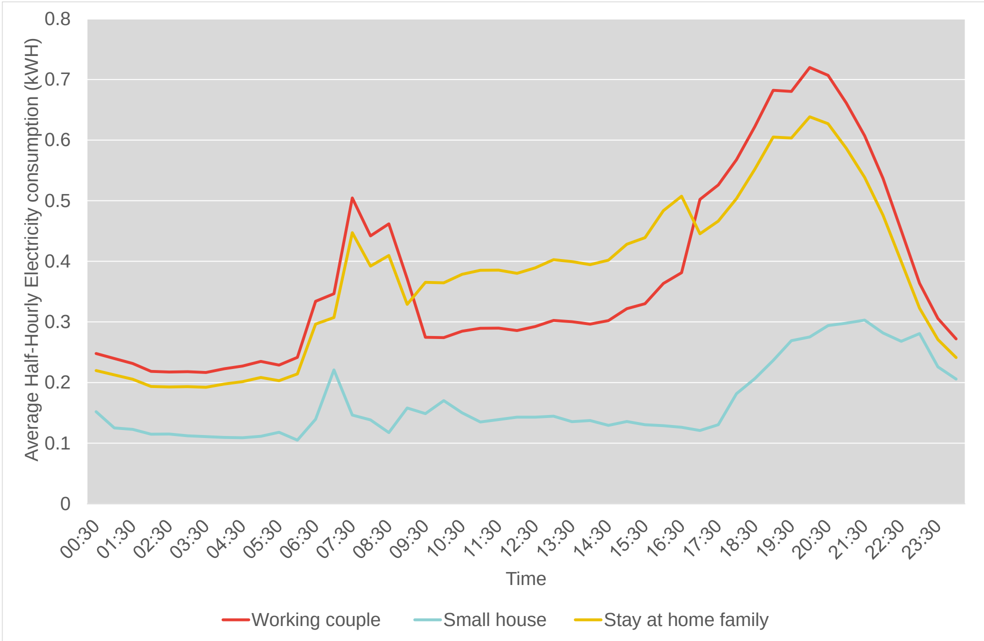
Any assumptions should be correctly documented	The ATA note that assumptions are documented in the accompanying methodology documents and they will be revised to ensure that they are explicit about all assumptions.
The models should only include information relevant to the calculation process	The models use a variety of locations in their estimation process, many of which are not used in the final fuel cost model. Including them in the other models makes it difficult to QA The models would benefit from the removal of irrelevant data.
	The ATA have indicated that as the models are used for a range of purposes, all possible locations are included. This will be more explicitly document in future, integrated versions of the model.

Source: Frontier Economics

Figure 7: Daily electricity consumption (kWh) excluding space heating, water heating and cooking, by household type in Sydney

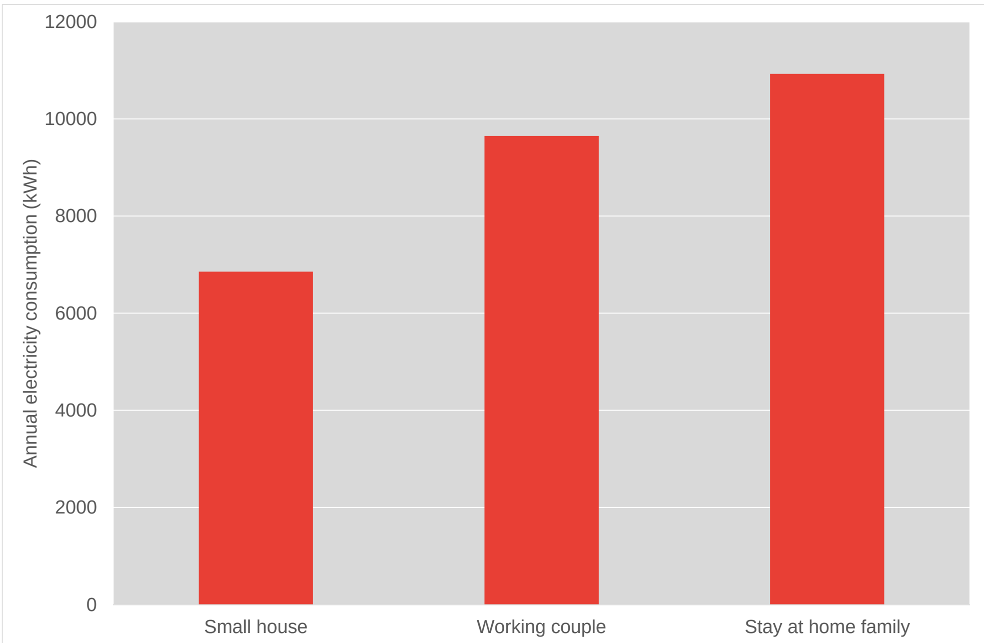
Source: ATA

Figure 8: Average half-hourly electricity consumption for households in Sydney (kWh)



