GAS-ELECTRICITY SUBSTITUTION PROJECTIONS TO 2050

ClimateWorks AUSTRALIA

SEPTEMBER 2016

Introduction and background

CSIRO and the Energy Networks Association (ENA) are partnering to create the Electricity Network Transformation Roadmap (ENTR) which aims to provide a blueprint for transitioning Australia's electricity system to enable better customer outcomes. A sub-program of research under the ENTR examines opportunities for efficient growth of electricity demand to offset the reduction in electricity demand from expected adoption of rooftop solar systems and ongoing energy efficiency improvements. The two largest opportunities identified were electrification of road transport and the potential for gas-electricity substitution.

Consequently, the Energy Business Unit of CSIRO commissioned ClimateWorks Australia to undertake analysis of the projected substitution of electricity for gas and the impact on the electricity load in providing residential, commercial and industrial consumer energy needs.

This report provides a long term analysis to 2050, quantifying **annual projections of additional electricity consumption (GWh or PJ)** and **annual projections of additional peak demand (MW)** for residential and commercial buildings, that is likely to be contributed due to gas to electricity substitution. This analysis was done based on demographic, technological and structural economic trends to 2050.

Drawing on earlier research, ClimateWorks Australia undertook an economic and barriers analysis of switching from gas to electrical appliances. These sources include the *Pathways to Deep Decarbonisation in 2050* (ClimateWorks Australia and Australian National University, 2014), the *Industrial Energy Efficiency Data Analysis Project* (ClimateWorks Australia, 2013), and the *Low Carbon Growth Plan for Australia* (ClimateWorks Australia, 2010).

Given the data limitations, a high level analysis only is conducted for the industry sector focussing on key industry subsectors and estimating the electricity consumption and demand of these subsectors in 2050.

Summary results

Across Australia, the impact of electrification in residential and commercial premises results in a 45% lower projected consumption of gas in 2050 (equivalent to 169 PJ) with a corresponding 5% increase in electricity consumption (43 PJ), due to switching to electric hot water systems and Heating Ventilation and Air Conditioning (HVAC).

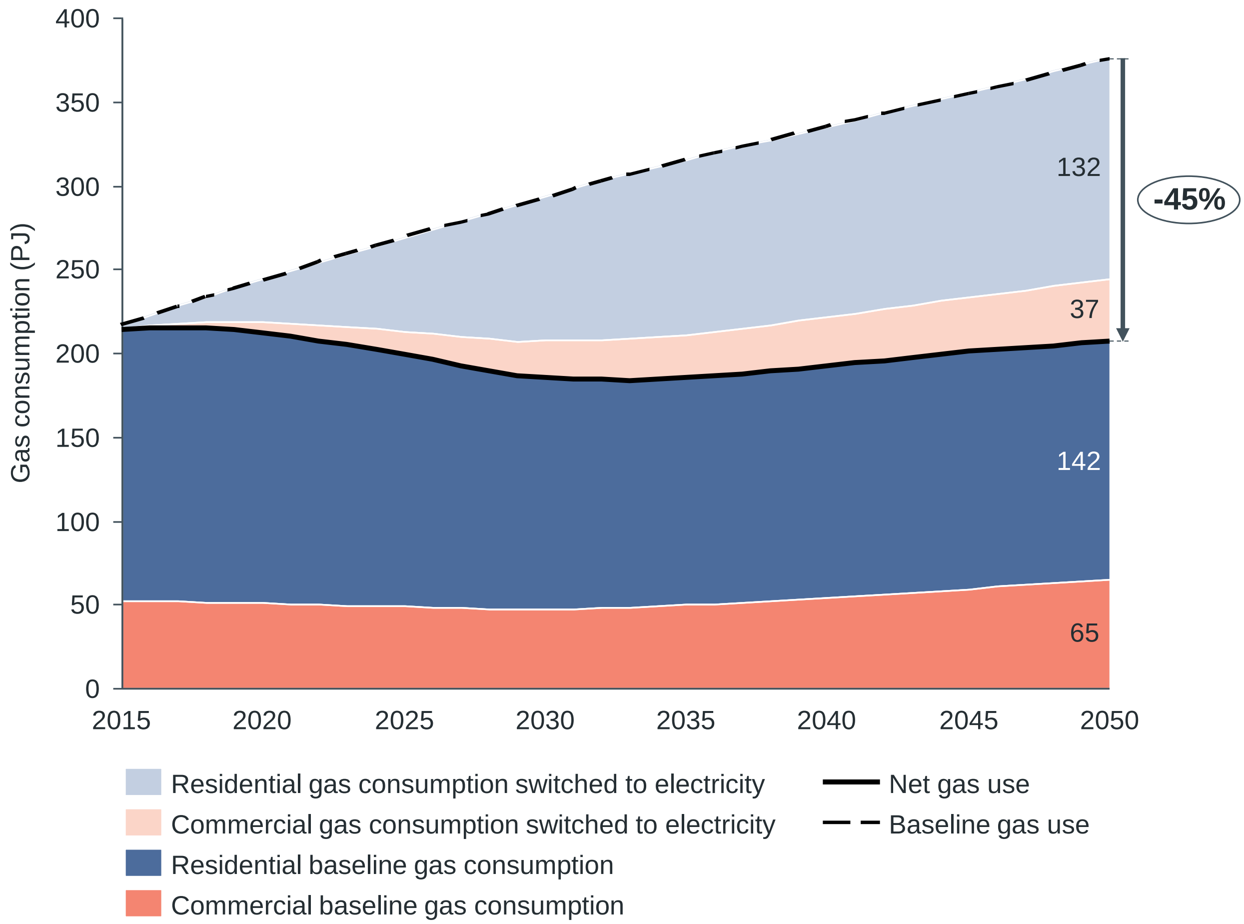


Figure 1: Gas consumption (PJ) in Residential and Commercial[1] sectors across Australia and impact of electrification

The impact of electrification shown in Figure 1 is greatest in the residential sector, resulting in 132 PJ of shift away from gas, equivalent to 78% of the total shift (169 PJ) from gas to electricity in 2050. In the commercial sector 37 PJ shifts from gas to electricity.

