Determinants of household energy consumption

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Executive Summary

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 household energy decision-making, including how households manage their energy needs, and the resulting impact on the supporting energy infrastructure that underpins household energy consumption.

However various factors influence household energy consumption, and there is a complex interplay between a range of short, medium and long term factors. Many of these factors – such as household income, and the stock and use of household appliances – are closely related. For example, numerous studies have observed that higher income households tend to live in larger dwellings, possess more energy consuming appliances, and use them more often. However, the strength of these relationships can vary significantly across households, location and time.

Understanding these relationships (and their variability), including how these various factors influence household energy consumption and over what timeframe, is critical in providing households, regulators and policy makers with the tools necessary for informed energy decision-making.

In this context, Frontier Economics was retained by the Independent Pricing and Regulatory Tribunal (IPART) to analyse the results of the 2015 Household Survey.[1] We have used a range of analytical tools, including econometric regression analysis and behavioural insights, to investigate the determinants or drivers of gas and electricity consumption,[2] as well as the underlying relationships between total energy consumption and a range of social and economic characteristics.

To present our analysis in a way that is of most use to a diverse set of stakeholders, the findings, the potential implications for regulators and policy makers, and the opportunities for further research and analysis are grouped into key themes. We consider our analysis and this report on the key relationships driving household energy consumption to be of use to IPART, policy makers, stakeholders and NSW households.

1 IPART (Sep 2016), *IPART 2015 Household survey – Energy usage.*

2 Both controlled load and non-controlled load electricity consumption.

Household energy consumption and sources of energy supply vary considerably across NSW

Household energy consumption varies significantly across NSW, with household:

- Energy and gas consumption being highest in the inland region of the Riverina compared to the other regions,
- Electricity consumption being lowest in the North Coast.

These differences are driven by differences in energy source uptake (refer Table 3), appliance stock and usage, and differences in household characteristics. To help understand the potential changing nature of energy consumption and household energy sources across NSW, we examined the factors that influence the likelihood of households adopting specific energy sources for particular uses – such as their location, household size and income – and the impact that these energy decisions have on electricity, gas and total energy consumption.

In terms of energy uptake we found that across NSW:

- In the medium term, household location, household size, dwelling type and income are significant determinants of the energy sources used by households. For example, households in inland areas (where gas is available) and free standing dwellings are more likely to take up gas[3] and use gas space heating,[4] while households in coastal areas such as the North Coast are more likely to have solar PV.
- Existing appliance stock can influence other household appliance ownership decisions in the medium term. For example, the uptake of gas cooking is related to whether or not the household has gas water heating (positively) or space heating (negatively).[5]

In terms of energy consumption we found that across NSW:

- In the long term, the key drivers of household non-controlled load electricity consumption are household size, income and the number of bedrooms. In the short to medium term the presence of electric hot water heating, cooking or space heating, their appliance stock and age and the presence of solar PV and/or gas, are the primary end use drivers of household non-controlled load electricity consumption.

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3 For example, 67.5% of households use gas in the Riverina (see Table 3). And the coefficient of 0.459 for the house variable in the logit regression model for gas use shown in Table 8 indicates that households living in houses are more likely than households living in apartments to take up gas.

4 For example, 73.5% of households with gas in the Riverina use gas for space heating (see Table 10)

5 These results are primarily driven by households with mains gas. For households using cylinder gas, there is still a significant negative relationship between using gas for cooking and space heating, but the relationship between cooking and water heating is no longer statistically significant.

- In the long term, the key drivers of household gas consumption are household location (especially in the Riverina), income and the number of bedrooms. In the short term, the presence of gas hot water and space heating, and the hours of use per day of gas space heating are the primary end use drivers of household gas consumption.

The choice of energy sources can influence household energy consumption, however the impact on bills is less clear

While the choice of energy sources can influence household energy consumption, the impact on customer bills of changes to energy consumption and energy sources is less clear. This is because:

- There is significant diversity in NSW household energy consumption, even within regions, with a households' specific consumption patterns 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 structures of electricity and gas tariffs), which can dampen or exacerbate the impact on bills from changes to consumption;
- There is uncertainty related to forecast changes to retail electricity and gas prices, due to electricity and gas network prices in NSW;[6] and
- The cost competitiveness or relative costs of energy supply options, are only one aspect of competitiveness, with households typically balancing a range of service quality, convenience, environmental and energy cost considerations when making energy decisions.

Household energy consumption increases with income, but income primarily drives household and lifestyle choices rather than consumption

In general, income is positively related to energy consumption, with higher income households, on average, consuming more energy. However, income in the short term does not have a statistically significant impact on consumption. Rather the key short term drivers of gas and electricity consumption are the number and frequency of use of appliances, which are influenced by location, household size and number of bedrooms.[7] For example:

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6 Resulting from the appeals process in the Australian Competition Tribunal and the AER's decision to appeal the ACT's decisions to the Federal Court.

7 That is, if we control for other factors that may be positively correlated with income, such as larger dwellings or families, increases in income do not significantly influence consumption. This does not mean that income has no effect on household energy consumption, but rather, its positive effect on electricity

- For electricity consumption, the number of fridges and their capacity is a key driver of electricity consumption. The number of fridges and their capacity is primarily influenced by household size, dwelling size, type of dwelling and the number of bedrooms (see Table 17), all of which are associated with higher incomes.
- For gas consumption, the presence of gas hot water and space heating, and the hours of use per day of gas space heating are the primary end use drivers of household gas consumption. While income has a very strong impact on whether or not a household uses gas (see Table 11), once this choice has been made, income has very little impact on how much gas is used (see Table 13).

Therefore we observe higher income households, on average, consuming more energy because higher income households are more likely to also have other characteristics associated with increased energy consumption (see Section 8.2).

However, partially offsetting these characteristics, is the fact that, compared to low income households, higher income households are more likely to have newer more efficient appliances or adopt energy saving measures (e.g. insulation) which reduce energy consumption (see Section 8.1).

Opportunities for higher income households to reduce their energy consumption through energy efficiency or conservation measures could increase in the future, which suggests that relying on historical surveys as a guide to policy makers, regulators and stakeholders regarding likely future electricity and gas consumption should be undertaken with some caution.

Various factors contribute to the vulnerability of low income households

Lower-income households are considerably more likely to experience financial difficulty in paying their energy bills than higher income groups[8].

However there are also some clear differences in characteristics between lower income households that have experienced financial difficulty and lower income households that have not experienced financial difficulty. For example, we found that across NSW, those lower income households that have experienced financial difficulty paying their electricity bills:

- Have more children on average, which increases consumption;
- Are less likely to have solar PV, which increases (grid) consumption; and

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and gas consumption is explained in part by its longer-term relationship with factors such as household type, size and appliance stock.

8 Middle income households with more than 3 people that do not own their own home outright also have a reasonably high likelihood of facing difficulty paying their bills. See IPART, *IPART 2015 Household survey – Payment Difficulties,* September 2016.

- Are more likely to be renting or less likely to have paid off their home, which may reduce disposable income.

This is consistent with research that has found that the households which had their electricity disconnected tended to be households on low to median income, experiencing housing stress or other bill obligations.[9]

Low-income households are the focus of various policies aimed at alleviating their financial vulnerability. For instance, policies such as The Energy Accounts Payment Assistance (EAPA) scheme and NSW Gas Rebate exist to assist households experiencing financial difficulty in paying their electricity and gas bills. However, the survey suggests that a significant proportion of households that have experienced financial difficulty are not accessing support that may be available.

Highly seasonal consumption in Riverina and low incomes in North Coast may contribute to vulnerability of households

Households in regional Riverina and North Coast are more likely to have experienced financial difficulty paying their energy bills in the last three years than households in Eastern Sydney, Hunter or Gosford (see Figure 12). This may be because:

- Households in Riverina have the highest and most seasonal energy consumption, driven by a higher penetration[10] and use of space heating and air-conditioning.[11] This seasonal variability in consumption can make it more difficult for households to plan their expenditure as they may be unable to predict the size of their next bill.[12]
- Households in the North Coast have the lowest average weekly income, and are the most likely to have experienced financial difficulty despite having the lowest and least seasonal (grid) energy consumption.

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9 See St Vincent de Paul Society and Alviss Consulting (2016), *Households in The Dark*, p.18

10 Our regression analysis indicates that gas space heating in the Riverina is associated with 21,674 MJ of increased gas consumption, compared with 10,217 MJ in Eastern Sydney and 9,830 MJ in Gosford (see Table 13).

11 Our regression analysis indicates that frequency of use also has a significant impact on household energy consumption (and the seasonal variability in their consumption) which each additional hour per day of air-conditioning use for instance, increasing annual non-controlled load electricity consumption by 146 kWh, while each additional hour per day of gas space heating increasing annual gas consumption by for 2,572 MJ (see Table 24 and Table 13).

12 However it is worth noting that the structure of retail prices, such as gas tariffs or electricity tariffs, will influence the variability in quarterly bills. Retail tariffs with a higher fixed charge but lower (or decreasing) usage charges will result in less variability in quarterly bills.

Barriers exist to the increased energy efficiency and conservation

Energy efficiency is a key focus area for policy makers and stakeholders in reducing energy bills, improving energy productivity and lowering greenhouse emissions.

Our regression analysis indicates that 'taking steps'[13] towards reducing electricity consumption does not have a statistically significant impact on household electricity consumption, yet there are many avenues for households to reduce electricity and gas consumption. This suggests that:

- Some households may not actually be taking steps to reducing consumption ('knowledge-action gap' or 'intention-action gap' – see Table 26).
- Some households may not be addressing the most material drivers of energy, such as the age of household appliances ('action-result gap') which could be the result of a number of barriers to reducing electricity consumption (such as income, tenancy, access to information etc.)[14]
- Some avenues to reduce energy consumption may not be 'rational' or cost effective (i.e. the upfront or ongoing costs may exceed the benefits).

Understanding which phenomenon is more likely to explain this gap between household intent and resulting energy bills, will be important given they are underpinned by different barriers and will influence what policy response may be most appropriate.

Under both phenomena, however, traditional education campaigns focused on the environmental and financial benefits of reduced energy consumption may not be addressing the key barriers to achieving Governments' energy efficient policy objectives. Gathering evidence from field studies and experimental trials on how and why customers make decisions – including any barriers (real or perceived) to reducing energy consumption – and the impacts of policy interventions on these decisions, could assist policy makers in understanding the potential opportunities to improve the effectiveness and efficiency of any policy response.

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13 The 2015 Household Survey asked households whether they had actively taken steps towards reducing the amount of electricity they consume over the past five years.

14 For example, the AEMC notes that many vulnerable customers were unable to manage their energy use as they could not "avoid using air conditioning on very hot days or when children are at home …. [and] they cannot afford more energy efficiency appliances so were generally resigned to having higher bills". See AEMC (2016), *2016 Retail Competition Review Final Report*, p.50.

1 Background

IPART sets the maximum prices gas retailers can charge customers who have not signed a market contact. It also recommends a benchmark range for unsubsidised solar feed-in tariffs that retailers may voluntarily offer customers, and has a role in monitoring competition in the retail electricity market. A sound understanding of what types of energy different households use, and how much, helps to provide a context for its decisions.

To assist in providing such a context, IPART commissioned a survey of household energy consumption in New South Wales in 2015 (the 2015 Household Survey).[15] The 2015 Household Survey was undertaken by Roy Morgan Research in the Sydney, Gosford, Hunter, the Riverina, and the North Coast regions (shown in Figure 1 below).

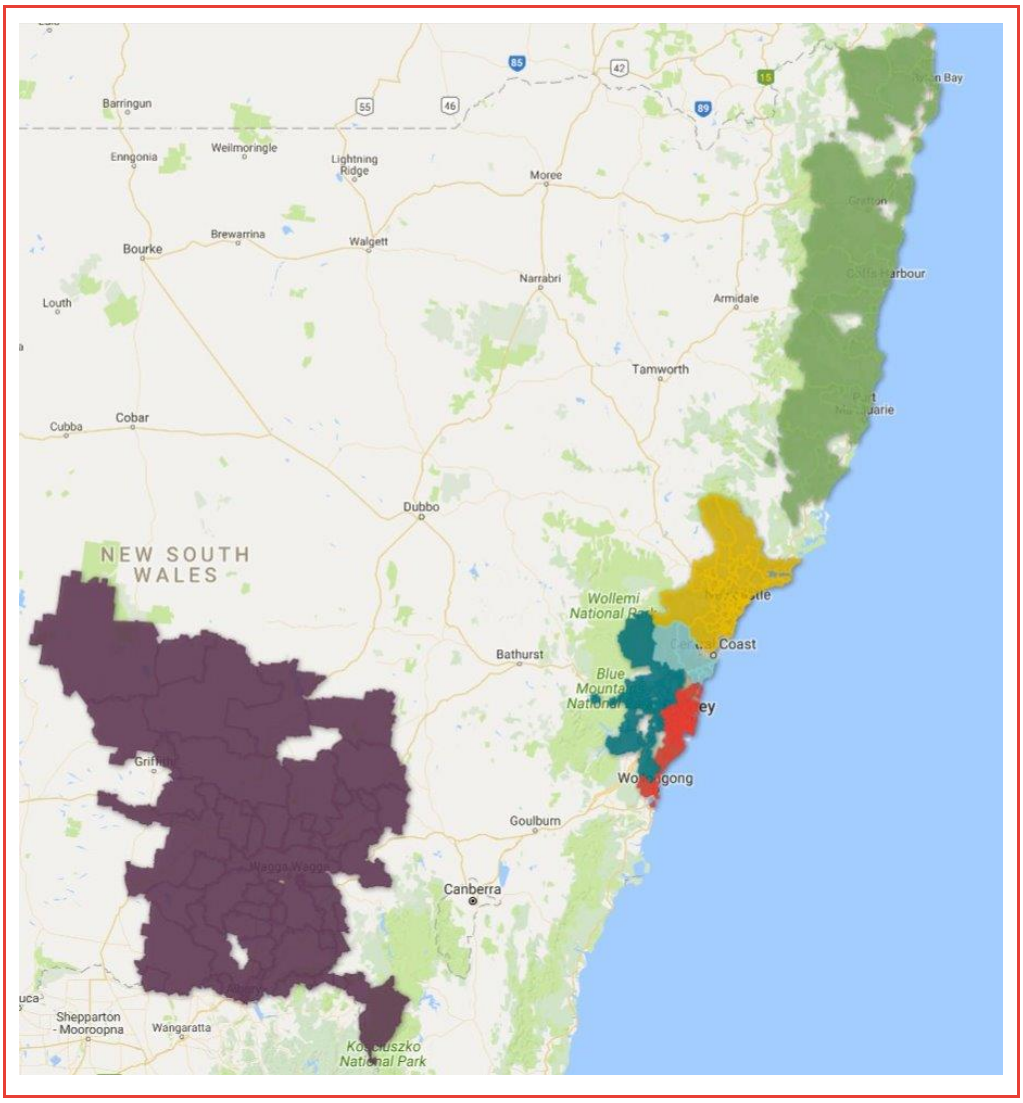
The survey obtained information regarding each household's demographics, appliance stock, how they used energy, and a number of other characteristics related to energy consumption. Roy Morgan also collected information from electricity and gas network providers on the households' electricity and gas consumption.[16] In order to ensure that the survey data was an accurate representation of Australian Bureau of Statistics data for each area, Roy Morgan weighted each respondent in the survey individually on the basis of their survey area, income distribution, dwelling type and household structure.[17]

15 See *IPART 2015 Household Survey of Electricity, Gas and Water Usage* at: http://www.ipart.nsw.gov.au/Home/Industries/Research/Reviews/Household_Survey/IPART_2015_Household_survey_of_electricity_gas_and_water_usage

16 See IPART (Sep 2016), *IPART 2015 Household Survey: About the Survey*.

17 For more information on the weighting of responses see Frontier Economics (2016), *Determinants of Household Energy Consumption: Technical Appendices*.

Figure 1: Coverage of IPART's 2015 Household Survey



Source: Google Fusion Tables using data from IPART's 2015 Household Survey

Note: 1) The uncoloured areas of the target regions correspond to postcodes in which there were no sample customers.

2) The six regions analysed in this report are Eastern Sydney (red), Western Sydney (teal), Gosford (light blue), Hunter (yellow), the Riverina (aubergine) and the North Coast (green).[18]

18 The survey treated Sydney as a single region; however, we have split the Sydney region into Western and Eastern Sydney in order to enable us to compare consumption patterns between these two Sydney sub-regions.