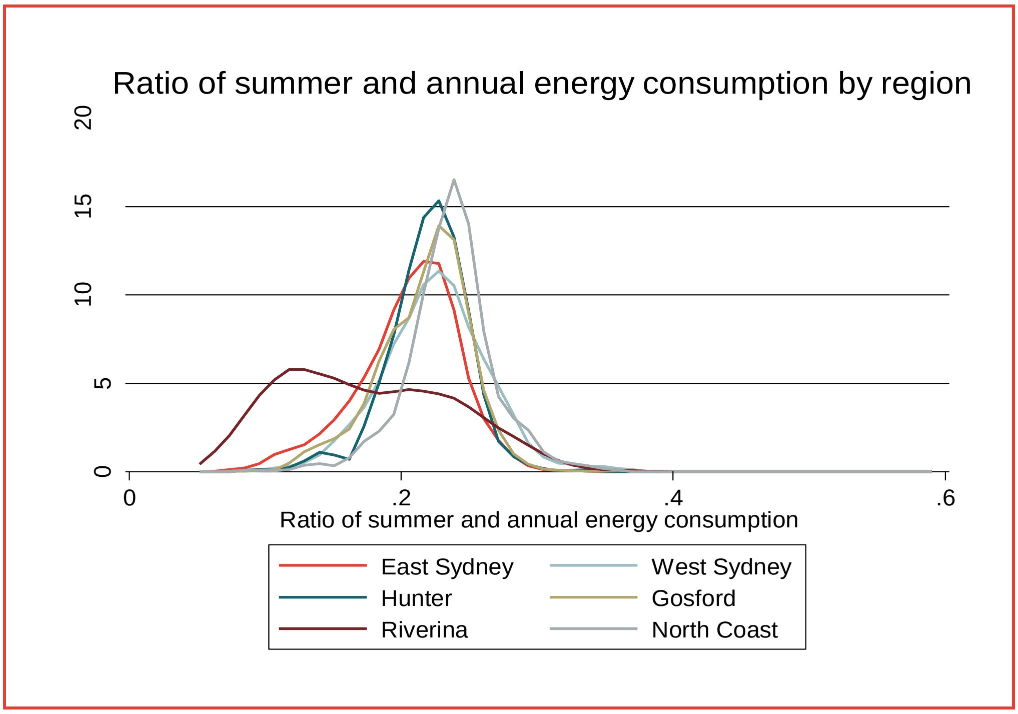
Source: ATA.

Figure 9: Annual electricity consumption by household type for households in Sydney (kWh)



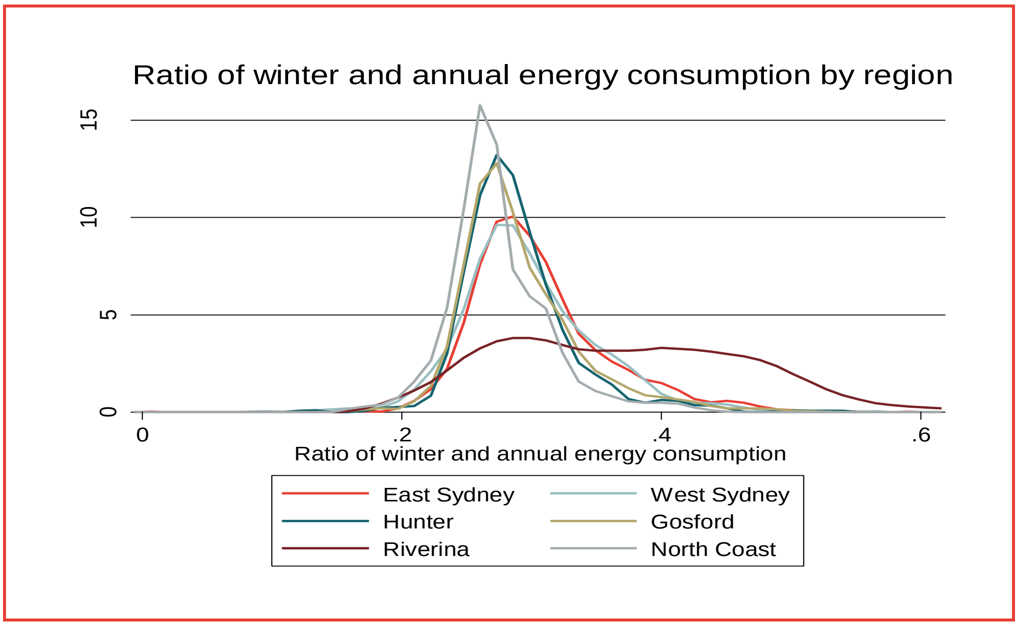
Source: ATA

Figure 10: Ratio of summer to annual energy consumption by region of NSW



Source: Frontier Economics (2016), Determinants of household energy consumption, a report prepared for the Independent Pricing and Regulatory Tribunal, p. 56.

Figure 11: Ratio of winter to annual energy consumption by region of NSW



Source: Frontier Economics (2016), Determinants of household energy consumption, a report prepared for the Independent Pricing and Regulatory Tribunal, p. 56.

4.1.1 Findings on household energy consumption

A household's energy bill varies significantly with its energy consumption behaviour, which depends, in part, on its choice of energy fuels. However, the relationship between energy consumption and bills is not straightforward.

Various factors influence household energy consumption, and, as shown in Table 5, there is a complex interplay between a range of short, medium and long term factors which influence the ability of households to address their consumption over time. For instance, after a household has made the decision to take up gas, how much energy they consume will depend on a complex interplay between household characteristics, appliance stock and usage, and regional differences, the effects of which differ depending on the time period analysed.

Table 5: Hierarchy of determinants of household energy consumption

Determinants of consumption	Household choices	Significant drivers	Short term	Medium term	Long term
Socio-economic drivers	n/a	Income Household size	✗	✗	✓
Household choice 1	Location House/plot size No. of bedrooms	Income Household size	✗	✗	✓
Household choice 2	Appliance stock and efficiency Alternative energy sources	Income Household size Number of bedrooms Dwelling type Location	✗	✓	✓
Household choice 3	Use of appliances	Appliance stock Location Household size Number of bedrooms	✓	✓	✗

Source: Frontier Economics (2016), Determinants of Household Energy Consumption: A Report Prepared for the Independent Pricing and Regulatory Tribunal, p.15.

Therefore, any model that aims to estimate the competitiveness of household fuels must accurately capture the variability in residential household consumption across key households in the NEM. In order to do this, the models and scenarios must:

- Capture the variability in household consumption; and
- Accurately model household energy consumption practices.

However, as shown in Table 4 (and discussed in more detail below), given the assumptions utilised in the models, it is unlikely that the models accurately capture the significant variation in household energy consumption across Eastern Australia, and thus, household bills.

Models should seek to capture the variability in household consumption

Household consumption (including take-up, use of and performance of appliances) varies significantly – driven primarily by location, dwelling type and household size. For example, households in more climatic, in-land regions are more likely to take up whole-house space heating and are more likely to use it more frequently.

However, the current models do not take into account some of the material drivers of household energy consumption. For example, the household archetypes do not include apartment dwellings, despite the fact that:

- increasing numbers of households (particularly in major urban centres) live in apartments
- dwelling type has been found to be a material determinant of household consumption, especially in the case of space heating.