[1] Commercial sector in this analysis refers to energy use in commercial buildings, as defined by the Office of the Chief Economist's Australian Energy Statistics (2015) Table 2.1 page 14. Available via: http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/aes/2015-australian-energy-statistics-guide.pdf. This includes ANZSIC Divisions F-H and J-S.

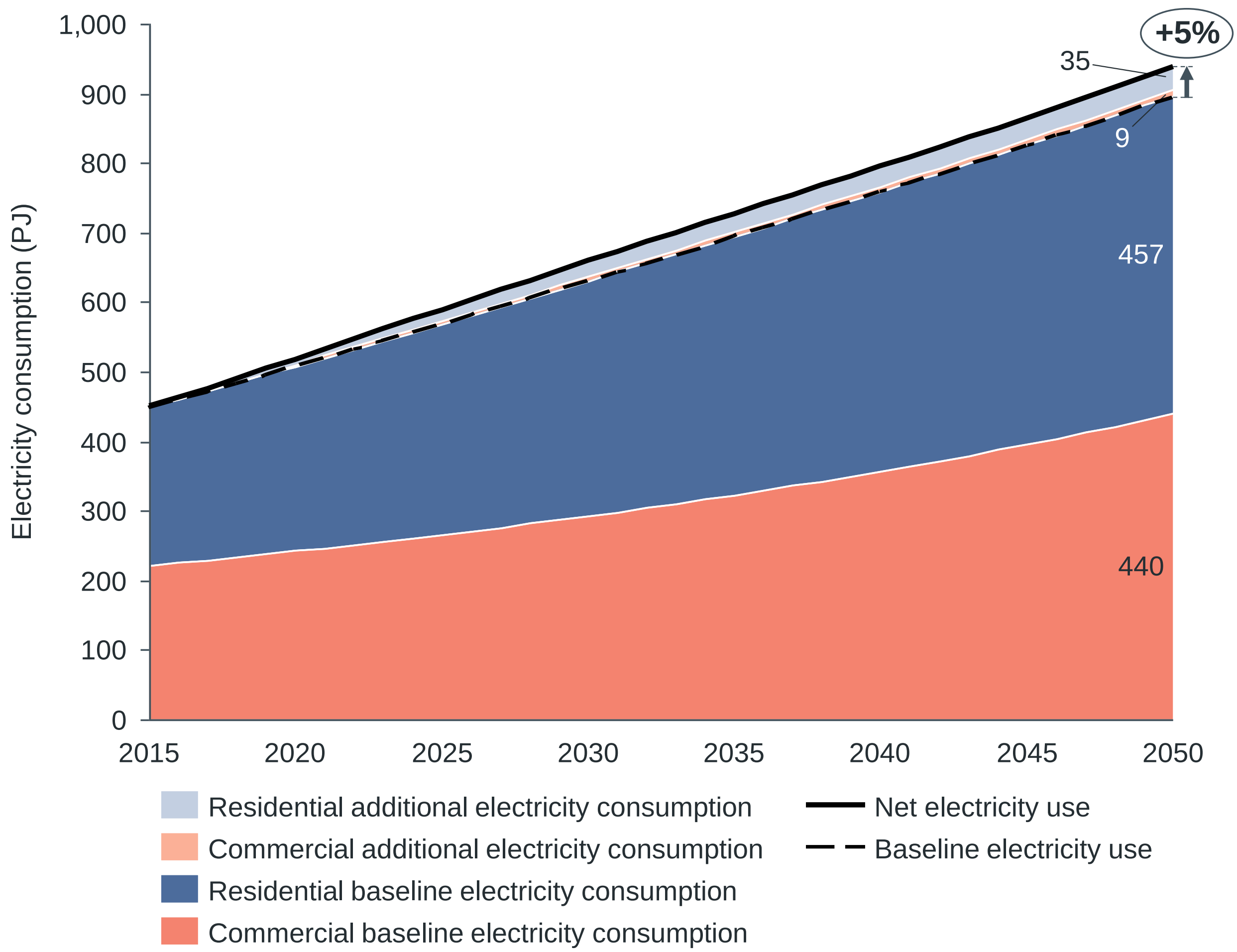


Figure 2: Electricity consumption (PJ) in Residential and Commercial sectors across Australia and impact of electrification

Across Australia, these shifts result in a corresponding additional 44 PJ of electricity consumption shown in Figure 2. While gas energy saved due to switching converts to much lower electricity energy consumed, this switch leads to greater primary energy consumption and losses upstream due to fuel consumption in the electricity generation process and transmission and distribution losses. Primary energy consumption and distribution losses in electricity are not shown.