1.1 Scope of our task

In this context, IPART has engaged Frontier Economics to undertake an analysis of the 2015 Household Survey data. In particular, IPART has requested that Frontier Economics:

- Conduct statistical and econometric analysis (including utilising behavioural insights) on the 2015 Household Survey data to identify the drivers of residential energy consumption;
- Present these findings in a clear and concise report that is accessible by a range of audiences; and
- Provide detailed technical appendices to inform a range of interested stakeholders and allow them to conduct further research into residential energy consumption.

1.2 Structure of the report

The remainder of the report is structured as follows:

- Section 2 provides an overview of energy consumption in the surveyed regions of NSW.
- Section 3 outlines the approach used to analyse the drivers of household electricity and gas consumption in the Sydney, Gosford, Hunter, the Riverina and the North Coast regions.
- Section 4 investigates what influences a household's propensity to take up different energy sources, including gas and solar PV.
- Section 5 summarises the drivers of household gas consumption over the short, medium and long term.
- Section 6 summarises the drivers of household non-controlled load electricity consumption over the short, medium and long term
- Section 7 summarises the drivers of household controlled load electricity consumption over the short, medium and long term.
- Section 8 discusses the implications of our findings on the drivers of household energy consumption:
  - Section 8.1 discusses differences in uptake and usage of energy sources across the regions, and their effect on household electricity and gas consumption
  - Section 8.2 examines the effect of income on household energy consumption.
  - Section 8.3 investigates the vulnerability of low-income households.

- Section 8.4 investigates the vulnerability of regional households to movements in energy prices.
- Section 8.5 discusses the barriers that exist to improved energy efficiency and conservation and potential behavioural explanations for these barriers.

- Appendix A provides additional information on the drivers of controlled load electricity consumption.
- Appendix B illustrates differences in air-conditioning uptake across the surveyed regions.

2 Overview of household energy consumption and energy sources across NSW

2.1 Overview of household energy consumption

Household energy consumption differs significantly across and within the surveyed regions. Table 1 summarises average household energy, electricity and gas consumption for each of the six regions.[19] These differences are driven by differences in energy source uptake (see Table 3), appliance stock and usage, and differences in household characteristics.

Table 1: Energy consumption across regions[1]

Energy source	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast[2]	All regions
Average energy consumption (MJ)	28,541	33,276	26,926	28,052	44,782		29,929
Average energy consumption (MJ) (households with gas)	34,757	40,136	36,196	33,490	55,309		36,477
Average energy consumption (MJ) (households without gas)	21,451	27,921	22,394	24,694	26,715	20,120	23,213
Average electricity consumption (kWh) (households with gas)	5,395	6,607	6,826	5,322	5,925	4,852	5,655
Average electricity consumption (kWh) (households without gas)	5,968	7,788	6,220	6,862	7,475	5,747	6,481
Average gas consumption (MJ) (households with gas)	17,584	18,610	15,821	16,407	36,919		18,322

Source: Frontier Economics using data from IPART's 2015 Household Survey

Note: 1) While we have information on whether or not households use cylinder gas, there is no data on how much gas they use. Hence households with cylinder gas are excluded from the calculations of gas consumption and energy consumption.

2) No data was collected on the gas consumption of the small proportion of North Coast households that said they have mains gas. Hence we have not calculated energy and gas consumption for the North Coast, and North Coast households have not been included in the calculation of energy consumption across all regions.

19 To enable comparisons to be made between households that use gas and households that do not use gas, we have converted the kWh of electricity consumption to its equivalent energy consumption in MJ using the standard conversion factor of 1 kWh = 3.6 MJ; see e.g. Department of the Environment (2014), *National Greenhouse Accounts Factors*, p.60.

For example, Table 1 shows that on average:

- Household energy consumption is higher in the inland region of The Riverina compared to the other regions, driven by the higher rate of mains gas penetration (as shown in Table 3) and higher average gas consumption in the region.[20]
- Household electricity consumption is lower in the North Coast despite having a lower penetration of either mains or cylinder gas. The lower electricity consumption is driven by a range of factors including lower average income, smaller families, and higher uptake in solar PV.

Table 2: Household electricity consumption across regions, by solar PV uptake

Average electricity consumption (kWh)	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast	All regions
Households without solar PV and without gas	5,811	7,806	6,262	6,661	7,215	5,686	6,325
Households with gross metered solar PV and without gas	7,956	8,217	4,270	6,049	7,050	5,185	6,924
Households with net metered solar PV and without gas	6,349	8,305	6,168	6,267	9,157	8,144	7,212

Source: Frontier Economics using data from IPART's 2015 Household Survey

While our regression results in Table 27 suggest that solar PV uptake is associated with a 336 kWh decrease in household electricity consumption (other things being equal),[21] Table 2 indicates that, on average across all regions, households with solar PV, in fact, consume more electricity than households without solar PV. This is likely

[20] On average, households without gas across NSW consume about 830 kWh more electricity per year than households with gas, although households on the North Coast (a region without mains gas), use materially less electricity than other surveyed regions. Differences in penetration rates can help explain some of the differences in average energy consumption between the regions.

[21] This estimate is obtained by multiplying the regression estimate of 110.2 kWh reduction in billed consumption per kW of PV panels (see Table 27) by the estimated average size of PV panels per household (3.045kW). The estimate is an average across both gross-metered and net-metered households with PV panels. Most households in NSW with PV panels were gross metered during the period of the survey. Billed consumption for gross-metered households is for all the electricity consumed by the household, including the electricity generated by the PV panels. Hence this average reduction is driven by the households with PV panels who were net metered, and does not reflect the average reduction in network-delivered electricity consumption.

the result of differences in the socio-economic characteristics of households with solar PV panels compared to households without, since households with solar PV panels have more adults, higher income and more bedrooms (see Table 7).

2.2 Overview of household energy sources

Table 3 shows the penetration of gas, controlled load electricity and solar panels (solar PV) across the different regions. About half of households (51%) are estimated to use either mains gas or gas from large, non-portable cylinders. Households in The Riverina and Eastern Sydney are the most likely to use mains gas, while households in the North Coast (where mains gas is less accessible) are more likely to use cylinder gas. Figure 2 shows the uptake of gas by LGA, and indicates that there are also considerable differences in the penetration rates within regions.

Table 3: Penetration rates of different sources of energy

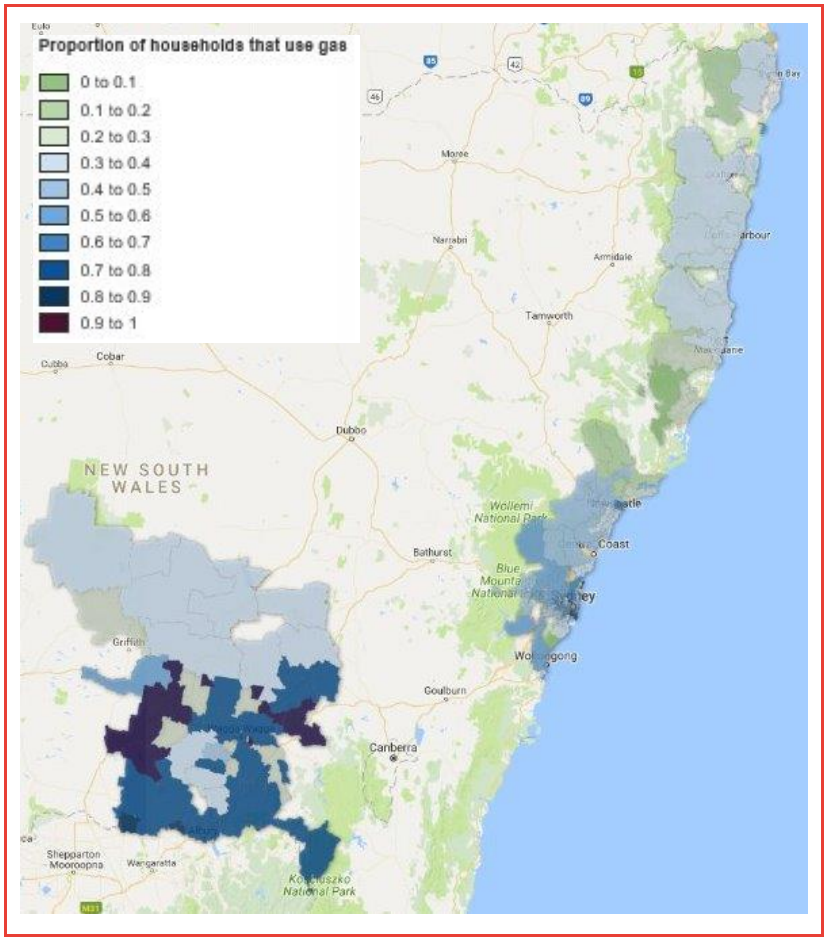
Energy source	East Sydney	West Sydney	Gosford	Hunter	Riverina	North Coast	All regions
Households that use mains gas	54%	43%	28%	36%	57%	2%	44%
Households that use cylinder gas	3%	6%	15%	8%	11%	28%	7%
Households with controlled load electricity	30%	48%	63%	58%	47%	78%	43%
Households with solar PV	12%	23%	22%	27%	31%	34%	19%

Source: Frontier Economics using data from IPART's 2015 Household Survey

Table 3 shows that, on average, households in regions outside Sydney are more likely to have controlled load electricity than Sydney households, particularly when compared to Eastern Sydney. By far the highest penetration of controlled load is in the North Coast where almost 80% of households utilise controlled load electricity.

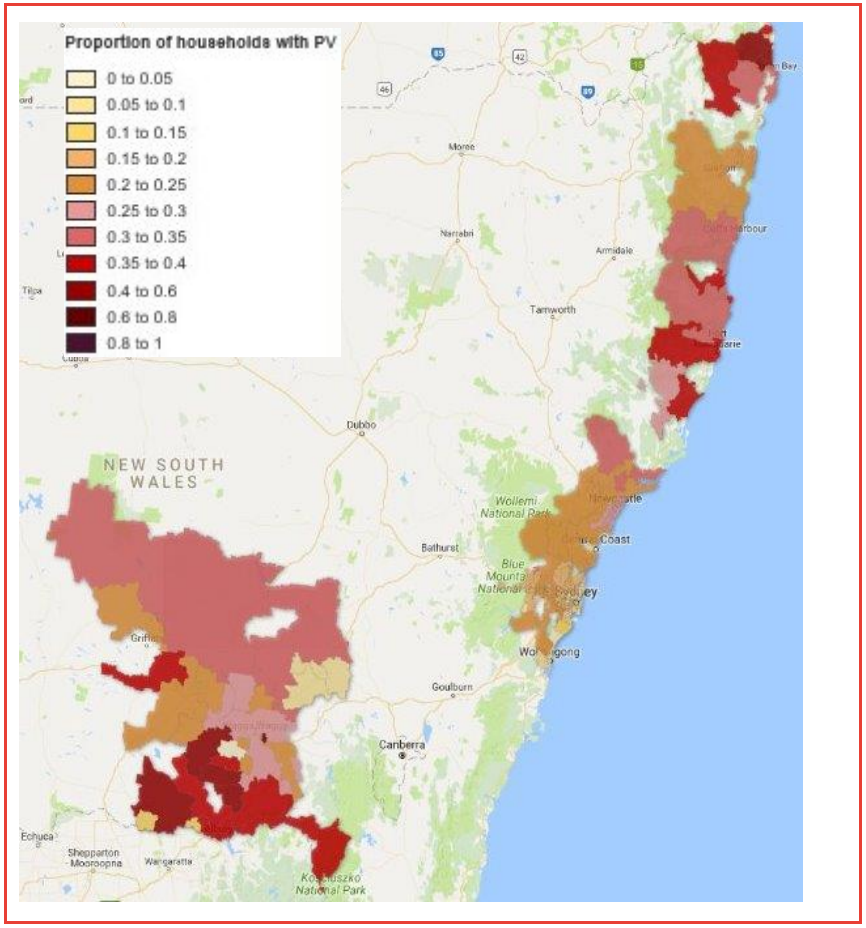
Table 3 indicates that around a fifth of surveyed households use solar PV. Eastern Sydney again stands out as having by far the lowest penetration rate. Figure 3 shows the uptake of solar PV by LGA, and indicates that there are considerable differences in the penetration rates within regions.

Figure 2: Gas uptake by LGA



Source: *Google Fusion Tables using data from IPART's 2015 Household Survey*

Figure 3: PV uptake by LGA



Source: *Google Fusion Tables using data from IPART's 2015 Household Survey*

3 Our approach to analysing household energy consumption

3.1 Factors influencing energy consumption

There is a complex interplay between a range of short, medium and long term factors that influence energy consumption. Observed differences in household energy consumption can be driven by differences in location, dwelling type and size, energy sources used, household characteristics, appliance stock and usage. Some variables impact on consumption at different levels. For example, income is likely to be a major influence on the location and size of dwelling a household lives in, as well as the appliance stock. However, it may have less influence on the usage of the appliance stock.

Table 4: 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 Number 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

In Table 4 we have categorised a household's energy consumption in terms of three broad choices made by the household that affect energy consumption in the short, medium and long term. We have used a number of analytical tools

including econometric regression analysis and behavioural insights[22] to investigate the underlying relationships between gas and electricity consumption and a range of social and economic characteristics.

Long term

Over the long term, households are able to choose the characteristics of their dwelling such as its location, dwelling type and block size. These choices affect a household's energy consumption over the long term. Important drivers of these choices are likely to be socio-economic variables such as income and household size, as well as family and attitudinal factors.

Medium to long term

In the medium to long term, dwelling location, dwelling type and block size are assumed to be constant. However, households can change their choice of energy sources, their appliance stock for different end uses, install insulation and so on. These choices are mainly driven by socio-economic and attitudinal variables. Hence the coefficients in a regression model that only contains socio-demographic and attitudinal drivers, but no appliance stock variables, can be interpreted as medium to long term responses to changes in the drivers.

Short to medium term

Over the short to medium term, a household's choice of energy sources and the type and capacity of their appliances is taken as fixed, so the amount of energy consumed for each end use is determined by socio-economic, behavioural and attitudinal drivers. As such, the effect of the drivers of household energy consumption in a model specification that includes appliance stock variables can be interpreted as short term responses to changes in the drivers, since the energy sources and appliance holdings are kept fixed.

3.2 Accounting for the factors that influence energy consumption

To gain insight into the factors that influence a household's energy consumption across different time scales, we have used a combination of regression analysis, tabulations, graphical analysis and behavioural insights. In particular, we have used logistic regression analysis to investigate factors that influence the uptake of different energy sources and appliances, and conditional demand regression

[22] Our analysis focuses on what influences household energy consumption, rather than household behaviour. Future research on what influences consumer behaviour, including changes in behaviour across time and place, could assist policy makers in meeting energy and environmental policy objectives.

analysis to investigate the drivers of household gas and electricity consumption by allocating total electricity or gas consumption to the various end uses or appliances in the home. The analysis has been performed across NSW, as well as for each region to help isolate any differences in consumption that arise from regional differences between households. The different types of analysis and results are discussed in more detail in Section 4 to Section 7.

4 Choice of household energy sources

4.1 Characteristics of households using different energy sources

Given a household's socio-demographic characteristics, dwelling type and size, and geographic location, one of the main factors that affects energy consumption is the household's choice of energy. As can be seen in Table 1, households with gas typically use less electricity than households without gas, but they use more energy in total.[23] Similarly, whether or not a household has controlled load or solar PV panels affects their consumption of non-controlled load electricity and gas.

These differences in consumption could be due to differences in the characteristics of households using the different types of energy. For example, a household using gas might, on average, have more people and live in a larger dwelling than a household without gas, which could partly explain the higher energy consumption.

The following three tables summarise key differences in characteristics between households with and without gas, with and without controlled load electricity and with and without solar PV.

Table 5: Household characteristics by gas uptake

Characteristics	Does not have gas	Has gas
Average number of people	2.42	2.82
Average income ($ per annum)	71,442	101,826
Proportion of households that live in a house	73%	81%
Average number of bedrooms	2.94	3.32

Source: Frontier Economics using data from IPART's 2015's Household Survey

The tables show that for each of the three energy sources, households that use the energy source are, on average, quite different to households that do not use the energy source in terms of household size, income, whether the household lives in a house or not, and the number of bedrooms. These socio-demographic factors are all higher for households that have the energy source, except that controlled load households have a lower average income than households that do

[23] As discussed in Section 8.1, while the choice of energy sources can influence household energy consumption, the impact on bills is less clear.

not have controlled load. Households with controlled load are also much more likely to live outside Sydney than households without controlled load.