The models estimate the energy required for space heating by assuming that every household type (except for new build) lives in a three star rated house and calculating the subsequent heating load. Given the diversity in dwelling types and housing stock across Australia, this assumption is unlikely to be representative of the population. In addition, previous work indicates that, all else equal, insulation is not the most material driver of household consumption.[10] Accounting for dwelling type (rather than insulation), is likely to be much simpler and provide a more accurate picture of household consumption across Eastern Australia.

In addition, although location is a material determinant of household energy consumption (and the significant climatic variation throughout the state), in South Australia there is only one location zone (due to lack of variability in gas tariffs throughout South Australia). In estimating household consumption across Eastern Australia there is a trade-off between having a sufficient number of locations to ensure that the consumption estimates reflect differences in consumption driven by different locations (i.e. cooler inland climates are more likely to have heating and use it more frequently) and not having too many locations such that the estimation process becomes too difficult or there is no robust data to utilise. However, there can be significant variability in consumption across a state and, as such, it is unlikely that a single location zone accurately reflects the variation of consumption across the state.

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10 Frontier Economics (2016), *Determinants of household energy consumption, a report prepared for the Independent Regulatory Tribunal.*

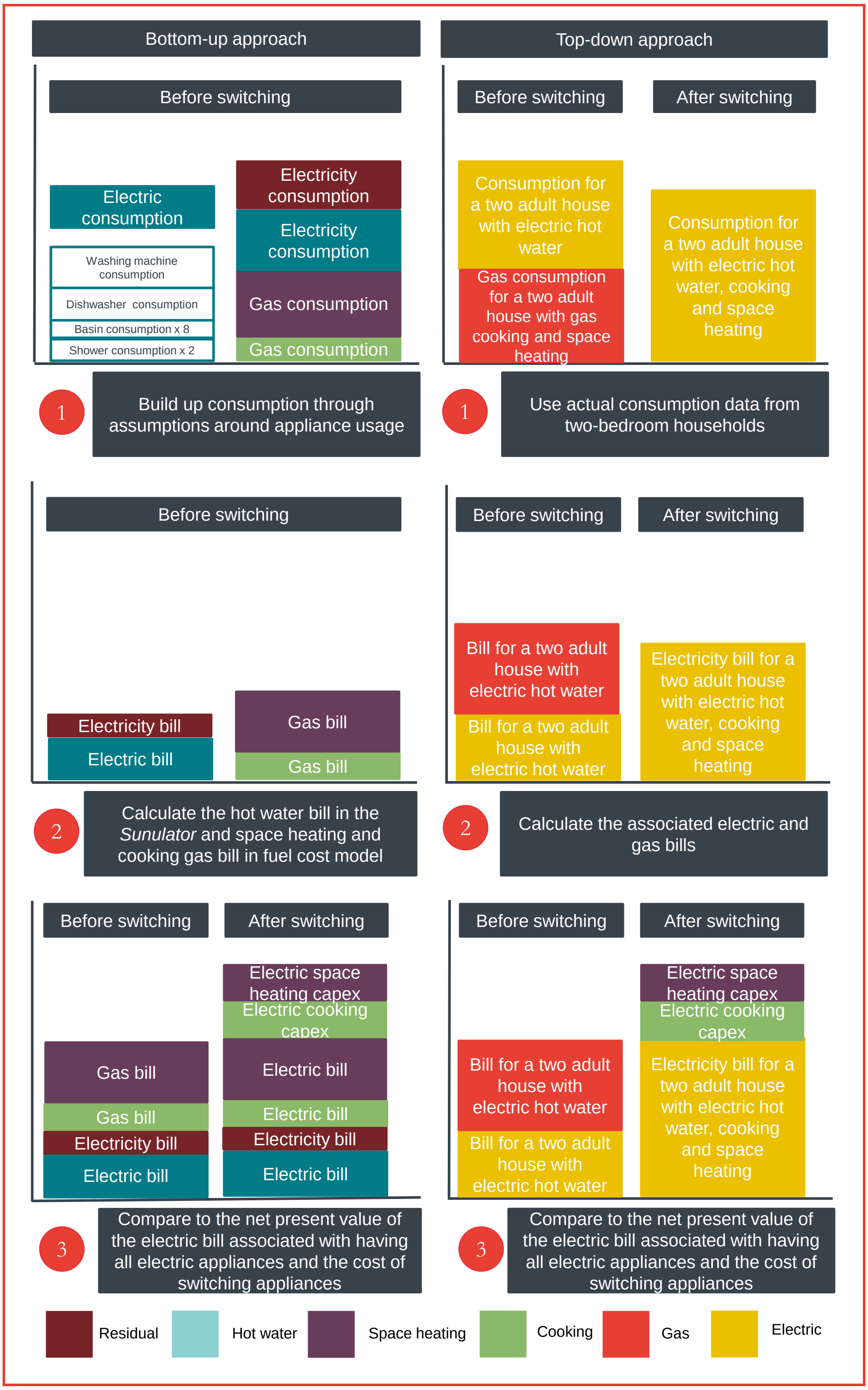
The models should accurately model household energy consumption

As shown in Figure 12, there are broadly two approaches to estimating household energy bills:

- A *bottom-up approach* which estimates household energy consumption by making assumptions around type and use of appliances (given that energy consumption is a 'derived demand') and estimating the consumption associated with each end-use (e.g. for space heating); and
- A *top-down approach* which estimates household energy consumption by allocating actual observed household energy consumption to appliances or end uses by employing conditional demand regression analysis.

Both approaches can draw upon actual consumption information taken from surveys and/or regression analysis using survey data.