Note that Figure 2 shows electricity consumption in residential and commercial sectors is forecast to grow at a rate broadly aligned with AEMO NEFR 2016 projections excluding Energy Efficiency and Rooftop Solar PV components. As such these projections should be understood as being before energy efficiency and agnostic of assumptions relating to future uptake of rooftop solar PV. The AEMO net outlook is that grid electricity demand will be generally flat due to these additional energy efficiency and Rooftop PV demand components.

Residential is a large share (78%) of the total switch on account of a high baseline gas consumption, of which gas is primarily used for HVAC and hot water, compared to commercial.

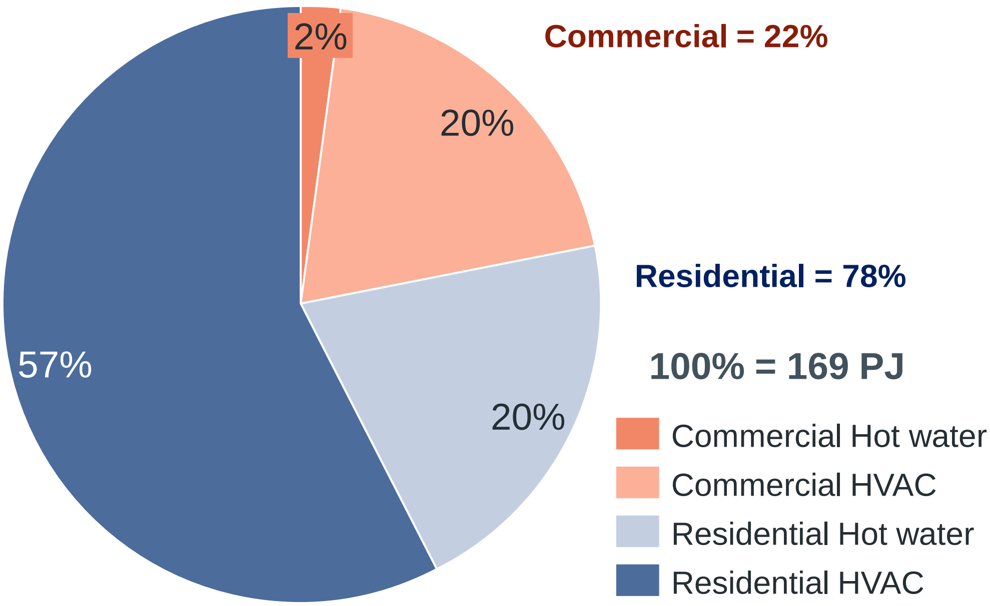


Figure 3: Share of gas consumption shifted to electricity in 2050 (%) in Residential and Commercial sectors across Australia; by end-use. Note: Numbers on the figure do not add to 100% due to rounding.

Of the gas consumption modelled to shift to electricity in 2050, 78% of the total gas switched is in the residential sector, as a result of replacing gas HVAC and hot water appliances with electrical heat pump appliances with higher coefficients of performance.

Of the total gas consumption switched in both residential and commercial sectors across all states, 77% is from HVAC (57% from residential, 22% Commercial). This reflects both the significance of gas consumption in HVAC and also the financial attractiveness of electrical appliances like reverse cycle air conditioners for space heating.

The smaller shift in the commercial sector is in part due to lower gas prices paid by commercial users, making it less financially attractive to switch to electrical appliances in many states, particularly in cases where commercial users pay retail electricity prices (which are relatively higher than users who can generate their own electricity through solar PV, with or without storage)[2]. Furthermore, substitute electrical appliances are not as readily available for some specific commercial end uses which require specialist gas equipment.

[2] See Assumptions for details on projected energy prices in each state.