Table 6: Household characteristics by controlled load uptake

Characteristics	Does not have controlled load	Has controlled load
Average number of people	2.58	2.65
Average income ($ per annum)	93,274	78,665
Proportion of households that live in a house	66%	92%
Average number of bedrooms	2.95	3.42
Proportion of households that live outside Sydney	17%	41%

Source: Frontier Economics using data from IPART's 2015's Household Survey

Table 7: Household characteristics by solar PV uptake

Characteristics	Does not have solar PV	Has solar PV
Average number of people	2.58	2.82
Average income ($ per annum)	86,149	91,031
Proportion of households that live in a house	72%	97%
Average number of bedrooms	3.01	3.67

Source: Frontier Economics using data from IPART's 2015's Household Survey

4.2 Determinants of the uptake of different energy sources

The analysis in the previous section does not enable us to assess the relative importance of the various factors in influencing the uptake of different energy sources. To provide insight into this issue we have estimated logit regression models for the uptake of each of the three energy sources. The logit models show the relationship between the likelihood of a particular household taking up different energy sources and factors such as their location, dwelling type, household size and income. The estimation results are reported in Table 8.

The coefficients reported in the table indicate whether the factor has a positive or negative effect on the likelihood of taking up a particular energy source, while controlling for the values of the other factors. The stars next to each figure

indicate how confident we can be that the effect of each driver is statistically different from zero, i.e. the statistical significance of each driver.[24]

Table 8: Drivers that affect the type of energy used by households

Variables	Household uses gas	Household has controlled load	Household has solar PV panels
Western Sydney	-0.503***	0.417***	0.398***
Gosford	-0.747***	1.111***	0.286
Hunter	-0.573***	0.857***	0.740***
Riverina	0.589***	0.272*	0.883***
North Coast	-1.072***	1.780***	1.136***
Per adult	0.0353	0.0187	0.0822
Per child	0.0582	-0.0832	-0.134**
Per bedroom	0.119***	0.179***	0.284***
Per $10,000 income	0.0538***	-0.0423***	-0.00262
Missing value for income	0.380***	-0.151	-0.13
Household lives in a house	0.459***	1.156***	
Constant	-0.958***	-1.851***	-2.618***
Number of observations	4,404	4,283	3,852
Pseudo R-squared	0.0653	0.1123	0.0409

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect of living in another region rather than Eastern Sydney on the likelihood of using a particular energy source.

3) Since there are very few apartments with solar PV, the model for solar PV has been estimated using only households in houses. Hence this model does not include the dummy variable for house.

4) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

[24] The sizes of the coefficients in a logit regression do not have a straightforward interpretation, since the impact of a variable on the probability of having the energy source is non-linear. However, the sign and significance of the coefficients enable us to determine how important a driver is, and the direction of the impact. The relative sizes are also an indication of which variable has the stronger impact on the probability of having an energy source. For example, the coefficients on the 'house' variable (0.459 for gas uptake and 1.156 for controlled load uptake) indicate that the impact of living in a house rather than an apartment has a much larger impact on the probability of having controlled load than it has on the probability of having gas.

The coefficients on the regional dummy variables show the impact on the likelihood of a household in that region having the energy source compared to a household in Eastern Sydney, after controlling for other differences between the households, such as differences in household size and income. For example the coefficient of 0.589 for The Riverina in the gas uptake equation indicates that, after controlling for differences in households size, number of bedrooms, income and so on, households in The Riverina are significantly more likely to have gas than households in Eastern Sydney, while households in all other regions are significantly less likely to have gas than households in Eastern Sydney. The difference for the North Coast is particularly large. Other observations include:

- The coefficients of 0.459 for the house variable in the gas uptake equation indicates that households living in houses are more likely to have gas than households living in apartments.
- The coefficient of 1.136 for the North Coast in the solar PV equation indicates that households in the North Coast are much more likely than households in Eastern Sydney to have solar PV.
- The coefficients on income show that income has a highly significant positive impact on the likelihood that a household uses gas, a highly significant negative impact on the likelihood of it using controlled load electricity, and no significant impact on the likelihood that the household has solar PV panels.

5 Determinants of household gas consumption

After a household has made the decision to take up certain energy sources, for instance, gas, how much they consume will depend on a complex interplay of household characteristics, appliance stock and usage and regional differences, the effects of which differ, depending on the time period analysed.

Long term

Over the longer term, households are able to choose the characteristics of their dwelling such as its location, dwelling type and block size, and thus household gas consumption in the long-run will depend primarily on household characteristics. Table 9 summarises results from a regression analysis modelling the relationship between household characteristics and gas consumption across the surveyed regions. In this equation we have not controlled for differences in appliance stocks. Hence differences in consumption between households with different characteristics could be due to differences in both the penetration rates in appliance stocks and to different levels of usage of those appliances.

The coefficients indicate the effect each driver has on gas consumption while controlling for differences in the other variables in the model. The stars next to the numbers indicate the statistical significance of each driver. For instance, the coefficient of 18,052 MJ for The Riverina indicates that a household located in The Riverina is estimated to consume 18,052 MJ of gas more than a similar household located in Eastern Sydney and that this difference is statistically significant at the 0.1% level of significance.

The results indicate that, in the long run, regional differences, dwelling type and size, and household size are the primary drivers of differences in household gas consumption.

Table 9: Impact of region and household characteristics on gas consumption

Driver of consumption	Impact on consumption (MJ)
Western Sydney	-2,540**
Gosford	-4,025**
Hunter	-2,801**
Riverina	18,052***
Per adult	2,524***
Per child	1,489**

Per bedroom	1,674***
Per $10,000 income	178.1*
Missing value for income	2,012
Household lives in a house	7,970***
Constant	-1,967
Number of observations	1,603
R-squared	0.2632
Average gas consumption across all regions (MJ)	18,063

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect on consumption of living in another region rather than Eastern Sydney.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Medium to long term

In the medium to long-term, household gas consumption will be a function of whether the household uses gas as a primary or secondary source for space heating, cooking and/or water heating, and the relationship between these end uses and household demographics such as region, household size and number of bedrooms.

Table 10: Penetration rates of gas end uses by region for households using gas (%)

Gas end use	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast	All regions
Proportion of gas households using gas for water heating	69.4%	71.7%	54.1%	65.0%	71.0%	32.4%	67.1%
Proportion of gas households using gas for space heating	58.1%	53.9%	55.3%	59.8%	73.5%	42.0%	57.0%
Proportion of gas households using gas for cooking	79.8%	84.2%	81.2%	77.2%	62.4%	79.5%	79.9%
Proportion of all households that use gas	56.9%	49.2%	43.3%	43.8%	67.5%	29.1%	51.0%

Source: Frontier Economics using data from IPART's 2015 Household Survey

Table 10 summarises gas penetration across the regions, and the use of gas for different end uses. It shows that gas uptake is highest in the Riverina and Eastern

Sydney, where 68% and 57% of households use gas, respectively. Across NSW regions, households that have gas are most likely to use it for cooking, with 80% of households with gas using gas for cooking, followed by water heating with 69% and space heating with 57%. The Riverina and the North Coast regions differ considerably from the other regions, with the use of gas for space heating being much more common in the Riverina than other regions, and much less common in the North Coast. The North Coast also has a very low usage of gas for water heating.

As discussed earlier, over the long term, households are able to choose the characteristics of their dwelling such as its location, type and size, which is likely to have a major impact on the choice of using gas, and on the choice of using gas for different end uses. Table 11 summarises the results of several logit regression models analysing the effect on the likelihood of using gas in general (in the last column), and on the likelihood of using gas for particular end uses. The explanatory variables are indicators for the region, household characteristics and indicators for the use of gas for other end uses.

The results in the last column show that households in Western Sydney, Hunter and Gosford are significantly less likely to use gas after controlling for differences in other factors. Income, the number of bedrooms and living in a house all have a significant positive impact on the uptake of gas.[25]

Interestingly, the results for the individual end uses show that while there is a strong relationship between the use of gas for cooking and water heating (positively) or space heating (negatively) and vice versa, the relationship between gas for water heating and space heating is negligible. [26]

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25 The coefficients reported in Table 11 indicate whether the factor has a positive or negative effect on the likelihood of taking up gas in general or for a particular end use. The stars next to each figure indicate its statistical significance. For instance, the coefficient of 0.589 for Riverina indicates that households in Riverina are more likely than households in Eastern Sydney to take up gas, and the difference is statistically significant at the 0.1% level. Note that since we have included all possible end uses for gas as explanatory variables, no constant has been included in the model.

26 These results are primarily driven by households with mains gas. For households using cylinder gas, there is still a significant negative relationship between using gas for cooking and space heating, but the relationship between cooking and water heating is no longer statistically significant.

Table 11: Drivers for using gas for different end uses in households that use gas

Variables	Gas water heating	Gas space heating	Gas cooking	Household uses gas
Western Sydney	0.0360	-0.363**	0.0331	-0.503***
Gosford	-0.758***	-0.510**	0.0272	-0.747***
Hunter	-0.248	-0.243	-0.151	-0.573***
Riverina	0.168	0.343*	-0.802***	0.589***
North Coast	-1.865***	-1.218***	0.0471	-1.072***
Per adult	0.0343	-0.118*	0.0937	0.0353
Per child	0.0699	-0.0777	-0.0966	0.0582
Per bedroom	-0.0184	0.0719	0.101	0.119***
Per $10,000 income	0.00244	0.00706	0.00552	0.0538***
Missing value for income	0.184	0.266	-0.319	0.380***
Household lives in house	0.129	1.290***	-0.0222	0.459***
Household has gas water heating		-0.129	0.692***	
Household has gas space heating	-0.128		-0.394***	
Household has gas cooking	0.688***	-0.392***		
Constant	0.174	-0.233	0.714**	0.459***
Number of observations	2,168	2,168	2,168	4,404
Pseudo R-squared	0.0628	0.0542	0.0432	0.0653

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect on the likelihood of using a particular gas end use of living in another region rather than Eastern Sydney.

3) Pseudo R-squared is an indication of how well the model explains the likelihood of a household using gas for different end uses.

4) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Short to medium term

Over the short to medium term, a household's choice of energy sources and the type and capacity of their appliances is fixed, so their gas consumption will depend on the characteristics of their households. Table 12 summarises the estimation results for regression models for relationship between end-use ownership and gas consumption, with the coefficients representing the contribution to household gas consumption of each end use. This kind of regression model was first estimated by Parti and Parti (1980)[27] and is often referred as conditional demand analysis. It can be used to estimate the contribution of each end use or appliance to total consumption. For example, the first column in Table 12 shows that, across all NSW regions, using gas for space heating is, on average, associated with a 14,580 MJ increase in gas consumption.

Table 12: Gas consumption by main end uses by region (MJ)

End use	All regions	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina
Water heating	11,311***	8,906***	10,795***	9,529***	10,755***	14,163***
Space heating	14,580***	13,356***	6,921***	11,632***	8,859***	25,157***
Cooking	1,544**	3,134***	4,936**	760	2,148	4,871
Number of observations	1,594	739	259	102	274	220
R-squared	0.65	0.67	0.73	0.64	0.74	0.73
Average gas consumption (MJ)	18,063	17,275	18,421	15,821	16,083	37,397

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) Since we have all the end uses for gas in the model, the model does not have a constant term – all gas consumption is allocated to the three end uses.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Comparing results across the regions shows that gas space heating is associated with a much higher gas usage in the Riverina than in the more coastal regions. The regional results for cooking show more variability across regions than seems plausible. This is due to the fact that the amount of gas used for cooking is relatively small compared to the other end uses, and given the small sample sizes for the regional regressions, it is not possible to identify the separate contribution

[27] Parti, M. and C. Parti (1980), "The total and appliance specific conditional demand for electricity in the household sector", *Bell Journal of Economics*, 11, 309-324.

of gas cooking to total gas consumption with a high level of precision in most regions.

Over the short term, household gas consumption also depends on how frequently the household uses each appliance. To capture this effect we have estimated a model specification that includes end use dummy variables as well variables for frequency of use for some end uses and household characteristics. Table 13 shows the estimation results for this model.

The coefficients in the table show the estimated effect in MJ of each driver on household gas consumption, while controlling for appliance stock, frequency of use and household characteristics. For example, the value of 8,827 MJ for gas main water heating in the first column indicates that, across all regions, a household with gas space heating is estimated, on average, to consume 8,827 MJ more of gas per annum, than a similar household without gas space heating. The estimate is lower than the estimate in Table 12, which is due to the fact that the amount of gas consumed for water heating varies by household characteristics, and this is captured in the coefficients of the household characteristics variables in the model.[28]

The results in Table 13 indicate that, across all regions combined, the use of gas for water and space heating, and the hours per day of gas space heating in winter, are the primary end use drivers of household gas consumption. This generally also holds across the regions. The household characteristics most responsible for driving gas consumption are whether or not a households lives in a house and the number of adults in the household.

Interestingly, income does not have a statistically significant impact on consumption in the short term. Thus, while Table 11 shows that income has a very strong impact on whether or not a household uses gas, once this choice has been made, income has very little impact on how much gas is used.

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28 A more complex model specification, with interactions between the end-use dummy variables and the household characteristics, would enable us to estimate how each of the end-use consumptions varies with household characteristics. We attempted to estimate such models for both gas and electricity, but the results were generally not plausible. The likely reason for this is that the more complex specification introduces multicollinearity between the interaction terms for different end uses, making it difficult to identify the separate effect of a household characteristic on the consumption for each of the end uses.

Table 13: Household characteristics and end use model for gas consumption

Driver of consumption (MJ)	All regions	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina
Gas is main fuel used for water heating	8,827***	7,108***	7,572***	517	9,230***	8,781*
Gas is only a secondary fuel for water heating	-3,001					
Gas is used for space heating	3,506***	10,217***	5,363***	9,830***	7,700***	21,674***
Per hour of gas space heating on average day in winter	2,572***					
Missing value for hours of gas space heating on average day in winter	13,382***					
Both gas and electricity are used for space heating	-3,490***					
Gas is used for cooking	-954	1,615	-1,047	-1,497	-1,359	4,481
Washing machine, per use per week	621**					
Dishwasher, per use per week	201					
Per adult	1,726***	2,485***	2,042**	1,178	2,726***	10,008***
Per child	1,166*	1,146	1,149*	2,113	855	5,827*
Per bedroom	1,087**	1,315*	849	2,507	1,238	954
Per $10,000 income	100	106	415**	-183	128	-348
Missing value for income	351	923	4,301*	843	-89	-3,830
Household lives in a house	4,625***	5,129***	15,501***	2,673	2,102	1,253
Constant	-8964***	-10,499***	-18,099***	-7,012	-7,993**	-14,333
Number of observations	1,592	744	260	102	277	220
R-squared	0.38	0.30	0.30	0.23	0.34	0.24
Average gas consumption (MJ)	18,063	17,275	18,421	15,821	16,083	37,397

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for gas cooking mostly have the wrong sign, but they are not statistically significant. The gas consumption for cooking is most likely captured by the household size

variables. In an attempt to obtain more reasonable estimates for gas cooking we interacted the end-use dummy variables with the socio-demographic variables, but the results were not plausible.

3) The small sample sizes at the regional level do not enable us to obtain reliable coefficient estimates for the less important drivers of gas consumption. Hence we are restricted to specifying a model containing only the most important drivers.

4) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

6 Determinants of household non-controlled load electricity consumption

After a household has made the decision of which energy sources to use, how much electricity it consumes will depend on a complex interplay of household characteristics, appliance stock and usage and regional differences, the effect of which differs, depending on the time period analysed.

Long term

Over the longer term, households are able to choose the characteristics of their dwelling such as its location, dwelling type and block size, and thus household electricity consumption in the long run will depend primarily on region and household characteristics. Table 14 summarises results from a regression model for the relationship between household characteristics and non-controlled load (NCL) electricity consumption across the surveyed regions. The coefficients indicate the effect that each driver has on electricity consumption, while the stars next to the numbers indicate how statistically significant each driver is from zero. For instance, the coefficient of 983.6 for adults indicates that a household with two adults would consume 983.6 kWh more of NCL electricity than a similar household with one adult.

While Table 11 indicates that regional differences play an important role in determining gas consumption, Table 14 shows regional differences have less effect on NCL electricity consumption, with only Western Sydney and the North Coast having significantly different consumption to Eastern Sydney. In the long term, it is household size, income and the number of bedrooms that are the major drivers of household NCL electricity consumption.