Figure 12: Methods for calculating household energy bills for a two adult household living in a house without solar (not to scale)

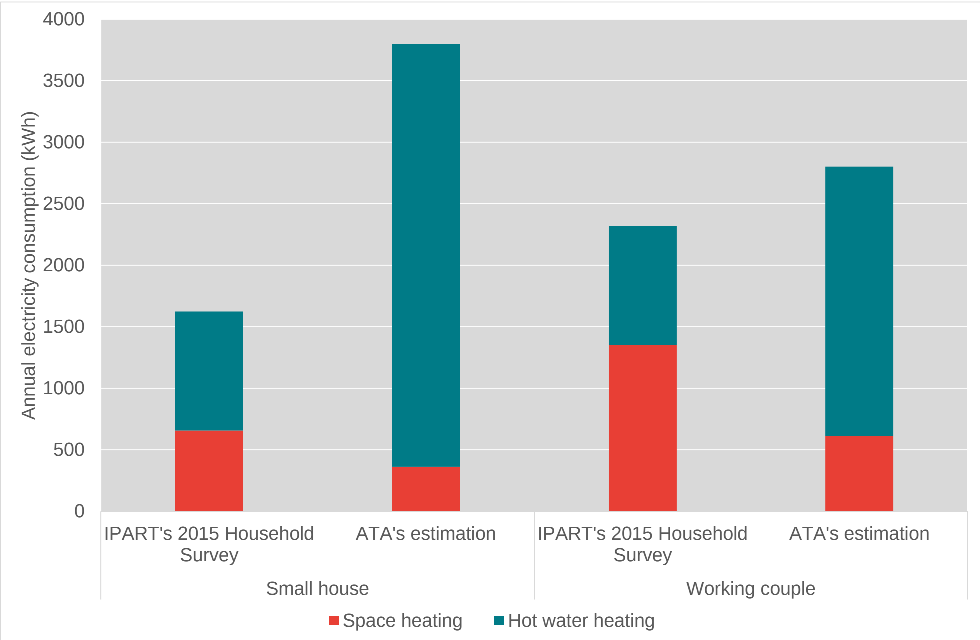


Source: Frontier Economics

While in theory both methods could provide similar estimates of household energy consumption, in practice they are likely to lead to different estimates of consumption, and therefore household energy bills.

For example, Figure 13 shows estimated annual electricity consumption for two all-electric household archetypes in Sydney (a small house and working couple) using the two different methods of estimation.[11]

Figure 13: Annual consumption associated with space heating and water heating for all-electric households in Sydney (kWh) by household type



Source: Frontier Economics (2016), Determinants of household energy consumption technical appendices.
Note: 1) The estimate from IPART's household survey for a small house is based on average characteristics of a two adult, one child household living in a house in Sydney with electric space heating, water heating and cooking, while the estimate for a working couple is based on the average characteristics of a two adult household living in a house in Sydney with electric space heating, water heating and cooking.

Compared to the IPART estimate (which is derived using regression analysis of actual consumption data), the estimate for water heating in the ATA models appears to overstate the electricity consumption associated with water heating, and understate the electricity consumption associated with space heating. This has the effect of overstating the cost of electric water heating compared to space heating (as the model attributes a large part of a household's electricity consumption to water heating) and may provide an unrealistic estimate of:

11 The estimate from IPART's household survey is based on average characteristics of a two adult, one child household living in a house in Sydney with electric space heating, water heating and cooking.

- How much a household's electricity bills would decrease as a result of switching hot water appliances (say from electricity to gas hot water) or reducing activities that drive hot water bills (such as number and length of showers).
- How much a household's electricity bills would increase as a result of switching space heating appliances (say from gas to electricity).

While using a bottom-up approach allows the model to capture a range of complex variables that may influence consumption (such as insulation), the complexity of the process and the choice of various assumptions,[12] means there are material risks associated with this estimation method including:

- The choice of assumptions may not reflect how many households use these appliances (see Table 6)
- The total derived household consumption may not be representative of actual household consumption across Australia.

Table 6: Estimates of frequency of appliance use

Household type	2015 IPART Household survey estimates of appliance use		ATA estimates of appliance use for all household types except working couple	
	Dishwasher	Washing machine	Dishwasher	Washing machine
Frequency of use (per week)	3.5	3.5	7	7

Source: Frontier Economics (2016), Determinants of Household Energy Consumption: A Report Prepared for the Independent Pricing and Regulatory Tribunal; ATA.

A top-down approach that uses actual consumption data based on a few key characteristics that drive energy consumption (number of people, dwelling type and size) is likely to be simpler, and in our experience, provide a more reliable estimate of actual household consumption.

12 For example, the hot water model attempts to estimate how much energy is used in water heating by assuming that each person showers once a day for eight minutes (except for individuals in stay-at-home families who shower for five minutes) and that each household (except for the working couple) uses a washing machine and a dishwasher once a day.

4.1.2 The relationship between tariff levels and consumption

Any model estimating the cost-effectiveness of household fuel types must account for the relationship between tariff levels and consumption.

The relationship between household consumption and tariff level is a complicated one, with consumption levels determining the tariff 'band' that a household falls into, but also being influenced itself by the tariff level (i.e. an elasticity response). In line with best practice, any model that seeks to estimate the cost competitiveness of household fuels must capture the interactions between current and future tariff levels and consumption, and vice versa.

However, ATA's models calculate a household's original (before switching) bill and the bill associated with switching separately (i.e. the *Sunulator* calculates a household's original bill, while the fuel cost model calculates a household's final bill by estimating the amount of electricity required for each appliance and assuming the household is on a flat rate tariff); failing to account for the fact that a household may move tariff bands depending on their final consumption, which may in turn, affect their future consumption. This means that there is no interaction between the tariff level the household is on before, and after, they switch.

For this reason it is unlikely that models are accurately capturing the relationship between tariff levels and consumption.

4.1.3 Current and future tariff levels and structures

In addition to household energy consumption, calculating energy bills requires consideration of current and future retail natural gas and electricity tariff levels and structures. The *Gasulator* assumes a constant 3% increase per year in gas tariff levels, regardless of tariff type and location. However, future household energy tariff levels are materially uncertain and likely to be driven by future climate policy, the mix of energy generation (distributed and non-distributed), fuel costs (incl. coal and gas) and demand across the NEM.

In our experience, there is benefit in capturing this uncertainty through a number of scenarios with differing 'escalation rates' applied to each tariff type and location. In the short term, we recommend using publically available data to inform trends and scenarios in future energy tariffs (including AEMC *2016 Residential Electricity Price Trends*, and AEMO assumptions). Over the longer term we recommend consideration be given to procuring specific advice around forecasting future tariff prices for the specified household archetypes and updating the models periodically.