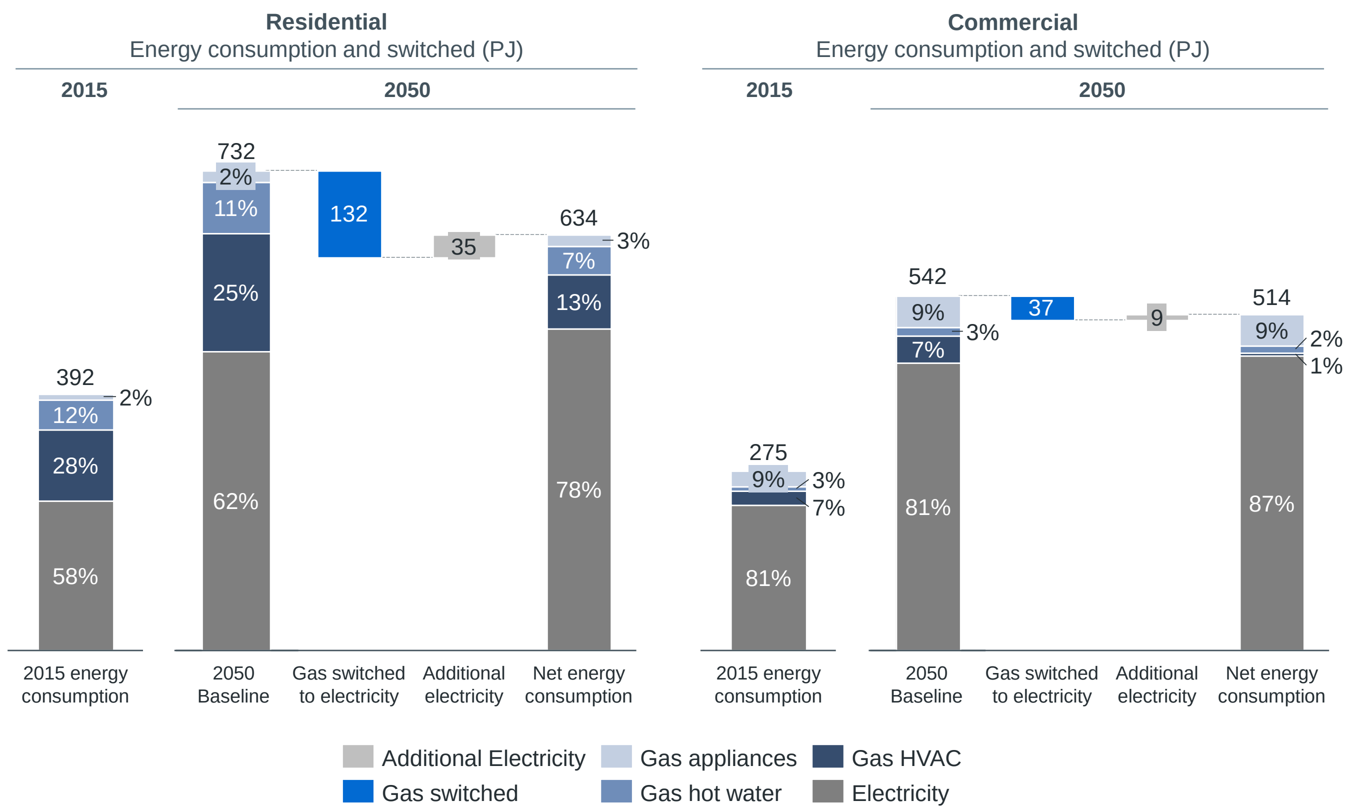
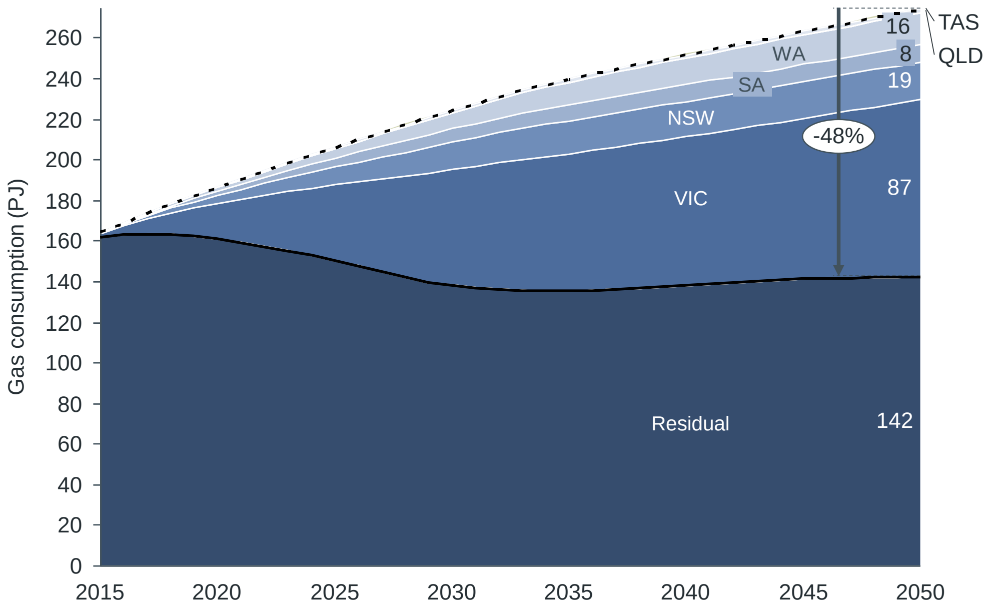


Figure 4: Component contributions of gas and electricity consumption switch across Australia in 2050 in residential and commercial sectors

The residential sector is the larger user of gas, using over 3 times more gas than the commercial sector in 2015. In residential buildings, gas represents 42% of total energy use today. Nearly all of the gas is used for HVAC and hot water heating in 2015 (40% of total energy use). In comparison, gas represents only 19% of total energy use in the commercial sector today. 10% of total commercial energy use (or 53% of gas use) is for HVAC and hot water systems in 2015.

The smaller share of current gas use, combined with lower potential for electrification in the commercial sector contribute to residential sector accounting for most of the shift.

Most of the electrification occurring in the residential sector can be attributed to Victoria (66%), New South Wales/ACT (14%), and WA (12%).