Table 14: Impact of region and household characteristics on non-controlled load electricity consumption

Driver of consumption	Impact on consumption (kWh)
Western Sydney	600.5***
Gosford	90.97
Hunter	-15.55
Riverina	214.4
North Coast	-646.9***
Per adult	983.6***
Per child	410.4***
Per bedroom	565.7***

Per $10,000 income	60.41***
Missing value for income	464.4**
Household lives in a house	69.84
Constant	424.7**
Number of observations	4282
R-squared	0.275
Average non-controlled load electricity consumption across all regions (kWh)	5,094

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect on consumption of living in another region rather than Eastern Sydney.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Medium to long term

In the medium to long term, household NCL electricity consumption will depend on factors such as, whether the household uses electricity for water heating, cooking or space heating, the household's appliance stock and age, the presence of solar PV, and the relationship between these end uses and household demographics and characteristics such as region, household size and number of bedrooms.

Table 15 summarises penetration rates for NCL electricity end uses and appliance capacities. The table shows that, in general, appliance penetration rates and capacities do not vary widely across regions. Some exceptions are that Eastern Sydney has a much higher penetration rate of NCL water heating than other regions and a lower penetration rate of electric cooking, while the Riverina has lower penetration rates of electric space heating and clothes dryers.

Table 15: Penetration rates of non-controlled load electricity end uses and appliances using by region

NCL electricity end use or appliance	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast	All regions
Proportion of households using non-controlled load electricity for water heating	34.8%	19.4%	15.9%	15.3%	9.7%	12.8%	26.1%
Proportion of households using electricity for space heating	73.2%	84.8%	75.6%	78.9%	53.9%	67.5%	75.4%

Proportion of households using electricity for cooking	67.8%	71.0%	79.7%	78.9%	74.7%	84.4%	71.8%
Proportion households with a dishwasher	62.2%	62.7%	66.3%	57.2%	55.3%	55.5%	61.1%
Proportion households with a dryer	66.8%	71.7%	72.2%	70.4%	56.4%	63.5%	67.8%
Average number of large fridges per household	0.57	0.66	0.54	0.62	0.59	0.69	0.61
Average number of medium fridges per household	0.54	0.54	0.60	0.55	0.65	0.50	0.54
Average number of other fridges per household	0.29	0.32	0.35	0.33	0.36	0.25	0.30
Average litres of refrigeration capacity per household	721	785	715	756	773	782	745

Source: Frontier Economics using data from IPART's 2015 Household Survey

Table 16 and Table 17 provide information on the socio-economic factors that influence the presence and capacity of important NCL electricity end uses. Table 16 shows the results of logit models for the likelihood of using non-controlled load electricity for difference end uses. For example, Table 16 shows that:

- Having gas has a major impact on the likelihood of all the main electricity end uses, a negative impact for the competitive end uses (water heating, space heating and cooking), and a positive impact for a dishwasher or dryer.
- For each of the end uses, there are also regional differences.
- Living in a house has a strong negative impact on using NCL electricity for water heating, but it has little impact on the other end uses.
- Income has a strong positive impact on the likelihood of having NCL space heating, a dishwasher and a dryer.
- The number of bedrooms impacts positively on the likelihood of having a dishwasher and dryer, while the number of adults has strong negative impact on the likelihood of having electric cooking and a strong positive impact on the likelihood of having a clothes dryer.

Table 16: Drivers for using electricity for different end uses

Variables	NCL electric water heating	Electric space heating	Electric cooking	Dishwasher	Dryer
Western Sydney	-0.296*	0.529***	-0.0437	-0.399***	0.0131
Gosford	-0.690***	-0.0257	0.283	0.191	0.354**
Hunter	-0.814***	0.0807	0.237	-0.407***	0.0358
Riverina	-1.274***	-0.979***	0.556***	-0.643***	-0.642***
North Coast	-1.022***	-0.556***	-0.0358	-0.271*	-0.275*
Per adult	0.00512	-0.104*	-0.217***	-0.0162	0.197***
Per child	0.164**	-0.00207	0.0498	-0.0657	0.0806
Per bedroom	-0.404***	0.133**	0.0738	0.807***	0.336***
Per $10,000 income	0.0116	0.0273***	0.0209*	0.0988***	0.0456***
Missing value for income	-0.418*	0.0943	0.480**	0.473***	0.222
Household lives in a house	-1.151***	0.326*	0.199	-0.0253	0.0729
Household has gas	-0.575***	-0.809***	-4.117***	0.567***	0.211**
Household has controlled load electricity		0.0802	0.544***	-0.0392	0.118
Constant	1.432***	0.880***	3.678***	-2.699***	-1.221***
Number of observations	4283	4283	4283	4283	4283
Pseudo R-squared	0.147	0.060	0.347	0.175	0.071

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect on the likelihood of using a particular end use of living in another region rather than Eastern Sydney.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Table 17 shows the results of linear regression models for the number of fridges per household and refrigeration capacity. It is noteworthy that regional differences play almost no role in determining the number and capacity of fridges. The main finding is that the size of the household, the number of bedrooms and living in a house rather than apartment impact positively on the number of large fridges and fridge capacity in the household, and the number of children impacts negatively on the number of medium sized fridges and positively on the number of large fridges.

Table 17: Drivers of fridge numbers and capacity

Variables	Number of large fridges per household	Number of medium fridges per household	Number of other fridges per household	Fridge capacity per household (litres)
Western Sydney	0.0180	0.00358	0.0205	13.41
Gosford	-0.0597	0.0571	0.112**	-25.64
Hunter	0.0133	0.0117	0.0514*	10.64
Riverina	0.00933	0.108**	0.0728*	50.43*
North Coast	0.0708*	-0.0186	-0.0127	35.86*
Per adult	0.105***	-0.00152	0.0287**	77.19***
Per child	0.0403**	-0.0451***	-0.0173	14.88
Per bedroom	0.0967***	-0.0121	0.0193	63.92***
Per $10,000 income	0.00482*	-0.00201	0.00298	3.161**
Missing value for income	0.0577	-0.0219	0.0335	38.01*
Household lives in a house	0.0894**	0.0200	-0.0171	82.82***
Constant	-0.0590*	0.615***	0.162***	281.2***
Number of observations	4,404	4,404	4,334	4,298
R-squared	0.108	0.0081	0.0113	0.154

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect on the number/capacity of fridges of living in another region rather than Eastern Sydney.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Short to medium term

Over the short to medium term, a household's choice of energy sources and the type and capacity of their appliances is fixed, so their NCL electricity consumption will depend on the characteristics of the household and the frequency of use of each appliance.

Table 18 summarises the average NCL electricity consumption in kWh of each end use estimated using a condition demand analysis model. In interpreting these results it is important to note:

- For some end uses there are considerable differences in the estimated NCL consumption across regions. For instance, average NCL electric water heating consumption is materially higher in Gosford and the Riverina that in Eastern Sydney and the North Coast. However, for some of the regions the estimate of NCL consumption for water heating was not statistically significant. The same is true for cooking. [29]
- On the other hand, the estimates of the contribution of space heating, dishwasher, dryer and different sizes of fridges are all highly significant in every region. Moreover, the estimates are reasonably consistent across regions. It is noteworthy that in every region, the consumption of a large fridge is higher than that of a medium fridge, which is higher than that of a small (other fridge). [30]
- While having electric space heating is estimated to increase electricity consumption by 857 kWh, on average, across all NSW regions, a direct comparison between the energy required for electric space heating in Table 18) and the energy required for gas space heating (Table 12) should not be made. This is because regression analysis cannot perfectly control for all the variables that influence consumption.

29 It appears that the contribution of these end uses to NCL consumption at the regional level is difficult to estimate precisely using the regional sample sizes in the current sample.

30 The 'other' fridge category consists of small fridges, bar fridges and spare fridges that are not used all year round.

Table 18: Non-controlled load (NCL) electricity consumption by main end uses and appliance numbers

Electricity end use or appliance	All regions	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast
Uses non-controlled load electricity for water heating	489.1***	102.3	625.6	1020.6**	863.2**	1135.9	268.7
Uses electricity for space heating[31]	856.9***	669.2***	1359.9***	912.8**	943.3***	1067.4***	353.3
Uses electricity for cooking	272.0**	641.7***	541.5	-337.6	118.3	341.9	-149.8
Dishwasher, per use per week	966.6***	1107.8***	948.2**	1141.8***	841.5***	1275.0***	486.5**
Dryer, per use per week	866.5***	615.8***	1011.5***	774.5**	1063.5***	1097.6***	811.2***
Per large fridge	1959.6***	1998.2***	1947.6***	2470.7***	2180.5***	1312.9***	1482.0***
Per medium fridge	1319.4***	1318.2***	1230.2**	1685.6***	1491.6***	959.3***	1075.8***
Per other type of fridge	854.8***	982.9***	759.1*	974.5***	721.5***	693.5**	602.0*
Constant	581.4***	624.7*	636.3	272.4	229.6	1114.7**	1233.4***
Number of observations	4,215	1,459	614	411	819	368	544
R-squared	0.229	0.243	0.189	0.272	0.263	0.273	0.179
Average non-controlled load electricity consumption (kWh)	5,094	4,897	6,048	5,124	5,021	5,169	4,182

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

[31] While regression analysis seeks to control for the variables that influence consumption, it cannot perfectly control for all the variables that that influence consumption. For this reason a direct comparison between the energy required for electric space heating (Table 18) and the energy required for gas space heating (Table 12) should not be made. Households that use electric space heating are likely to heat their homes in a different way to households that use gas space heating, and there are also differences in the characteristics of households using electric rather than gas space heating.

Since the effect of an end use on electricity consumption depends in part on household characteristics such as the number of adults in the household, it is also important to investigate the relationship that end uses and demographics have with electricity consumption. The impact of household characteristics on consumption in the short term is two-fold; firstly, they capture the consumption of end uses and appliances that have not been explicitly included in the model; secondly, they capture variations in the frequency or intensity with which the end uses and appliances are used.

We have estimated such models for all NSW regions and for each region separately. Since the results are quite extensive, they are presented in Table 27 at the end of this report. We make the following observations on the results:

- The model for 'all regions' is much more detailed than the regional models. The sample sizes in individual regions are not large enough to enable plausible estimates to be obtained for the less important drivers of electricity consumption.
- On average across NSW regions, for a household with electric space heating, using the heating for an extra one hour per day in winter increases annual NCL electricity consumption by 183.7 kWh.
- When this is multiplied by the average number hours of use per day in winter (2.54) and added to the coefficient for the space heating dummy variable we obtain an estimate of 757.9 kWh per annum per household using electricity space heating across NSW regions.
- A similar calculation for air-conditioning produces an estimate of 600.1 kWh per annum per household using air-conditioning across NSW regions.
- The estimates for the consumption for electric cooking are not consistent across regions, and not always plausible. (We have noted the difficulty in obtaining precise estimates for the energy used for cooking earlier in this report.)
- We have not included frequency of washing machines in the models since the impacts were small and statistically highly insignificant. It is likely that the impact on consumption of washing machines is subsumed by the household size variables.
- We have left some variables of interest (such as the impact of taking steps towards electricity conservation and income) in the model although their estimates were not statistically significant, as they still had the expected sign and a plausible magnitude.
- The estimates for many of the other end uses are statistically highly significant and reasonably consistent across regions.

7 Determinants of household controlled load electricity consumption

Long term

As with gas and non-controlled load electricity consumption, over the longer term, households are able to choose the characteristics of their dwelling such as its location, dwelling type and block size, all of which could affect whether or not a household uses controlled load electricity. In in long run, household controlled load electricity consumption is likely to depend primarily on these choices and on household characteristics.

Table 19 summarises results from a regression analysis of controlled load consumption on household characteristics across the surveyed regions.[32] The results suggest that in the longer term, household size and regional differences are the primary drivers of controlled load consumption with an additional adult accounting for 479 kWh of consumption per year, and an additional child accounting for 346 kWh, all else equal. Controlled load electricity consumption, per household with controlled load, is far higher in the Riverina than in any of the other regions, being 518 kWh higher than Eastern Sydney per year, and even higher compared to the other regions.

Table 19: Impact of region and household characteristics on controlled load consumption

Driver of consumption	Impact on consumption (kWh)
Western Sydney	-118.873
Gosford	-259.124***
Hunter	-334.048***
Riverina	518.225***
North Coast	-581.978***
Per adult	479.425***
Per child	345.775***
Per bedroom	49.735*
Per $10,000 income	17.564

[32] The coefficients provide an indication of the effect each driver has on controlled load electricity consumption, while the stars next to each coefficient indicate the statistical significance of the driver. The coefficient of -118.873 for Western Sydney, for instance, indicates that a household in Western Sydney consumes around 119 kWh less than a similar household living in Eastern Sydney.

Missing value for income	17.861
Household lives in a house	-49.231
Constant	991.585***
Number of observations	2,172
R-squared	0.2467
Average controlled load consumption across all regions of households with controlled load (kWh)	2,260

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The variables for the different regions show the consumption in each region compared to the consumption in Eastern Sydney.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Medium term

Controlled load electricity is primarily used for off-peak water heating. We assumed that all surveyed households with controlled load consumption who used electricity as their primary source for water heating used controlled load electricity for their primary water heating.[33]

Table 20 summarises controlled load penetration by end use across the regions, and indicates that, on average, uptake is highest in Gosford and the North Coast, where 63% and 78%, respectively, of households use controlled load electricity. Households that have controlled load are much more likely to use it as a primary source of water heating (including possibly as a primary and secondary source), rather than only as a secondary source.

Across the regions, the North Coast stands out as having the highest penetration of controlled load. However, in the North Coast controlled load is used less frequently as the primary source of water heating than in other regions, and much more likely to be used as a secondary source. The region also has the highest uptake of solar hot water (around three times the average), which could explain why controlled load is more likely to be a secondary source for water heating.

Over the medium term, household controlled load electricity consumption mainly depends on whether the household uses controlled load electricity as a primary source or only as a secondary source for water heating. The difference

[33] There were also households with controlled load consumption who only used electricity as a secondary source of water heating or for electricity boosted solar water heating. We grouped the households with controlled load into those who used controlled load electricity for either their primary water heating or only as a secondary source of water heating.

between these choices depends on household demographics such as region, household size and number of bedrooms.

Table 20: Penetration rates of controlled load end uses by region for households using controlled load (CL) electricity (%)

CL end use	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast	All regions
Proportion of CL households using CL as their primary source for water heating	83.6%	81.6%	86.4%	80.1%	82.8%	67.9%	80.0%
Proportion of CL households using CL as their secondary source of water heating only	16.4%	18.4%	13.6%	19.9%	17.2%	32.1%	20.0%
Proportion of all households using CL	29.6%	48.0%	63.0%	58.2%	47.2%	78.3%	42.9%

Source: Frontier Economics using data from IPART's 2015 Household Survey

Table 21 summarises the results from a logit regression for the choice between using controlled load for primary water heating or only as a source for secondary water heating. We also reproduce the results of the logit regression in Table 8 for the uptake of controlled load as an energy source.[34]

The results indicate that households in regions other than Eastern Sydney are more likely to have controlled load electricity than households in Eastern Sydney, with the North Coast being the most likely, followed by Gosford, Hunter, Western Sydney and the Riverina. The main socio-demographic drivers are whether the household lives in a house and the number of bedrooms, both of which have a strong positive impact, and income, which has a strong negative impact.

The main driver of whether controlled load is used as a primary or secondary source of water heating is whether a household lives in the North Coast, which has a far lower likelihood of households using controlled load as the primary rather than secondary source of water heating. Living in a house, the number of bedrooms and income all have a significant negative impact on the likelihood of using controlled load for primary rather than secondary, water heating.

[34] The coefficients reported in Table 21 indicate whether the factor has a positive or negative effect on the likelihood of taking up gas in general or for a particular end-use, while the stars next to each figure indicate its statistical significance.

Table 21: Drivers for using controlled load for different end uses in households that use controlled load

Variables	CL used as primary source for water heating	Household uses CL
Western Sydney	-0.099	0.417***
Gosford	0.188	1.111***
Hunter	-0.388	0.857***
Riverina	-0.077	0.272*
North Coast	-1.085***	1.780***
Per adult	-0.088	0.0187
Per child	0.042	-0.0832
Per bedroom	-0.186**	0.179***
Per $10,000 income	-0.033**	-0.0423***
Missing value for income	-0.271	-0.151
Household lives in a house	-1.787**	1.156***
Constant	4.522***	-1.851***
Number of observations	2,200	4,283
Pseudo R-squared	0.05	0.1123

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) The coefficients for the different regions indicate the effect on the likelihood of using an end use of living in another region rather than Eastern Sydney.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

Short to medium term

Over the short to medium term, a household's choice of energy sources and the type and capacity of their appliances is fixed. For controlled load we can estimate the consumption for primary water heating versus secondary water heating directly from the data, since we have classified households as having only one of these two options. Across the NSW regions these estimates are 2,516 kWh for primary water heating and 1,314 kWh for secondary water heating only.