Tariff structures are also uncertain over the long-term given:

- Retailers market a range of retail tariff offerings with some of these having different tariff structures (for example, some retail electricity offers involve 'capped' bills which alter the price signals provided to customers)

- Some households will have choice relating to their retail tariffs and associated tariff structures (for example, some households may be supplied controlled load 'off-peak' electric hot water)
- Electric tariff structures are likely to evolve given changes to metering technology, *Power of Choice* reforms, and changes made to the *National Electricity Rules* to encourage cost reflective network tariffs, however in some jurisdictions there are policy constraints to customers accessing these tariffs.

4.2 Fuel cost model

The key findings of our review of the Fuel cost model and the ATA's responses are summarised in Table 7, with more detail provided in the QA log. Our QA process focused on the overarching issues of ensuring that the input assumptions and the flow of the Fuel Cost model are correct, rather than checking every line of code individually.

Table 7: Model 1: Frontier Economics' key findings regarding the fuel cost model

Principle	Frontier Economics findings and recommendations
Economic relationships	
Scenarios should capture the variability in residential household consumption across the key household types in the NEM	The model estimates the fuel required for space heating based on the number of rooms in each dwelling and by assuming that every house in every location has the same energy rating (three stars for old house and six for a new build). However, this is unlikely to reflect the diversity in dwelling insulation across Eastern Australia Given this (and the fact that insulation is not a material determinant of household energy consumption), the models would benefit from estimating the fuel necessary for space heating using factors such as: • The number of hours of space heating used (rather than assuming the heating is operational during all heating hours[13]) to reflect the fact that some household types (stay at home families) and some locations (inland, colder climates) are more likely to use space heating more frequently • The use of actual household consumption data (rather than trying to build up the energy required for space heating)
	The ATA have indicated that the new heating/cooling model will generate 30-minute heating and cooling data to add to household profiles which enables them to differentiate heating and cooling use by stay-at-home and low-weekday-usage households. The ATA note that they have selected 3-star ratings as a compromise between granularity and simplicity- representing typical performance of an owner-occupied dwelling.
Models/scenarios should capture the variability in household appliance stocks and options available to households	Model assumes that a household must replace a gas oven and cooktop with an electric cooktop and oven (i.e. you cannot have a gas cooktop and an electric over). However, many Australian households have a mix of cooking appliances. The model would benefit from the inclusion of the option to replace a gas cooktop and oven with a gas cooktop and electric oven (and vice versa).
	The ATA note that cooking energy usage is so low that fuel choice is unlikely to make a significant difference to overall fuel costs unless replacing a gas cooker with an electric one enables disconnection of gas supply. The ATA will continue to model single fuel cookers, but will model duel-fuel cookers in some scenarios as a sensitivity analysis.
Modelling techniques and practices	

13 These operational hours were not provided.

The models should only include information relevant to the calculation process	There are multiple values for household consumption for the same household type (e.g. cooking consumption is 2,000MJ in the *Hometypelocn* tab across all household types, while consumption in the cooking tab varies by household type). If information is not necessary it should be removed.
	The ATA have indicated that this in an error that will be corrected.
General comment	Vlookup formula to import *Sunulator* bills is incorrect - Excel doesn't treat TRUE and FALSE generated by the OR command the same as typed true or false.
	The ATA have indicated that they will correct the formula.

Source: Frontier Economics

4.3 *Sunulator*

The key findings of our review of the *Sunulator* model and the ATA's responses are summarised in Table 8, with more detail available in the QA log.

Our QA process focused on overarching issues associated with the *Sunulator,* rather than checking every line of code individually given that:

- The ATA did not have the relevant consumption profiles finalised when we were engaged to perform this QA; and
- The *Sunulator* has been QA'd previously.

Table 8: Model 2: Frontier Economics' key findings regarding the *Sunulator*

Principle	Frontier Economics findings and recommendations
Economic relationships	
Models/scenarios should capture the material variability in solar PV generation across the key household types in the NEM	According to the documentation, the model assumes that any existing or new 5kW solar PV system will only power (in part) the hot water load. While this can be considered a helpful 'rule of thumb', it does not reflect actual household consumption patterns.
	The ATA note that solar generation does not offset heating and cooking loads because they were calculated in aggregate, rather than added to interval data. The new heating/cooling model will ensure that heating, cooling and hot water are all included in solar calculations.
Models/scenarios should capture the material variability in solar PV generation across the key household types in the NEM	The model assumes households only have 5kW solar panels, which does not reflect the diversity in the size of solar PV panels on households across Australia. The model would benefit from the option to incorporate different panel sizes such as 1.5 kW, 3 kW and 5kW, particularly given that some jurisdictions have closed their subsidised gross feed-in-tariff schemes.
	The ATA note that 5 kW is typical of new solar installations, but not existing ones. They have indicated that they have adjusted the solar modelling to use 5 kW for new systems, but 2.5 kW for existing ones.
Models/scenarios should capture the material variability in solar PV generation across the key household types in the NEM	As shown in Box 1, the model assumes the 'ideal situation' around PV output (i.e. it does not capture issues associated with actual PV output that will cause some households within a region to have materially different PV output than other households). For instance, weather data for a given city is based on only one weather station in the city despite the fact that solar output could vary considerably within the city
	The ATA note that the Sunulator accounts for solar variability and sub-optimal conditions by using detailed weather data and by de-rating output by 12 percent.

Source: Frontier Economics

Box 1: Models should capture the material variability in solar PV generation across households in the NEM

Given the increased awareness and uptake of solar PV by households around Eastern Australia, and the impact that this can have on household energy consumption (and thus bills), it is important to account for solar PV when estimating the cost effectiveness of household fuels.