State	Shift PJ	Shift %
TAS	0.2	0%
QLD	1.8	1%
NT	0.0	0%
WA	15.7	12%
SA	8.5	6%
NSW	18.6	14%
VIC	87.2	66%

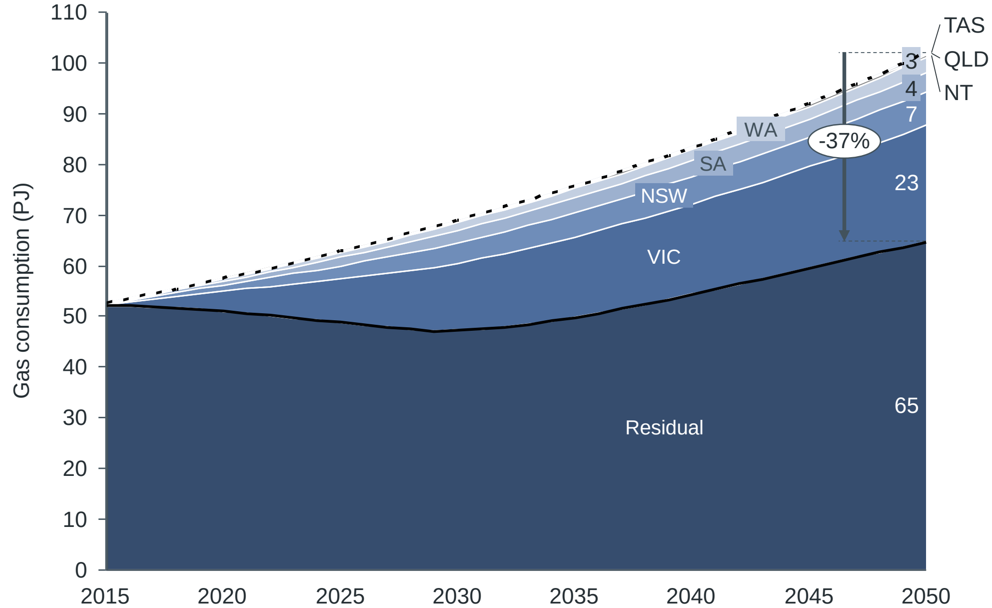
Figure 5: Contribution of gas consumption shifted to electricity by state in the residential sector (NB ACT is included in NSW data for this analysis)

Close to half (48%) of gas consumption in 2050 in the residential sector is expected to be switched, with 142 PJ of gas use remaining. A small number of states account for the vast majority of gas consumption within the residential sector and therefore corresponding shift to electricity. Victoria, NSW and WA see the largest amount of gas shifted to electricity, together contributing 92% of the total amount of residential gas shifted in 2050 with Victoria alone accounting for 66% of the shift.

Victoria and NSW/ACT together account for nearly 84% of total residential gas consumption in 2015. These states share a number of characteristics that can provide insight into the high gas consumption and switch - 1) high space heating requirements owing to their climate, and 2) a high proportion of mains gas heaters.

In other states, the magnitude of shift was limited. This is due in part to the milder climate and therefore lower heating demand and lower penetration of gas space heating appliances. Western Australia (12%), South Australia (6%) and QLD (1%) make up the remaining shift. Electrification in Tasmania and Northern Territory is limited due to very low gas consumptions in both states. Gas consumption is very low in Tasmania due to a very new reticulated gas network, while Northern Territory has very low heating requirements and therefore low gas consumption in residential and commercial sectors.

Similarly in the commercial sector, Victoria and NSW also accounted for most (80%) of the gas shifted.



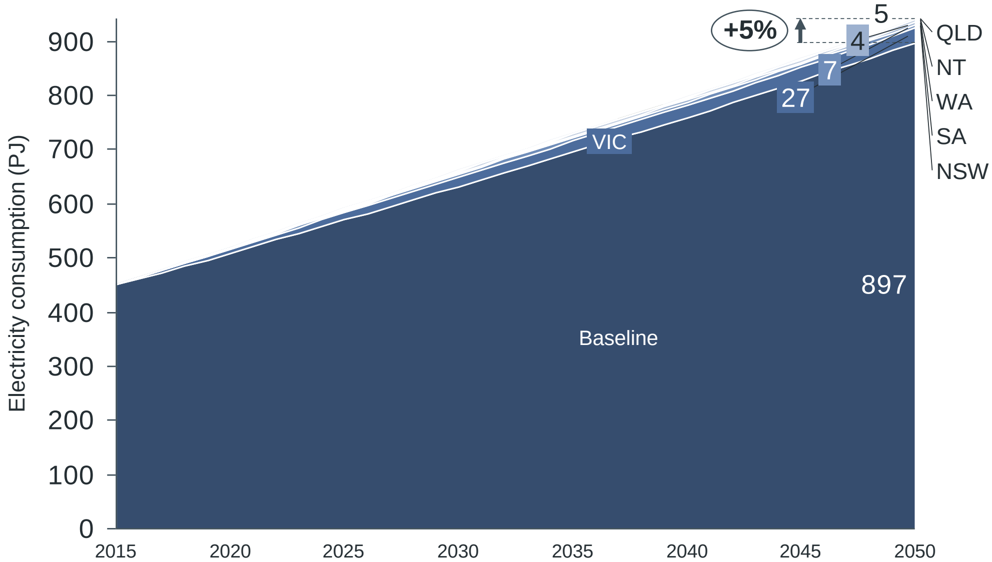
State	Shift PJ	Shift %
TAS	0.0	0%
QLD	0.4	1%
NT	0.4	1%
WA	3.0	8%
SA	3.8	10%
NSW	6.7	18%
VIC	23.0	62%

Figure 6: Contribution of gas consumption shifted to electricity by state in the commercial sector

In the commercial sector almost all of the electrification projected was in Victoria (62%), NSW/ACT (18%) and South Australia (10%), together accounting for 90% of the total shift in 2050. Western Australia (8%), Northern Territory (1%) and Queensland (1%) made up the remaining shift.