Controlled load consumption will also vary by household characteristics and the frequency of use of appliances such as dishwashers and washing machines. Table 22 summarises the results from regression analysis that models the relationship between end-use ownership and usage, household demographics and controlled load electricity consumption, with the coefficients representing the contribution to household controlled load electricity consumption.

The number of adults and children both have a strong impact on controlled load consumption, with each adult contributing about 70% more than each child across the regions. Income and the frequency of washing machine use per week also have strong positive impacts on consumption. Households in the North Coast have lowest consumption, all else equal, most likely due to the fact that many of them only use controlled load for secondary water heating.

Table 22: Impact of household characteristics and end uses on controlled load electricity consumption

Driver of consumption (kWh)	All regions	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast
Controlled load used as primary source for water heating	882.6***	1095***	1267***	732.7***	944.5***	1429***	962.4***
Controlled load used only as secondary source for water heating	-339.4**	-137.7	87.96	-385.3	-310.8	662.2	-243
Per adult	410.0***	642.2***	500.3***	673.4***	552.4***	680.0***	487.00
Per child	242.2***	288.8***	378.8***	284.0**	455.3***	447.3*	391.39
Western Sydney	-91.77						
Gosford	-312.1***						
Hunter	-310.0***						
Riverina	462.2***						
North Coast	-386.4***						
Per bedroom	58.86*						
Per $10,000 income	21.16***						
Missing value for income	68.56						
Washing	95.42***						

machine, per use per week							
Dishwasher, per use per week	23.73*						
Number of observations	2,158	485	310	275	501	171	430
R-squared	0.82	0.84	0.88	0.88	0.77	0.74	0.77
Average controlled load consumption (kWh)	2,260	2,536	2,419	2,157	1,991	2,681	1,677

Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) For the regional models, the small sample sizes do not enable us to obtain reliable coefficient estimates of many of the less important drivers of controlled load electricity consumption. Hence we are restricted to specifying a model containing only the most important drivers.

3) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

8 Implications of our findings on the drivers of household energy consumption

8.1 Choice of energy sources can influence household energy consumption, however the impact on bills is less clear

Household (grid) electricity consumption in Australia has decreased over the last few years.[35] Part of the reason for this reduction in electricity consumption could be due to underlying changes occurring in the energy sources used by households, such as the uptake of solar PV panels and switching fuel types, which are likely to have a significant impact on household energy consumption.[36]

The penetration rates of gas, controlled load electricity and solar PV vary considerably across regions, as do the rates of fuel switching. Significant regional differences remain in the choices of energy sources even after controlling for socio-demographic differences between households, such as income, household size, dwelling type and the number of bedrooms (see Section 4.2). These remaining differences are most likely due to differences in climate, the availability of gas and other regional characteristics. This suggests that regional shifts in population can also impact on the type and amount of energy used by the average household in NSW.

The regression results in Sections 4 to 7 highlight that the choice of energy sources can significantly influence household energy consumption. However, the impact on customer bills is less clear. While an analysis of the competitiveness of household energy choices is beyond the scope of this report, it is important that several key factors are taken into account when seeking to understand the impacts that changes in energy sources and energy consumption may have on household energy bills including:

- There is significant diversity in NSW household energy consumption, even within regions, with a households' specific consumption patterns 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 structures of electricity and gas tariffs), which can dampen or exacerbate the impact on bills from changes to consumption;

35 See, for example, AEMO (2016), *National Electricity Forecasting Report,* p19.

36 See BIS Schrapnel (2014), *Household Appliances Market in Australia.*

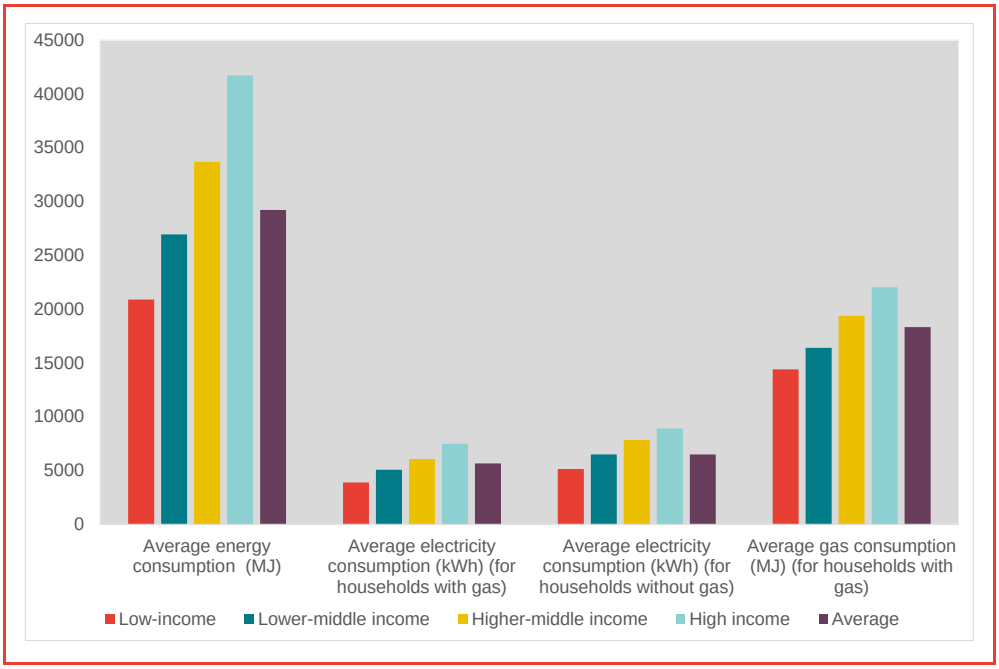
- There is uncertainty related to forecast changes to retail electricity and gas prices, due to electricity and gas network prices in NSW.[37]
- The cost competitiveness or relative costs of energy supply options, are only one aspect of competitiveness, with households typically balancing a range of service quality, convenience, environmental and energy cost considerations when making energy decisions.

8.2 Household energy consumption increases with income, but income primarily drives household and lifestyle choices

In general, income is positively related to energy consumption, with higher income households consuming more energy on average (see Figure 4). However, income in the short term does not have a statistically significant impact on consumption. Rather the key short term drivers of gas and electricity consumption are the number and frequency of use of appliances. For example, Table 27 indicates that each additional use of a clothes dryer per week (i.e. increasing usage from once to twice a week) increases annual electricity consumption by 253 kWh, with the number and frequency of use of appliances influenced by location, household size and number of bedrooms. That is, if we control for other factors that may be positively correlated with income, such as larger dwellings or families, increases in income do not significantly influence consumption.

[37] Resulting from the appeals process in the Australian Competition Tribunal and the AER's decision to appeal the ACT's decisions to the Federal Court.

Figure 4: Household energy consumption by income group



Source: Frontier Economics using data from IPART's 2015's Household Survey

Table 23: Demographics and other characteristics by income group

Household characteristic	Low income	Lower-middle income	Higher-middle income	High income	Average
Number of adults	1.57	2.06	2.48	2.84	2.15
Number of children	0.23	0.42	0.72	0.67	0.48
Proportion of households that live in a house	70%	79%	80%	82%	77%
Proportion of households that live in a flat	30%	21%	20%	18%	23%
Number of bedrooms	2.65	3.08	3.41	3.69	3.14
Proportion of households with a pool	5%	12%	19%	25%	14%
Proportion that live outside of Sydney	36%	29%	22%	13%	27%
Proportion of households with insulation	56%	66%	68%	75%	65%
Proportion of households that have solar PV	16%	22%	18%	21%	19%
Proportion of households that own a dryer that is less than 2 years old	10%	10%	15%	16%	13%

Proportion of households that own a dryer that is greater than 15 years old	21%	18%	11%	9%	16%
Proportion of households that own a gas space heater that is less than 2 years old	10%	13%	13%	19%	13%
Proportion of households that own a gas space heater that is greater than 15 years old	24%	15%	16%	11%	17%

Source: Frontier Economics using data from IPART's 2015's Household Survey

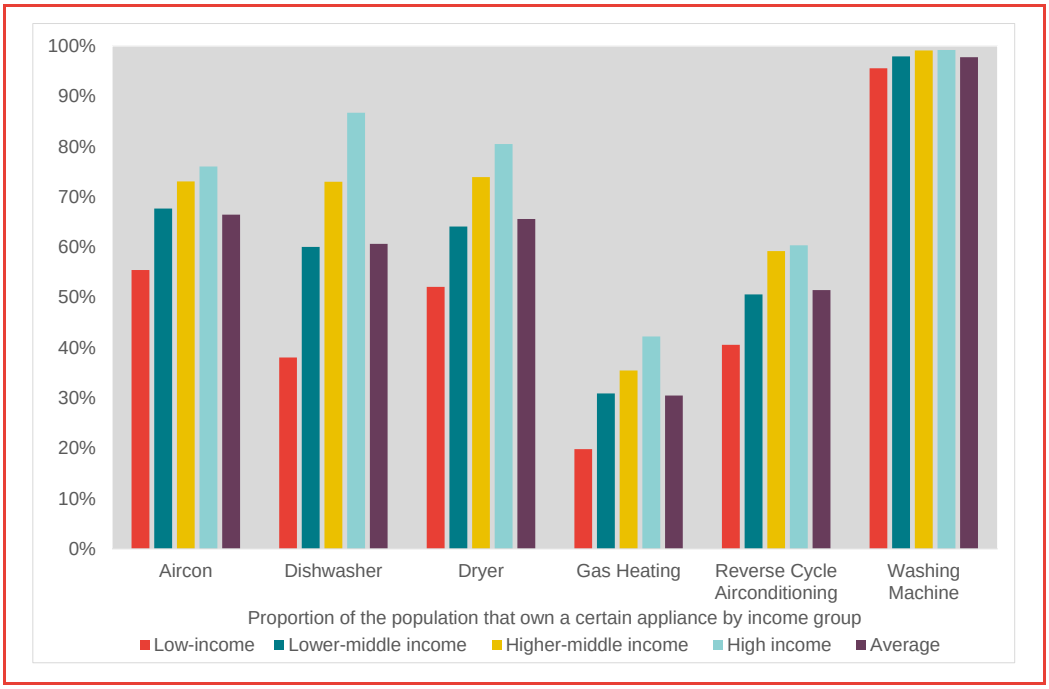
Note: Our income groups are as follows:
Low income: households with income less than $41,600 p.a.
Lower-middle income: households with income between $41,600 and $78,000 p.a.
Higher-middle income: households with income between $78,000 to $156,000 p.a.; and
High income: households with income greater than $156,000 p.a.

However this does not mean that income has no effect on household energy consumption. Over the longer term, income influences a household's type and size of dwelling and its stock of appliances, all of which drive energy consumption. As a result we observe that higher income households, on average, consume more energy because higher income households are more likely also to have other characteristics associated with increased energy consumption such as owning swimming pools, air-conditioning, and to use appliances such as dryers more frequently (see Table 23, Figure 5 and Figure 6).

However, higher income households are also more likely than lower income households to have newer, more energy efficient appliances and to have energy saving features such as insulation (see Table 23) which may reduce their energy consumption.

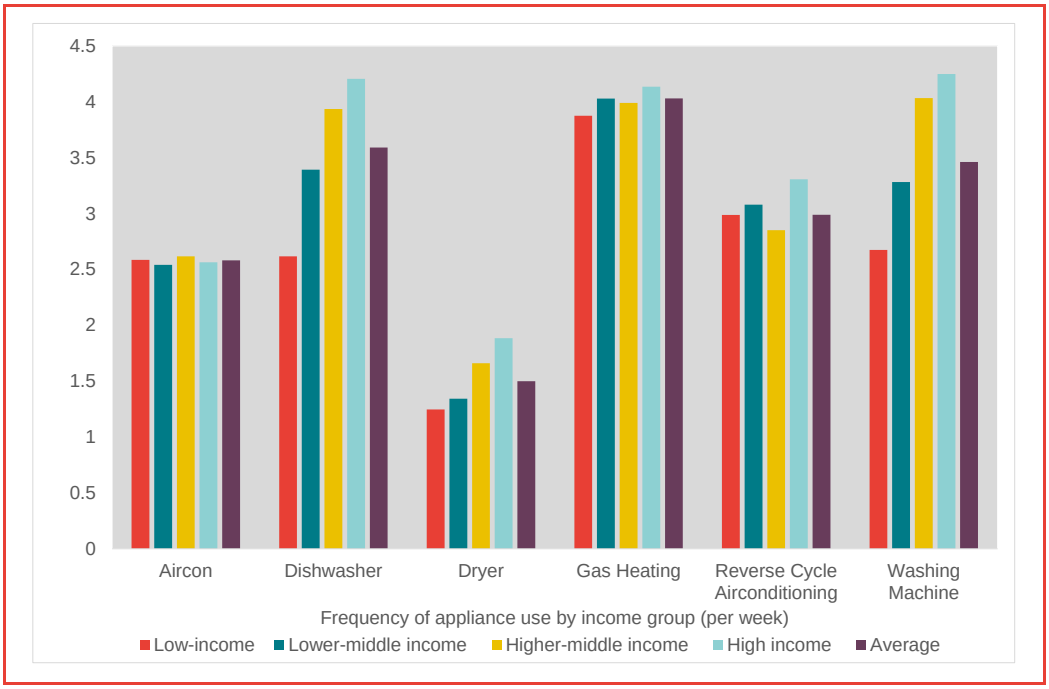
Opportunities for higher income households to reduce their energy consumption through energy efficiency or conservation measures could increase in the future, which suggests that relying on historical surveys as a guide to policy makers, regulators and stakeholders regarding likely future electricity and gas consumption should be undertaken with some caution.

Figure 5: Proportion of households that own certain appliances by income group



Source: Frontier Economics using data from IPART's 2015 Household Survey

Figure 6: Frequency of appliance usage per week by income group

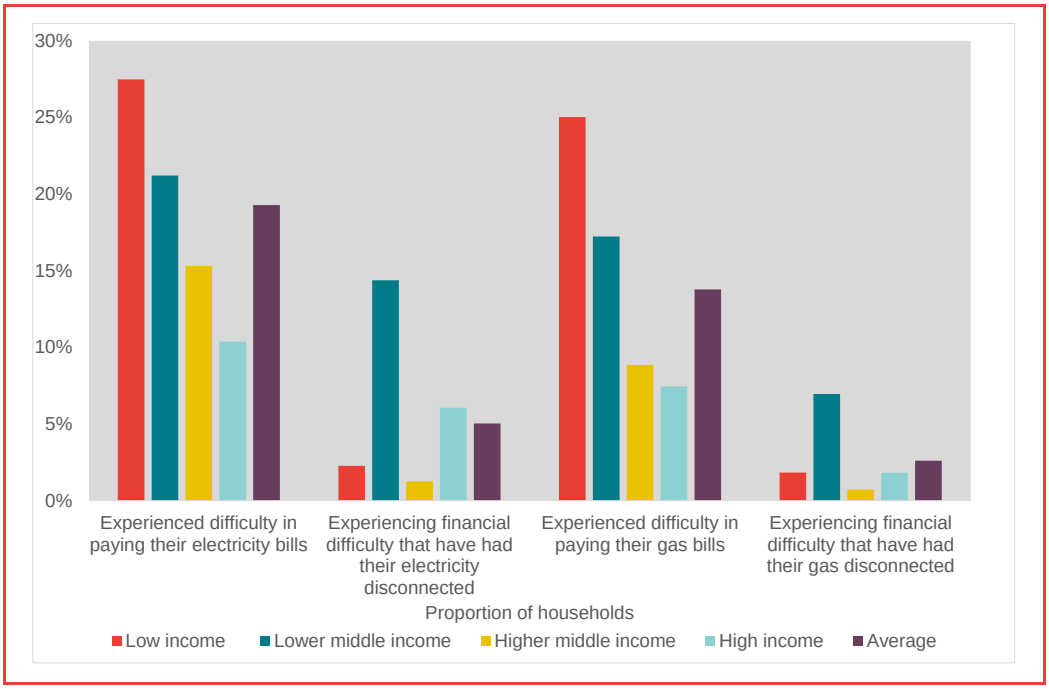


Source: Frontier Economics using data from IPART's 2015 Household Survey

8.3 Various factors contribute to the vulnerability of low income households

Figure 7 shows that lower-income households are more likely to experience financial difficulty than households in higher income groups.[38] This is consistent with previous work by IPART[39] and other studies that indicate household energy expenditure as a proportion of disposable income is much higher for lower income households and declines as income rises.[40]

Figure 7: Proportion of households that have experienced financial difficulty over the previous three years by income group.[41]



Source: Frontier Economics using data from IPART's 2015 Household Survey

Understanding the nature and drivers of financial vulnerability for lower-income households, and the factors that make them different to other households, is critical for developing targeted policy support.