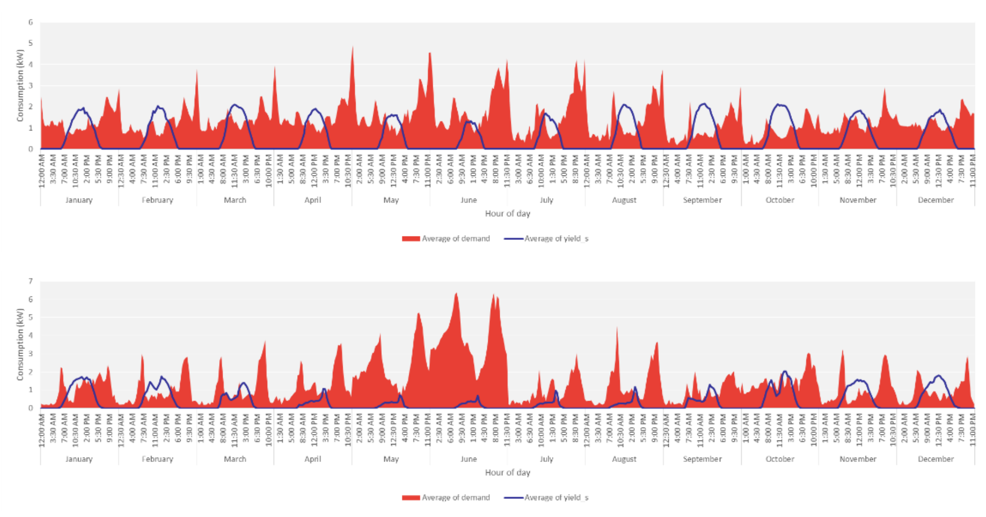
However, estimating the level of solar generation on household consumption and energy bills depends significantly on variables such as the size of the panels, the panel location and tile and the potential coverage of the household roof. As such, there are challenges in capturing the significant diversity in actual solar generation that occurs across climate zones and household types in Australia (Figure 14) within the sample used by the *Sunulator* solar generation model.

In particular, the *Sunulator* assumes the 'ideal situation' around solar output and does not capture factors that result in actual PV output being materially different across households within a city. For instance, weather data is based on only one weather station in the city despite the fact that, in large cities, solar output would vary within the city. In particular, each household in each location is assumed to have the same half-hourly solar generation, regardless of the household type. However, as shown in Figure 14 and Figure 15, solar generation varies significantly between similar households (Figure 14) and in the same location (Figure 15).

This means it is unlikely that assuming that each household generates the same solar output accurately estimates actual solar PV output and the impact of solar PV output on customer bills.

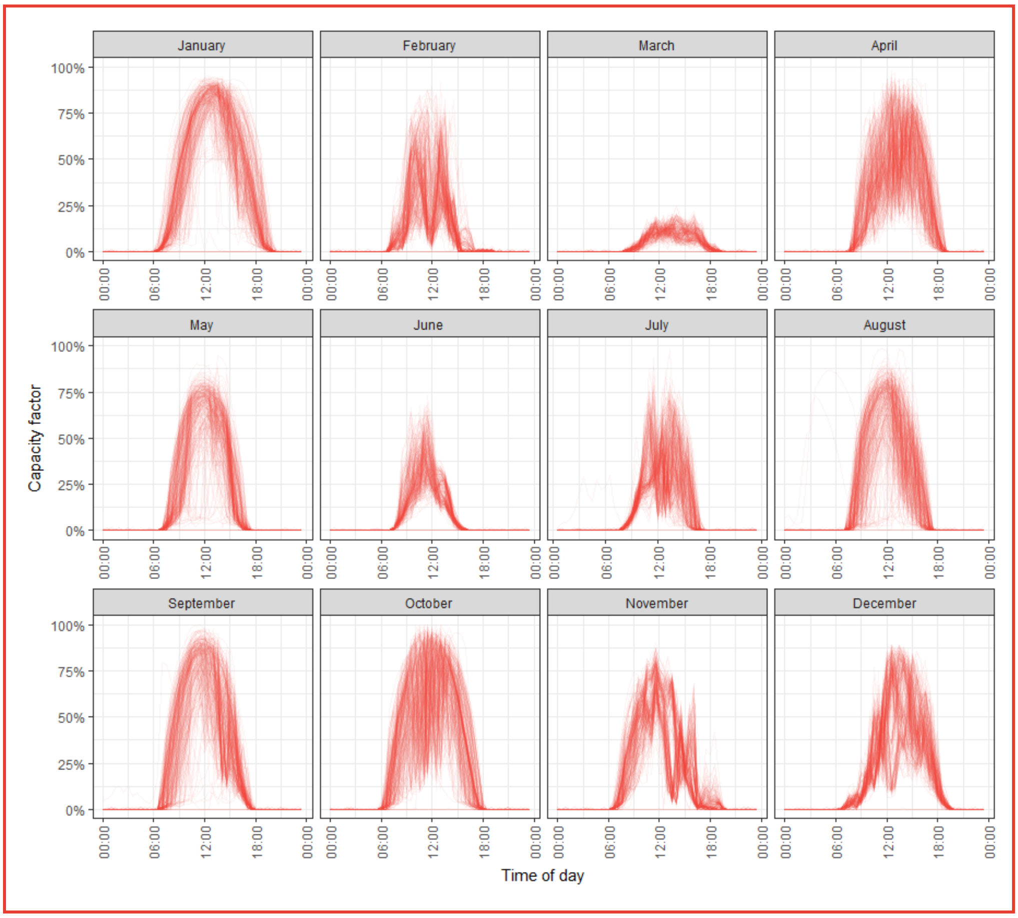
Source: Frontier Economics

Figure 14: Variability in solar generation output two across similar households (FY2013)



Source: Customers on the Ausgrid network, Smart Grid Smart City trial; Analysis by Frontier Economics

Figure 15: Solar traces (capacity factor) for customers on the Ausgrid network



Source: Customers on the Ausgrid network, Smart Grid Smart City trial; Analysis by Frontier Economics
Note: Calculated using data from Ausgrid customers for the financial year 2013. Shows solar traces (capacity factor) for 300 customers on the Ausgrid network for the first day of each month.

4.4 *Gasulator*

The key findings of our review of the *Gasulator* model and the ATA's response are summarised in Table 9 with more detail available in the QA log.