Gas consumption in the commercial sector remains significant in 2050, with 65 PJ or 63% of baseline remaining. This residual gas consumption reflects the higher share of gas use in commercial appliances, where shift was not modelled. Often this energy use is more difficult to switch as it is used for special equipment or required for high grade heating in hospitals, etc.

Together, the electrification modelled in the residential and commercial sectors resulted in an additional 44 PJ of electricity consumption across all states (see Figure 7). Given the relative size of gas shifted away from HVAC and hot water heating in Victoria and NSW, the corresponding increase in electricity consumption is also highest in these states. This is followed by South Australia and Western Australia.



State	Shift PJ	Shift %
TAS	0.0	0%
QLD	0.7	2%
NT	0.2	0%
WA	5.2	12%
SA	3.6	8%
NSW	7.0	16%
VIC	26.8	62%

Figure 7: Contribution of additional electricity consumption after shift, by state, across residential and commercial sectors.

Projections for states by residential and commercial sectors only are provide in Figures 8 A-N.

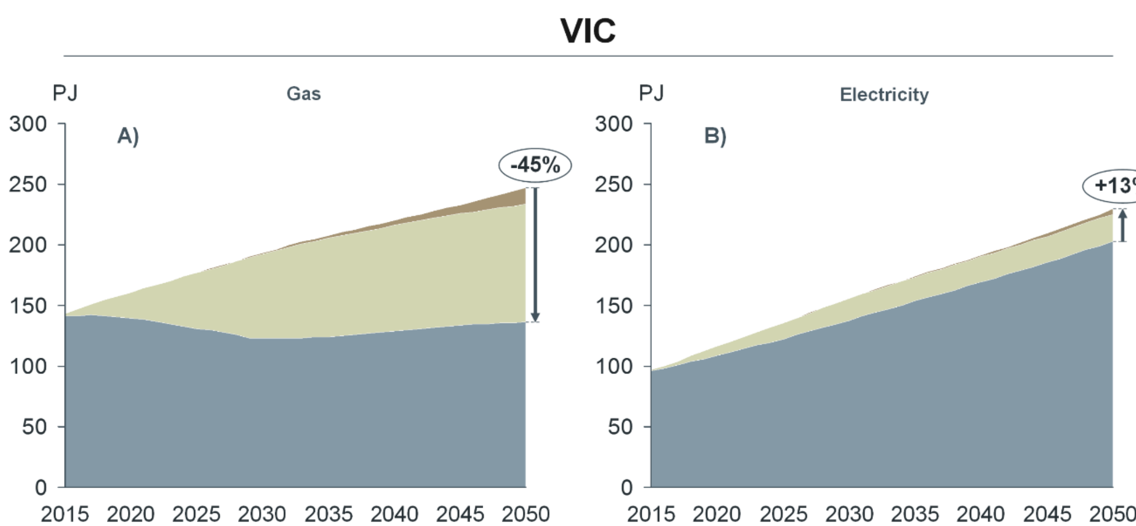
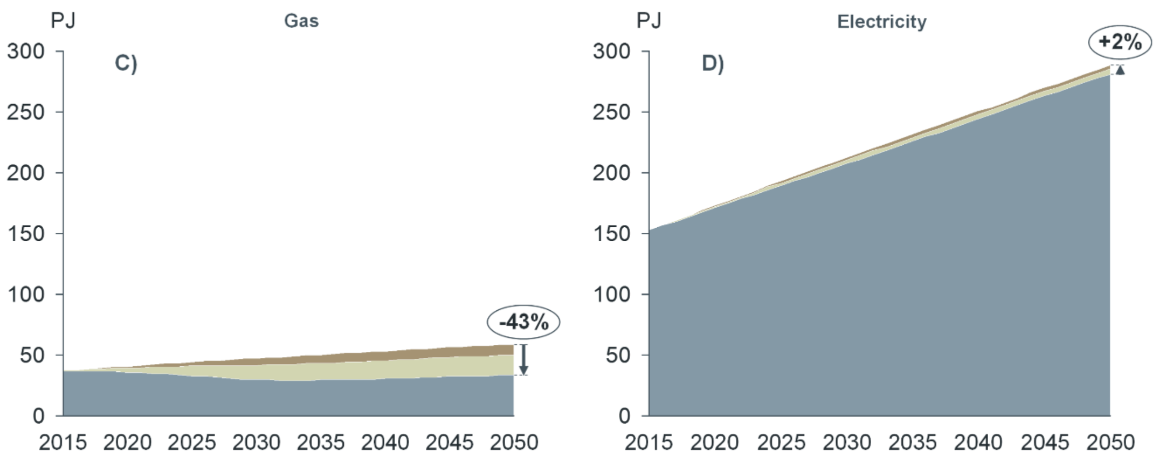