38 However, it is the lower-middle income group, rather than the low income group, that has had the highest incidence of electricity or gas being disconnected in the past three years.

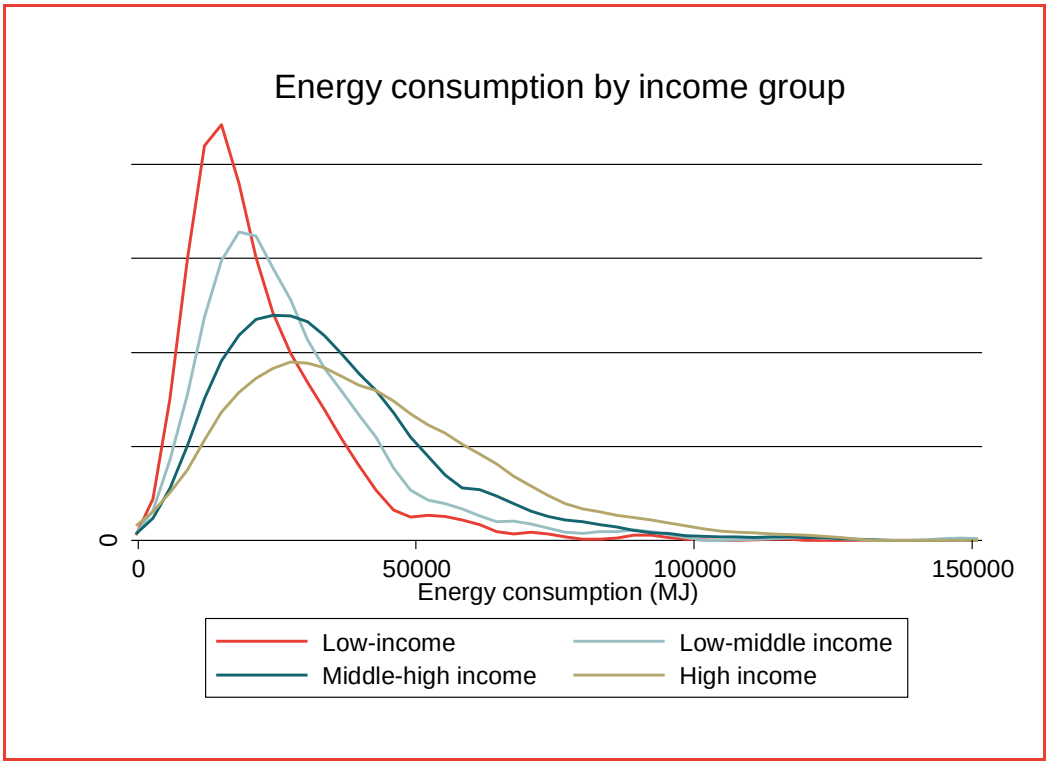
39 See IPART (2010), *Residential energy and water use in Sydney, the Blue Mountains and Illawarra, Results from the 2010 household survey* and IPART (2016), *IPART 2015 Household Survey: Payment Difficulties*.

40 Chester, L (2013), *The Impacts and Consequences of Low Income Australian Households of Rising Energy Prices*, p121.

41 For more information see IPART (2016), *IPART 2015 Household Survey: Payment Difficulties*.

Figure 8 shows that, while on average energy consumption is lower for lower income groups, some low income households are very large energy consumers (shown in Figure 8 by the red tail to the right). These low income, high energy consuming households may be more vulnerable to experiencing financial difficulty than other households with similar characteristics, as their energy consumption accounts for a larger share of their total income.

Figure 8: Energy consumption by income group



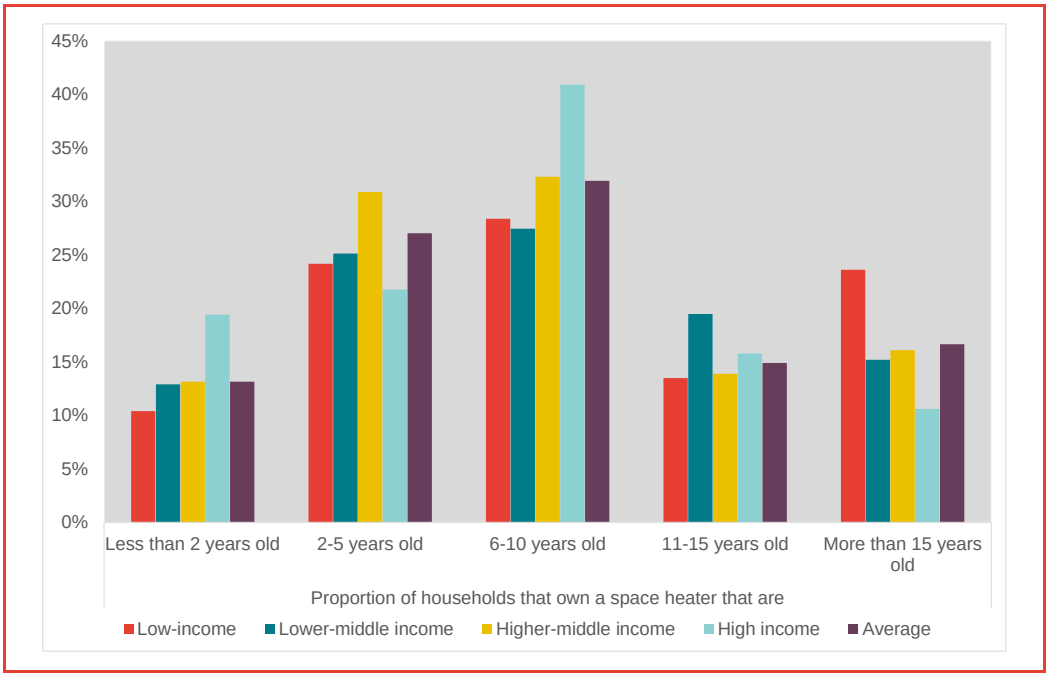
Source: Frontier Economics using data from IPART's 2015 Household Survey

In addition, low income households tend to have different characteristics to high income households, which may lead to higher consumption. For example, low income households are more likely to possess very old appliances and less likely to possess very new appliances than other income groups (see Figure 9 and Figure 10), and are less likely to have energy-saving features such as insulation (see Table 23). Our regression analysis indicates that having older appliances or not having insulation increases energy consumption.[42]

[42] The regression analysis summarised in Table 27 indicates that older appliances increase electricity consumption. The coefficient of 32.83 on fridge age, for example, indicates that increasing the age of the household's fridge by one year (all else equal) is associated with an increase in electricity consumption of 32.83 kWh. Similarly, not having insulation increases electricity consumption by 242.9 kWh, all else equal.

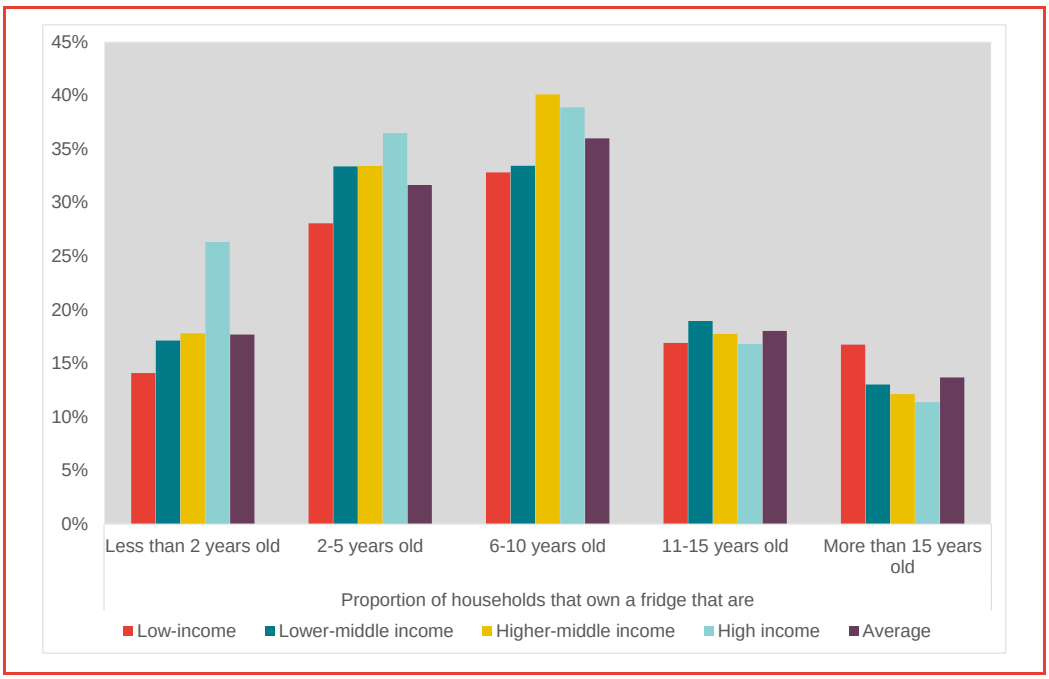
However, low income households experiencing financial difficulty do not always have higher consumption. This indicates that it may be other factors, combined with household energy consumption, that increase their vulnerability to financial difficulty.

Figure 9: Relationship between income and gas space heater ownership



Source: Frontier Economics using data from IPART's 2015 Household Survey

Figure 10: Relationship between income and fridge ownership



Source: Frontier Economics using data from IPART's 2015 Household Survey

Table 24: Characteristics of low income households by level of financial difficulty

Household characteristic	Have not experienced difficulty paying electricity bills	Have experienced difficulty paying electricity bills	Have not experienced difficulty paying gas bills	Have experienced difficulty paying gas bills
Average number of adults	1.54	1.59	1.66	1.49
Average number of children	0.14	0.48	0.14	0.46
Average income ($ per annum)	24,186	23,916	23,959	21,625
Proportion of households that have paid off their home	64%	26%	71%	20%
Proportion of households with a mortgage	4%	12%	5%	13%
Proportion of households that are renting	32%	62%	24%	68%
Proportion of households that do not live in Sydney	38%	33%	39%	17%
Proportion of households that have solar PV	19%	8%	20%	11%

Source: Frontier Economics using data from IPART's 2015 Household Survey

There are also some clear differences in characteristics between those low income households that have experienced financial difficulty and those low income households that have not experienced financial difficulty (see Table 24). Low income households that have experienced difficulty paying their electricity bills:

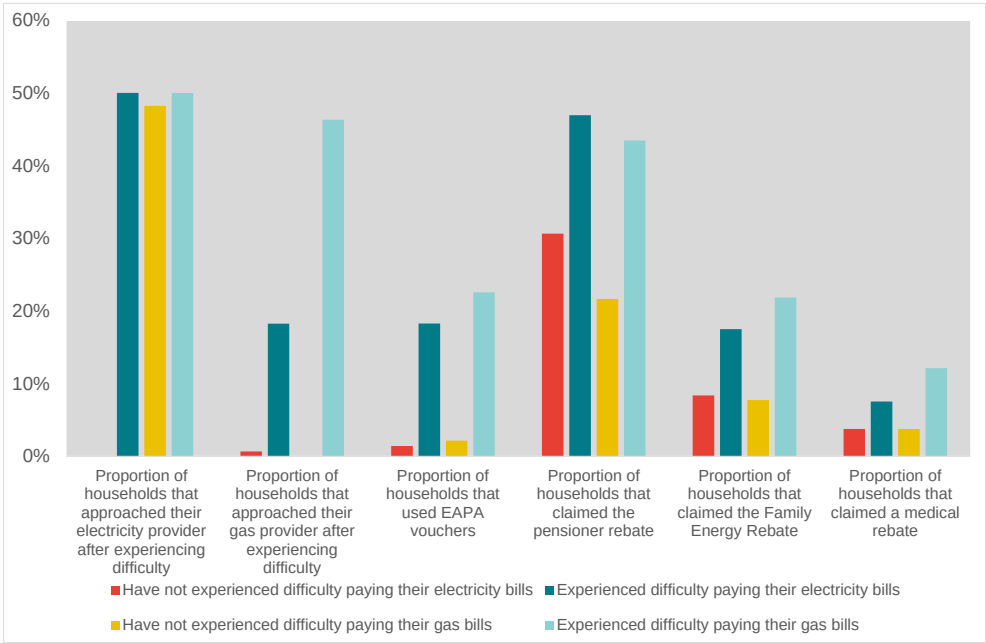
- Are likely to have more children, which positively influences consumption
- Are less likely to have solar PV, which positively influences (grid) consumption
- Are more likely to be renting or less likely to have paid off their home, which may reduce disposable income.[43]

This is consistent with research that has found that the households which had their electricity disconnected tended to be households on low to median income, experiencing housing stress or other bill obligations.[44]

43 Also see IPART (2016), *IPART 2015 Household Survey - Payment Difficulties*

Low income households are the focus of various policies aimed at alleviating their financial vulnerability. For instance, policies such as the Energy Accounts Payment Assistance (EAPA) scheme and NSW Gas Rebate assist households experiencing financial difficulty in paying their electricity and gas bills.[45] However, a significant proportion of households that have experienced financial difficulty are not accessing support that may be available (Figure 11), with the most frequently cited reason being that they either did not know about the existence of EAPA vouchers or did not understand how to claim them.

Figure 11: Proportion of households that sought assistance by financial difficulty



Source: Frontier Economics using data from IPART's 2015 Household Survey

8.4 Highly seasonal consumption in Riverina and low income in North Coast may contribute to vulnerability of these regional households

Households in Riverina and North Coast are more likely to have experienced financial difficulty paying their energy bills in the last three years than households

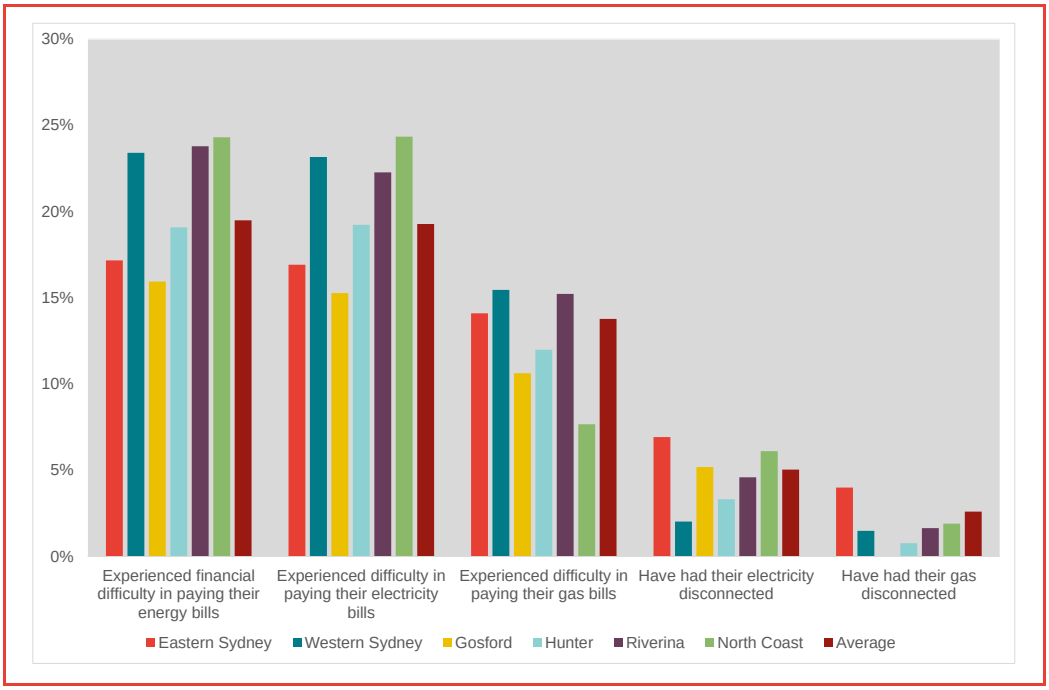
44 See St Vincent de Paul Society and Alviss Consulting (2016), *Households in The Dark*, p.18

45 For more information regarding the available rebates see NSW Government Department of Industry Resources and Energy, *Rebates*, available at: http://www.resourcesandenergy.nsw.gov.au/energy-consumers/financial-assistance/rebates

in Eastern Sydney, Hunter or Gosford (see Figure 12).[46] Possible reasons for these high rates of difficulty in paying bills include:

- Households in the Riverina have a highly seasonal pattern of energy consumption.
- Households in the North Coast have the lowest average income.