Our QA process focused on overarching issues associated with the *Gasulator* rather than checking every line of code individually given that the calculations used to estimate household gas bills are performed in VBA.

Table 9: Model 1: Frontier Economics' key findings regarding the *Gasulator*

Principle	Frontier Economics findings and recommendations
Economic relationships	
General comment	The model uses daily consumption to calculate monthly bills (i.e. it does not multiply the consumption generated by the hot water model and the assumed daily heating and cooking consumption by the number of days in each month). The estimates of daily consumption should be multiplied by the number of days in each month to calculate the associated monthly gas bills
	The ATA have indicated that they have checked the *Gasulator* and verified that it correctly calculates gas bills
Scenarios should capture the variability in residential household consumption across the key households (or customer archetypes) in the NEM	The model calculates space heating loads without reference to the likely time that different household types will be at home (e.g. stay-at-home families are more likely to be at home during the day and thus use more energy during the day). However, they are assumed to use significantly less energy for space heating). The model should capture the variability in the number of hours of space heating used between locations and household types.
	The ATA have indicated that the new heating/cooling model generates 30-minute heating data and allows the ATA to differentiate between stay-at-home and low-weekday-usage household types.
Scenarios should capture the variability in residential household consumption across the key household types in the NEM	The model assumes that a stay-at-home family and a large family use the same amount of energy for cooking and, similarly, that a working couple and a new build use the same amount of energy for cooking, which seems implausible. The model would benefit from the use of actual consumption data.
	The ATA note that this is an error that has been corrected. Cooking is to be modelled according to household size and type, based on data from IPART and ClimateWorks.
Modelling techniques and practices	
The models should only include information relevant to the calculation process	The model contains data that is not used in the model itself, or fed through to the fuel cost model. For example, Alice Springs, Ball Brunei, Darwin, Perth and Thursday Island are listed as using 200 MJ of energy for space heating every month, but this information is not used in the calculation process If the figures are not used, they should be removed from the model or clearly identified.

	The ATA have indicated that they have removed the data.
The models should only include information relevant to the calculation process	The *Gasulator* can forecast future gas bills but the fuel cost model does not use the forecasted values (it just adjusts the bill from the current year for inflation).
	The ATA note that the Gasulator is used for other purposes than just this project and are applying price increase indices based on AEMO forecasts to all bill calculations for consistency.

Source: Frontier Economics

4.5 Hot water model

The key findings of our review of the hot water model are summarised in Table 10, with more detail available in the QA log.

Table 10: Model 1: Frontier Economics' key findings regarding the hot water model

Principle	Frontier Economics findings and recommendations
Economic relationships	
Scenarios should capture the variability in residential household consumption across the key household types in the NEM	Some locations are unlikely to be representative of the population. For instance, one of two locations in Queensland used in the model is Thursday Island which is quite far north and unlikely to reflect a large proportion of Queensland's residents. The model would benefit from: • The use of more representative locations, e.g. Cairns. • The use of Australian climate zones to reduce the number of scenarios modelled while accounting for the material drivers of household consumption and ensuring that any estimates are as representative as possible.
	The ATA note that the hot water model is based on NatHERS climate zones and have indicated that they will revise the locations chosen to better reflect typical households.
Scenarios should capture the variability in residential household consumption across the key household types in the NEM	The model is based on a bottom-up approach to estimating consumption, which requires making assumptions around length of shower time and the number of times that a household uses a hand basin. However, as shown in Section 4.1.1, a bottom-up approach is unlikely to accurately estimate a household's water consumption (e.g. it assumes that every household has an 8 minute shower time except for stay-at-home families who have 5 minute showers. However, it seems unlikely that a stay at home family has the shortest shower time).
	The ATA note that hot water usage activities are based on survey data. The difference in shower time between stay-at-home households and all others was an error that has been corrected. The ATA also note that dishwasher and washing machine usage is set to zero in the model, with one-per-day proposed as a sensitivity analysis. The ATA has indicated that they will still do a sensitivity analysis for a household with high hot water usage by adding hot washing machine loads (1 per 2 adults, and 1 per child, per week).
Scenarios should capture the variability in residential household consumption across the key household types in the NEM	The model uses average temperature by month, but average temperature at the time of peak water consumption is more appropriate (and could be very different to the average monthly temperature). The model would benefit from: • The use of average temperature at the time of peak water consumption (if possible); or The use of average minimum temperature.
	The ATA note that average water temperature by month is used because it affects the temperature of mains water, which does not fluctuate with differences in daily temperature. Mains temperature affects hot water energy use much more than transient ambient temperature.

Source: Frontier Economics

5 Recommendations and response pathways

Some of the findings outlined in Section 4 may be straightforward to implement, while other recommendations may be challenging to implement in the short-term. As such, step four of our quality assurance process outlines both short-term and long-term pathways to implementing our recommendations. Table 11 highlights our recommendations and response pathways regarding the most material issues and ATA's response (in blue). In particular, we recommend that the ATA review the opportunities to incorporate best practice model design features in the models, with a mind to incorporating some of these prior to public release of the models and report. For more detail regarding our recommendations see the QA log.

Table 11: Frontier Economics' key recommendations and potential response pathways

Principle	Frontier Economics recommendations and response pathway
Models/scenarios should reflect household consumption for the key household types in the NEM	The consumption assumptions (both total household consumption and 'end-use' appliance consumptions) are not representative of household consumption in the NEM. Over the longer term we recommend estimating consumption via a top down approach (rather than trying to build up the energy required for each end-use appliance) using actual data from publically available sources such as IPART's 2015 household survey (which contains information on the relationships between household energy consumption and key household characteristics by climate zone) and the AER's consumption benchmarks.[14] Over the short term we recommend including an estimate of the number of hours of space heating in the estimation of a household's heating load. The total energy assumed for electric space heating is materially understated when compared to actual data (see, for example, IPART's 2015 household survey).
	The ATA have indicated they believe that the consumption figures are credible. The ATA have also indicated that as they will be developing a new model, they will use new underlying consumption profiles without cooling. They will use interval data from southern Victorian households matching the household types that have gas heating, cooking and hot water and no cooling.
Models/scenarios should capture the variability in residential household consumption across the key household types in the NEM	The models would benefit from using actual consumption data (either total consumption or 'end-use' consumption) to ensure the assumed household consumption figures (both total consumption and the pattern of consumption throughout the year and day) reflect the significant diversity in consumption that exists across household types. In the short term we recommend using actual consumption data to ensure that the consumption profiles are broadly in line with actual household consumption.
	The ATA have indicated that they will develop a heating and cooling model that uses NatHERS and E3 data along with 30-minute temperature data to determine