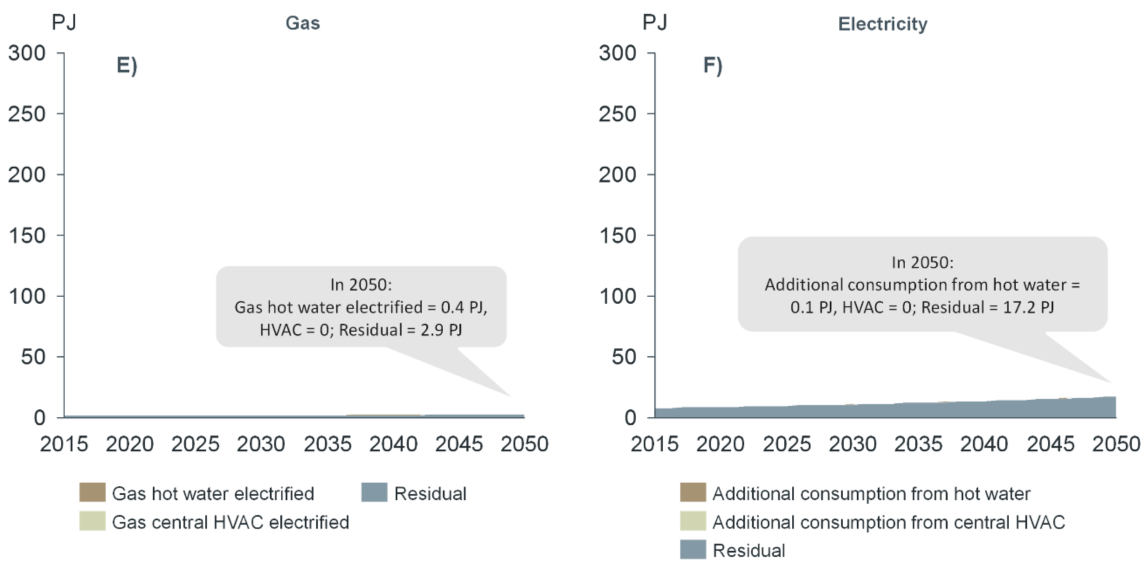
Figure 8: Figures A-N: Change in gas and electricity consumption from electrification in residential and commercial sectors, by state (A-N)

NSW



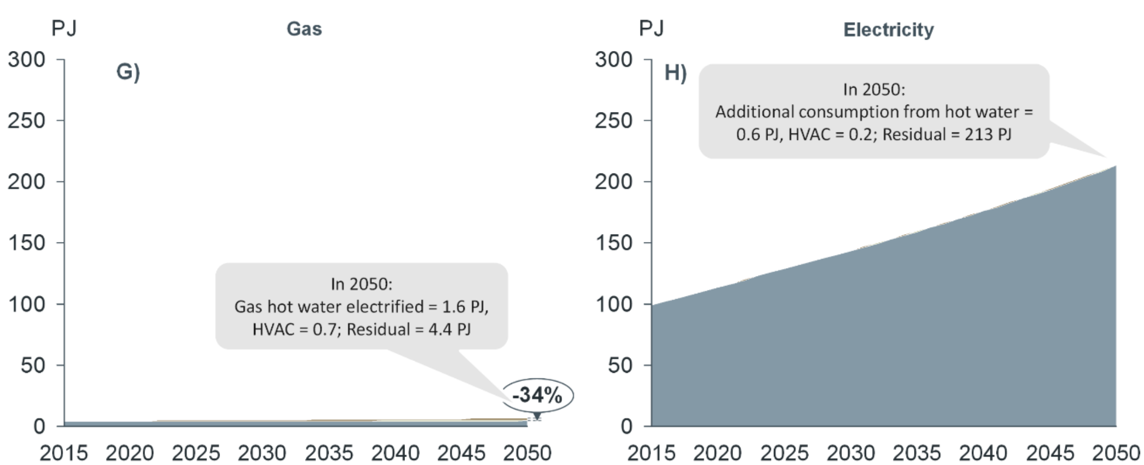
PJ
Gas
C)
-43%
PJ
Electricity
D)
+2%
2015 2020 2025 2030 2035 2040 2045 2050

NT



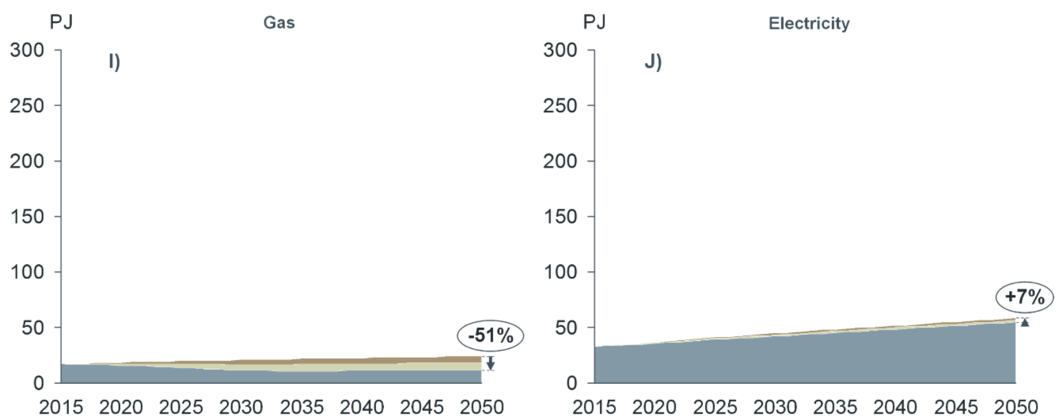
PJ
Gas
E)
In 2050:
Gas hot water electrified = 0.4 PJ,
HVAC = 0; Residual = 2.9 PJ
PJ
Electricity
F)
In 2050:
Additional consumption from hot water =
0.1 PJ, HVAC = 0; Residual = 17.2 PJ
2015 2020 2025 2030 2035 2040 2045 2050
Gas hot water electrified
Residual
Gas central HVAC electrified
Additional consumption from hot water
Additional consumption from central HVAC
Residual