Figure 12: Proportion of households that have experienced financial difficulty by region



Source: Frontier Economics using data from IPART's 2015 Household Survey

Highly seasonal energy consumption in Riverina

We found that on average, annual energy consumption is materially higher in Riverina than in any of the other regions (Table 1). Our regression analysis indicates that an average Riverina household with gas would consume 18,052 MJ more gas than a similar household located in Eastern Sydney (that is, controlling for all other household characteristics), and 214.4 kWh more non- controlled load electricity (Table 9 and Table 14).

These differences in annual consumption reflect a combination of factors, namely differences in household characteristics across the regions and the significant variability in seasonal consumption in the region. For instance, Table

46 Households in Western Sydney also have a very incidence of difficulty in paying energy bills. In this section we focus on the special features of the less urban regions.

25 shows that households in the Riverina are more likely to live in larger houses (increasing their energy consumption), despite their lower than average incomes.

Table 25: Household characteristics by region.

Household characteristic	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast	All regions
Number of adults	2.13	2.35	2.09	2.06	1.96	1.95	2.15
Number of children	0.47	0.56	0.38	0.44	0.46	0.41	0.48
Income	97,280	85,263	73,401	73,828	68,172	59,216	87,067
Proportion living in a house	63%	93%	91%	93%	90%	91%	77%
Number of bedrooms	2.91	3.52	3.39	3.28	3.36	3.24	3.14
Proportion using gas	57%	49%	43%	44%	67%	29%	51%

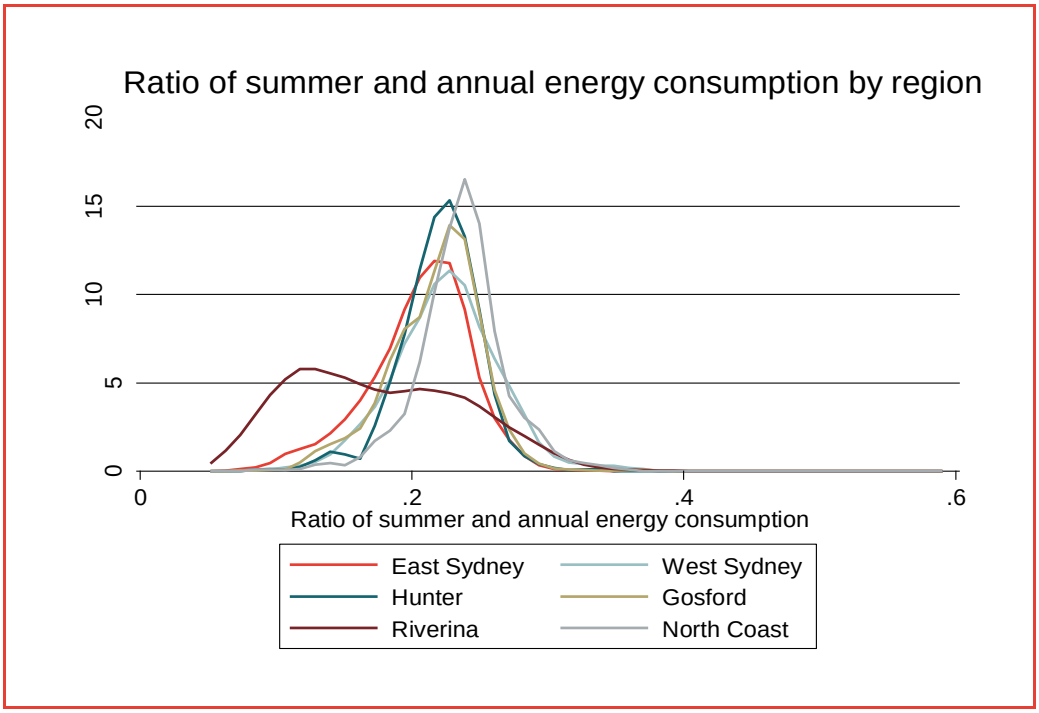
Source: Frontier Economics using data from IPART's 2015 Household Survey.

In addition, Figure 13 and Figure 14 show, respectively, the distribution of the proportion of annual energy consumption that occurs in summer and in winter. The figures show that while, across NSW, average energy consumption in winter accounts for a greater proportion of annual consumption than energy consumption in summer, the effect is especially pronounced for households in the Riverina.

This can be seen by comparing the curve representing the proportion of summer consumption for the Riverina in Figure 13, with the corresponding curve for the winter consumption for households in the Riverina in Figure 14. The curve representing the ratio of winter to annual consumption in the Riverina is shifted far to the right compared to the curve for the summer ratio, indicating winter consumption accounts for a much larger share of annual energy consumption than summer consumption.

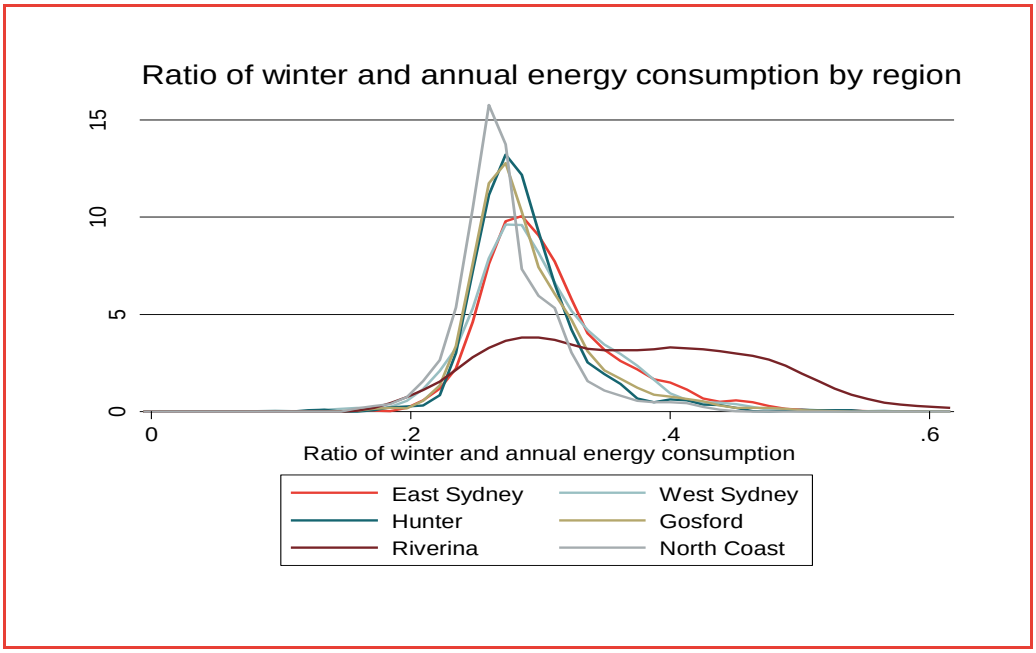
The highly seasonal consumption in the Riverina is primarily driven by climatic conditions and the greater ownership and use of space heating in winter. Figure 15 and Figure 16 indicate that households in the Riverina are materially more likely to have gas space heating than households in other regions. Our regression analysis indicates that gas space heating in the Riverina is associated with 21,674 MJ of increased gas consumption, compared with 10,217 MJ in Eastern Sydney and 9,830 MJ in Gosford (See Table 13 and Table 27).

Figure 13: Ratio of summer to annual energy consumption by region



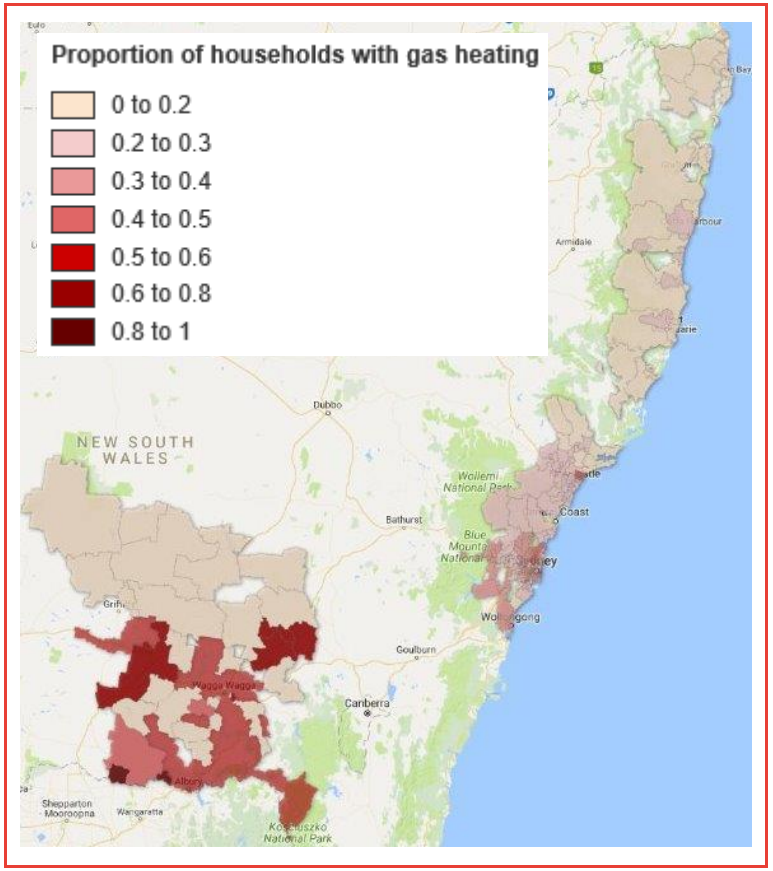
Source: Frontier Economics using data from IPART's 2015 Household Survey

Figure 14: Ratio of winter to annual energy consumption by region



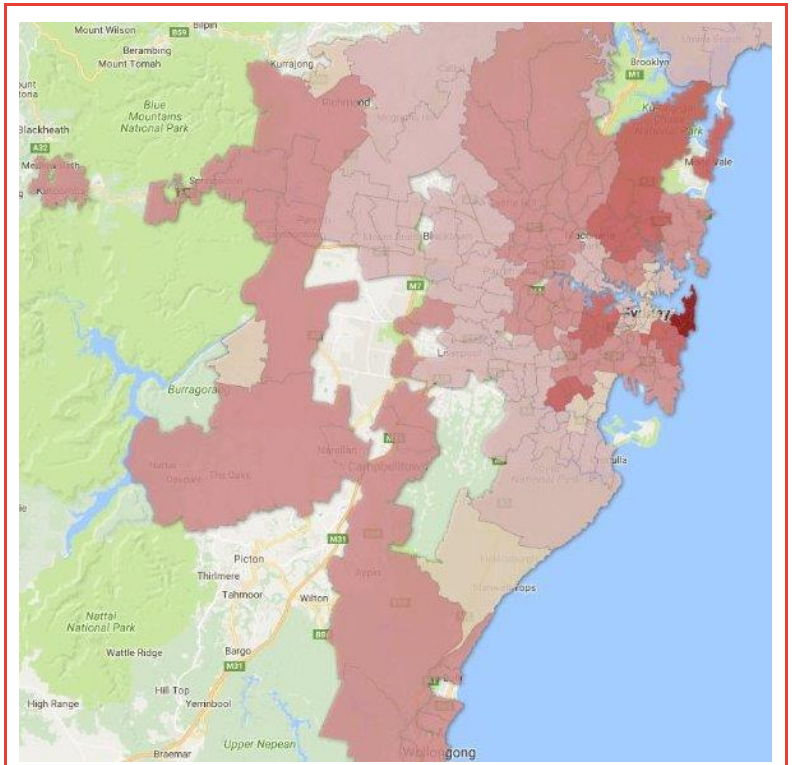
Source: Frontier Economics using data from IPART's 2015 Household Survey

Figure 15: Proportion of households with gas space heating in NSW by LGA



Source: Google Fusion Tables using data from IPART's 2015 Household Survey

Figure 16: Proportion of households with gas space heating in Sydney region by LGA

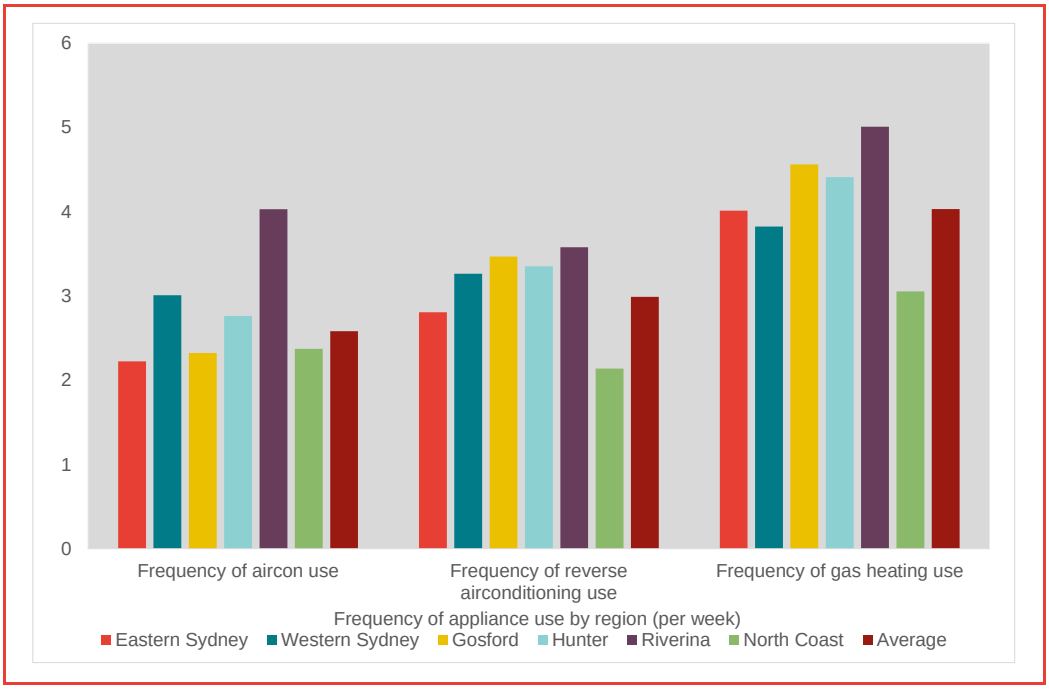


Source: Google Fusion Tables using data from IPART's 2015 Household Survey

Figure 17 shows that households in the Riverina are also more likely to use their energy intensive appliances like air conditioners and gas heaters more frequently. Our regression analysis indicates that the frequency of use of space heating and air-conditioning has a significant impact on household energy consumption (which will also impact on the seasonal variability in consumption). For example, each additional hour per day of air-conditioning use in summer, on average, increases annual electricity consumption by 146 kWh, while each additional hour per day of gas space heating increasing annual gas consumption by 2,572 MJ (See Table 27 and Table 13).

This seasonal variability in consumption can make it more difficult for households to plan their expenditure as they may be unable to predict the size of their next bill.[47] The ESC identified fluctuating costs as a major reason for falling into hardship.[48]

Figure 17: Frequency of appliance use per week by region



Source: Frontier Economics using data from IPART's 2015 Household Survey

Low incomes in North Coast

It should also be noted that households in the North Coast are the most likely to have experienced financial difficultly despite having the lowest and least seasonal

47 However it is worth noting that the structure of retail prices, such as gas tariffs or electricity tariffs, will influence the variability in quarterly bills. Retail tariffs with a higher fixed charge but lower (or decreasing) usage charges will result in less variability in quarterly bills.

48 See ESC (2015), *Supporting customers, avoiding labels Energy hardship inquiry draft report*.

energy consumption.[49] This may result from the fact that households in the North Coast have the lowest average weekly income (Table 25).

In addition, households in the North Coast are the least likely to use gas (Table 3), and the household survey found that households are less likely to experience financial difficulty paying their gas bills than their electricity bills.[50] Furthermore, these households use cylinder gas rather than mains gas (Table 3). This means that, unlike households in the Riverina, they do not benefit from the current (declining block) price structure for mains gas that acts to dampen the impact of seasonal consumption on quarterly bills.