14 While there are a number of methodological flaws in the AER's 2014 energy consumption benchmarks, the AER may address these issues in its 2017 update.

	heating and cooling energy requirements and add them to the interval data for each household type and location. The ATA is confident that their approach is robust, and that the estimates, when sense-checked against other estimates of both energy and water usage, are credible.
Models/scenarios should capture the variability in residential household consumption across the key household types in the NEM	It is not clear that the scenarios or household types capture the diversity in residential household consumption across key households (or customer archetypes) in the NEM. This diversity across the NEM occurs in terms of total consumption and end-use consumption (in annual, seasonal and hourly profiles). The diversity that currently is assumed between some scenarios is not representative of actual household consumption in the NEM or cannot be explained by the key drivers of household consumption. As shown in Figure 8 and Figure 9 the underlying consumption profiles (consumption excluding water heating, space heating and cooking) don't seem to reflect the relativities between household types. For instance, a small house has more people than a working couple (and are likely to be at home more than a working couple), yet the consumption profile is significantly lower than the working couple at all times, despite the fact that they live in the same size house. The models would benefit from using actual consumption data (either total consumption or 'end-use' consumption) to ensure the assumed household consumption figures reflect the significant diversity in consumption that exists across household types. Household scenarios would benefit from: • The inclusion of an apartment household type • Using Climate Zones to capture most material differences across household consumption driven by location. In the short term we recommend including an apartment household type and adding an additional zone in South Australia. Over the long-term we recommend using Australian climate zones as the locations in the models (rather than gas and electric zones).
	The ATA have indicated they have corrected the household composition information and clarified the dwelling types. They have also derived new profiles for the Large Home and New Build. The ATA considers that the inclusion of an apartment household type is impractical for the purposes of this project. The ATA have indicated that the will develop a new model that will add more granular heating and cooling loads to move accurately reflect locational differences in underling profiles and heating loads. However, they note that as they will calculate heating, cooling and hot water loads separately, and climate-related factors are part of the modelling approach, climate-related differences in the underlying consumption are of less significance that if the profiles were representing all consumption.
Models/scenarios should capture the seasonal nature of household consumption	The models would benefit from calculating bills on a consistent, monthly basis, as calculating some bills on a monthly basis and some on an annual basis will not capture the significant variability in household consumption across the year. In the short term we recommend using a consistent approach to calculating bills across all four models. Over the longer term we recommend integrating the four models into a single model.
	The ATA have indicated they will calculate all bills quarterly (except Victorian gas bills, calculated bi-monthly).

Models/scenarios should capture the material variability in solar PV generation across the key household types in the NEM	Models / scenarios would benefit from the option to: • have the solar PV system power a household's energy consumption regardless of the end-use driving the consumption; • incorporate different panel sizes such as 1.5 kW, 3 kW and 5kW; • the use of actual PV output data (e.g. data from IPART's household survey). In the short term we recommend incorporating different panel sizes. Over the long term, we suggest using actual PV output data and allowing the solar PV system to power a household's energy consumption regardless of the end-use driving the consumption.
	The ATA have indicated that the new model will ensure that heating, cooling and hot water will be included in solar calculations. The ATA have indicated that they have adjusted the solar modelling to use 5 kW for new systems, but 2.5 kW for existing systems. The ATA have indicated that the Sunulator accounts for solar variability and sub-optimal conditions.
Models/scenarios should capture the uncertainty in future energy tariff structures and levels over the forecast period (25 years)	The models would benefit from the use of scenarios in forecasting future tariffs given the uncertainties around the future cost of retail gas and electricity supply (incl. climate policy and fuel costs) and future tariff structures. In the short term, we recommend using publically available data to inform trends and scenarios in future energy tariffs (including AEMC price trends, and AEMO assumptions). Over the longer term we recommend considering getting specific advice around forecasting future tariff prices.
	The ATA have indicated that the index used to estimate future price changes is based on the most recent AEMO forecasts and that this approach is no less accurate than any other. ATA have indicated that they will undertake sensitivity analyses using higher and lower indexes.
Models should capture the interactions between tariff levels and consumption and vice versa	The models do not consistently calculate bills to incorporate the interactions between tariff levels and consumption and vice versa. The models would benefit from having one section/model calculate the relevant electricity and gas consumption and another section/model calculate the relevant bills, rather than having multiple models calculate household consumption and bills. In the short term we recommend using the *Sunulator* and the *Gasulator* to calculate total consumption with and without solar PV (rather than calculating a household bill with and without solar PV) and calculating the household's relevant bills in the fuel cost model. In the long term we recommend consolidating the four models into one.
	The ATA have indicated that their new model will allow the Sunulator to calculate all household quarterly consumption (except for cooking, which will be added to quarterly consumption at the appropriate tariff rate) The ATA will continue to calculate gas bills in the Gasulator as it incorporates the seasonal nature of most gas tariffs.
Calculations that rely on results from other	The models would benefit from consolidation. In the short term, care should be taken to ensure that each model uses exactly the same assumptions as the other models and calculates bills in the same way

calculations should be integrated into the same model	across the four models. In the long term, the four models should be consolidated into one model.
	The ATA have indicated they are ensuring that assumptions and calculations are done consistently across scenarios.
General comment	The models would benefit from correcting the Vlookup formula in the ResultsSS tab in the fuel cost model as per the QA log. In the short term, correct the vlookup formula as per the QA log.
	The ATA have indicated they are implementing all the proposed changes to formulas and functions

Source: Frontier Economics

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