8.5 Barriers exist to improved energy efficiency and conservation

Energy efficiency is a key area of focus for policy makers and stakeholders for reducing energy bills, improving energy productivity and lowering greenhouse emissions. Developing effective policy initiatives to improve energy efficiency and conservation requires an understanding of which barrier is most prominent in hindering households from taking steps that can materially reduce their energy consumption.

Across NSW, households are taking steps towards energy conservation, with a high proportion of households across income groups and regions taking steps towards reducing their electricity and gas consumption.[51] Figure 18 indicates that income is not a barrier to taking steps towards reducing energy consumption, with a large proportion of households across income groups taking steps to reduce their electricity bills, primarily driven by the size of their electricity bills or concern for the environment.[52]

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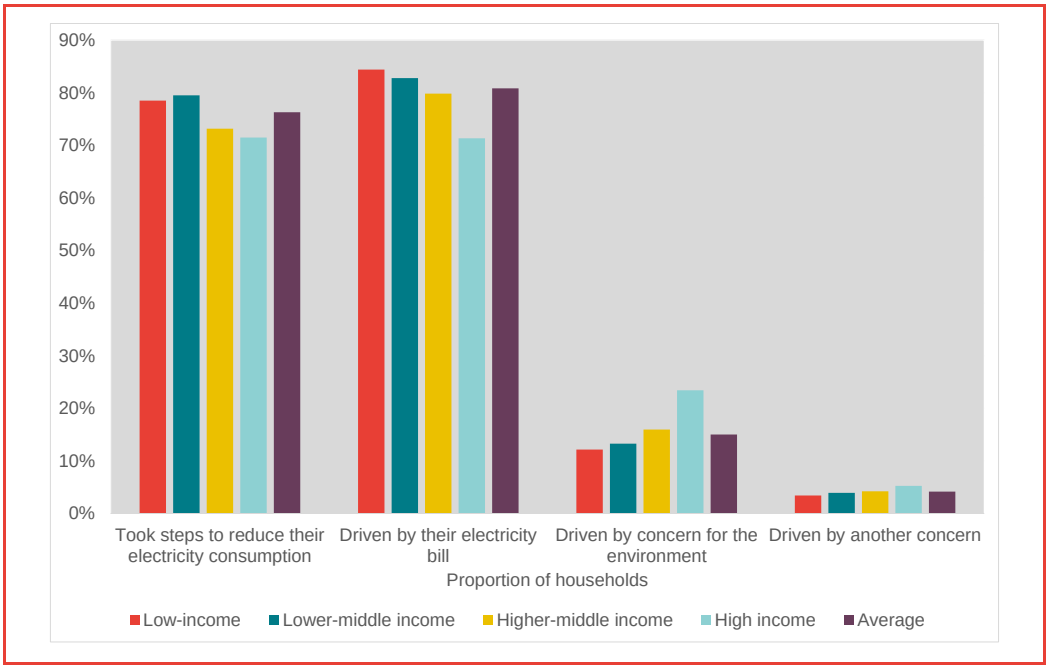
49 Note, however, that we had no information cylinder gas consumption and North Coast had the highest uptake of cylinder gas (see Table 3).

50 For more information see IPART (2016), *IPART 2015 Household Survey: Payment Difficulties,* September 2016

51 See Frontier Economics (2016), *Determinants of Household Energy Consumption: Technical Appendices.*

52 See IPART (2016), *IPART 2015 Household Survey: Energy and Water Conservation.*

Figure 18: Conservation habits, by income group.



Source: Frontier Economics using data from IPART's 2015 Household Survey

However, although a large proportion of households are taking steps towards energy conservation, this is not always reflected in their consumption data. In fact, our regression analysis indicates that taking steps towards reducing electricity consumption does not have a statistically significant impact on household electricity consumption. This supports the findings of Chester (2013), who found that in a survey of over 300 low income households, nearly all households had tried to reduce their energy use in response to rising energy bills but were of the view that they had not seen commensurate reductions in their electricity bills.[53]

This suggests that households may not be addressing the most material drivers of energy, such as the age of household appliances. For instance, our regression analysis indicates that the age of a fridge has a statistically significant impact on household electricity consumption (see Table 27).[54]

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53 The study notes that many of the measures adopted to reduce household energy use are: lights turned off in rooms not being used; the use of compact fluorescent globes instead of incandescent globes; appliances manually switched off at power-points and standby mode switched off. Chester, L (2013)., *The Impacts and Consequences of Low Income Australian Households of Rising Energy Prices*, p121.

54 The regression analysis summarised in Table 27 indicates that older appliances increase non-controlled electricity consumption. The coefficient of 32.83 on fridge age, for example, indicates that increasing the age of the household's fridge by one year (all else equal) is associated with an increase in non-controlled load consumption of 32.83 kWh.

Possible reasons why taking steps to reduce energy consumption may not lead to a noticeable reduction in energy consumption include:

- Some households may not actually be taking steps to reduce consumption ('knowledge-action gap' or 'intention-action gap' – see Table 26)
- Some households may not be targeting the most material drivers of energy, such as the age of household appliances ('action-result gap') which could be the result of a number of barriers to reducing electricity consumption (such as income, tenancy, access to information etc.)[55]
- Some avenues to reduce energy consumption may not be 'rational' or cost effective (i.e. the upfront or ongoing costs may exceed the benefits).

Table 26 summarises some of the key behavioural explanations around household appliance choice and their associated barriers around the two phenomena in the left-most column. Understanding which type of phenomenon is most relevant in the current context is important, given the two phenomena are underpinned by different barriers, and hence will require different policy responses.

Under both phenomena, however, traditional education campaigns focused on the environmental and financial benefits of reduced energy consumption may not be addressing the key barriers to achieving governments' energy efficiency policy objectives. Gathering evidence from field studies and experimental trials on how and why customers make decisions – including any barriers (real or perceived) to reducing energy consumption – and the impacts of policy interventions on these decisions could assist policy makers in understanding the potential opportunities to improve the effectiveness and efficiency of any policy response.

55 For example, the AEMC (2016) notes that many vulnerable customers were unable to manage their energy use as they could not "avoid using air conditioning on very hot days or when children are at home …. [and] they cannot afford more energy efficiency appliances so were generally resigned to having higher bills". AEMC 2016, *2016 Retail Competition Review Final Report*, p.50.

Table 26: Behavioural explanations for household behaviour

Potential explanation of behaviour	Barrier	Potential policy responses
Knowledge-action gap**: People have information but fail to take action** Intention-action gap**: people intend to take action or say that they are taking action, but fail to do so**	**Social norms** – Customers may be less motivated to change if they do not know other people with new appliances. **Sunk cost biases**- people may be unable to ignore losses already incurred, and thus may find it uneconomic to switch to more energy efficient appliances or from electricity to gas. **Sources of trust/ credibility may be limited** – households may be more likely to respond to messages from the Government rather than energy businesses.	Campaigns that draw attention to ongoing costs, losses with retaining inefficient appliances Framing energy saving practices as common practice (other people like them have taken action) as studies suggest social framing is more effective than energy savings tips
Action-result gap: **People are taking action in ways that has a relatively limited impact on consumption**	**Present bias**– customers do not replace large appliances that have high present costs of installation (which hold a much higher weighting than the longer term gains from reduced electricity bills), meaning they stick with old appliances until they need to be replaced. **Lack of information** - Customers may not be aware that some appliances use a lot of electricity (as bills do not give a breakdown of electricity consumption by appliance) and as such, may be less inclined to replace existing appliances as they are not aware that it can save them money in the longer term. **Information overload** - Given it is likely to be too complex for households to accurately calculate the net benefits from new appliances, consumers may be unable to choose the most beneficial steps to take from a long list of energy saving tips/tools	Programs such as No Interest Loan Schemes (NILS) Campaigns with simple and concise information that gives instructions rather than list of tips or tools

Source: Frontier Economics

Appendix A: Further regression results for non-controlled electricity consumption

Table 27 presents the results of a regression of the short to medium term determinants of non-controlled electricity consumption. See Section 6 for a discussion of the results.

Table 27: Non-controlled load electricity consumption by main end uses and appliance numbers

Electricity end use or appliance	All regions	Eastern Sydney	Western Sydney	Gosford	Hunter	Riverina	North Coast
Uses non-controlled load electricity for water heating	968.5***	547.5***	1306.0***	1334.9***	1082.9***	1118.3*	415.2
Uses electricity for cooking	296.5***	603.8***	688.8**	-0.579	357.7*	78.30	35.36
Uses electricity for space heating	292.2**	630.2***	1321.8***	691.6**	720.5***	1668.9***	123.9
Uses electric and gas space heating	-188.9	-340.0	-417.5	-226.1	-453.7*	-517.2	-891.3*
Space heating in winter, per hour per day	183.7***						
Uses air-conditioning in summer for cooling	297.4***	490.4***	701.5*	625.0**	677.5***	123.1	810.6***
Air-conditioning in summer, per hour per day	146.3***						
Uses fans in summer for cooling	-310.2***						
Per large fridge	937.7***	1103.3***	929.6**	830.2**	1342.6***	735.8**	488.9*
Per medium fridge	774.7***	917.2***	661.2*	651.5*	1071.5***	637.9**	664.7**
Per other type of fridge	586.1***	729.8***	334.6	540.9**	525.5**	422.8*	595.8**
Per year of average age of fridges	32.83***						

Dishwasher, per use per week	125.2***	159.1***	178.2**	137.6**	125.8***	119.2*	111.9*
Clothes dryer, per use per week	253.4***	299.4***	391.6**	195.4*	342.5***	200.7	460.8**
Per TV	234.0***	183.1*	263.1*	199.5	49.76	52.58	82.01
Per computer	251.7***	334.3***	176.8	149.0	199.2*	228.3	503.2**
Pool	2018.1***	1996.0***	2197.4***	2491.3***	2102.3***	2338.7***	1468.6***
Uses electricity for pool heating	1430.0						
Per kW of PV panels	-110.2**						
Has solar PV		-332.8	-742.5**	-817.0**	-432.8*	-640.3*	-329.5
Has taken steps to reducing electricity consumption	-20.70						
Has insulation	-242.9**						
Per adult	545.0***	504.8***	693.7***	775.9***	510.7***	905.6***	447.2*
Per child	205.8**	54.33	354.5*	354.9	192.2	86.19	252.8
Per bedroom	372.6***	164.0	412.1**	331.7	362.2**	363.8*	117.2
Per $10,000 income	13.36						
Missing value for income	281.9*						
Constant	-1508***	-965.3***	-2458***	-1494.1*	-1657***	-875.3	-210.0
Number of observations	3515	1432	604	405	807	365	537
R-squared	0.538	0.441	0.440	0.558	0.481	0.470	0.477
Average non-controlled load electricity consumption (kWh)	5,094	4,897	6,048	5,124	5,021	5,169	4,182

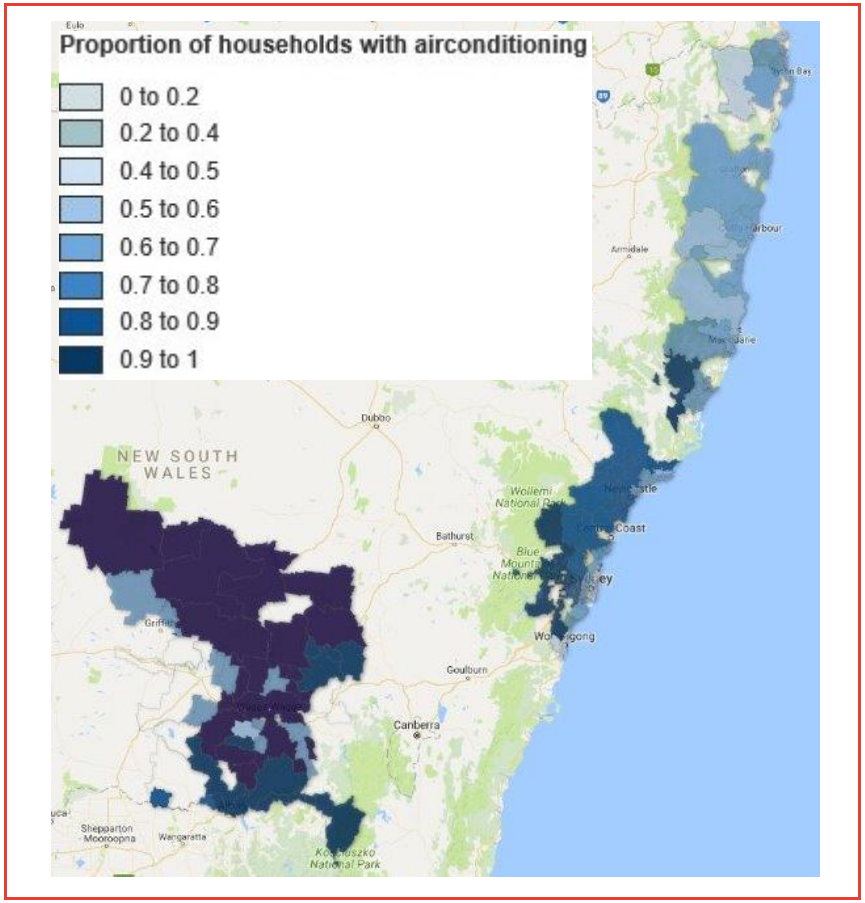
Source: Frontier Economics using data from IPART's 2015 Household Survey

*Note: 1) Significance levels are indicated by * p<0.05, ** p<0.01, *** p<0.001.*

2) For the full set of regression results of household consumption and of logit regressions of appliance ownership see Frontier Economics (2016), Determinants of Household Energy Consumption: Technical Appendices.

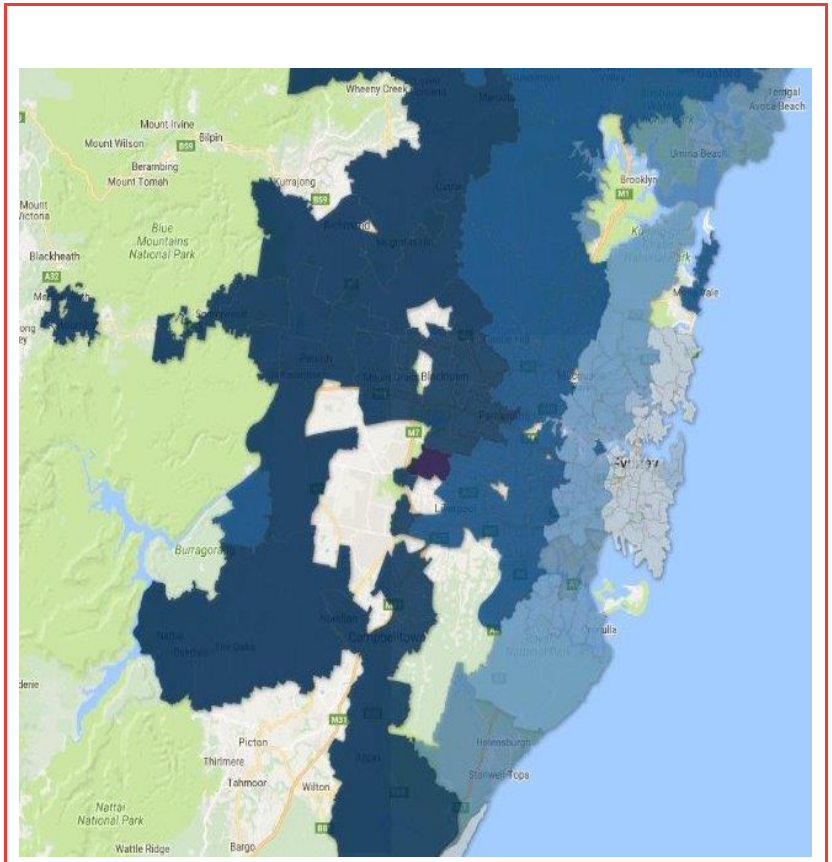
Appendix B: Proportion of households with air-conditioning by LGA

Figure 19: Proportion of households with air-conditioning by LGA



Source: Google Fusion Tables using data from IPART's 2015 Household Survey

Figure 20: Proportion of households with air-conditioning by LGA – Sydney region



Source: Google Fusion Tables using data from IPART's 2015 Household Survey

FRONTIER ECONOMICS
BRISBANE | MELBOURNE | SINGAPORE | SYDNEY
Frontier Economics Pty Ltd 395 Collins Street Melbourne Victoria 3000
Tel: +61 (0)3 9620 4488 Fax: +61 (0)3 9620 4499 www.frontier-economics.com.au
ACN: 087 553 124 ABN: 13 087 553 124