QLD



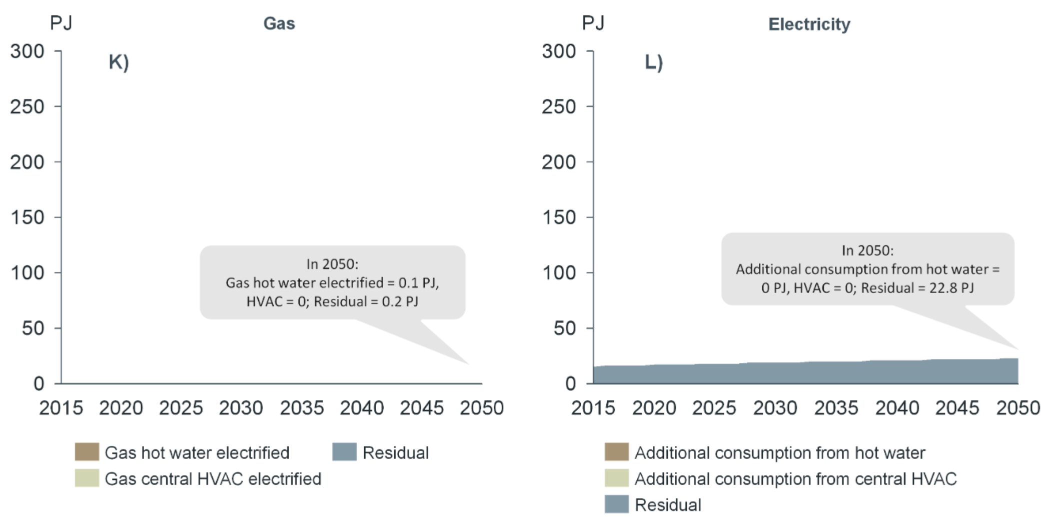
PJ
Gas
G)
In 2050:
Gas hot water electrified = 1.6 PJ,
HVAC = 0.7; Residual = 4.4 PJ
-34%
PJ
Electricity
H)
In 2050:
Additional consumption from hot water =
0.6 PJ, HVAC = 0.2; Residual = 213 PJ
2015 2020 2025 2030 2035 2040 2045 2050

SA



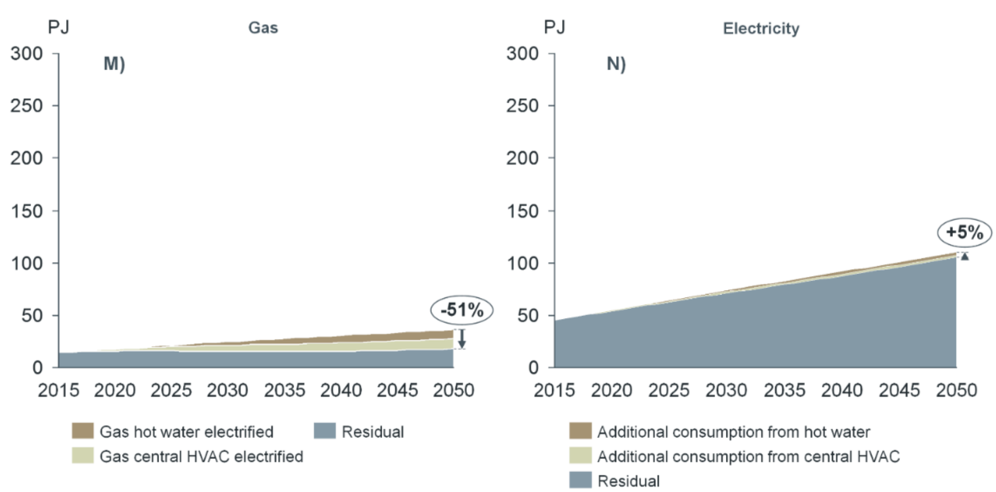
PJ
Gas
I)
-51%
300
250
200
150
100
50
0
2015 2020 2025 2030 2035 2040 2045 2050
PJ
Electricity
J)
+7%

TAS



PJ
Gas
K)
In 2050:
Gas hot water electrified = 0.1 PJ,
HVAC = 0; Residual = 0.2 PJ
PJ
Electricity
L)
In 2050:
Additional consumption from hot water =
0 PJ, HVAC = 0; Residual = 22.8 PJ
300
250
200
150
100
50
0
2015 2020 2025 2030 2035 2040 2045 2050
Gas hot water electrified
Gas central HVAC electrified
Residual
Additional consumption from hot water
Additional consumption from central HVAC
Residual

WA



PJ
Gas
M)
-51%
PJ
Electricity
N)
+5%
300
250
200
150
100
50
0
2015 2020 2025 2030 2035 2040 2045 2050
Gas hot water electrified
Gas central HVAC electrified
Residual
Additional consumption from hot water
Additional consumption from central HVAC
Residual

The impact of the additional electricity consumption on peak demand, as a result of electrification, is small. The largest increase occurs in Victoria during winter - although this increase does not rise above maximum summer demand levels.

Winter demand
The impact on peak demand is greatest in Victoria and South Australia in winter, with an additional 1018 MW and 146 MW required in 2050 in each respective state. This amounts to an increase above baseline winter demand in each state of approximately 11% in Victoria and 6% in South Australia respectively. There is a 279 MW increase in maximum winter demand in NSW in 2050, or approximately 2% of baseline winter demand.

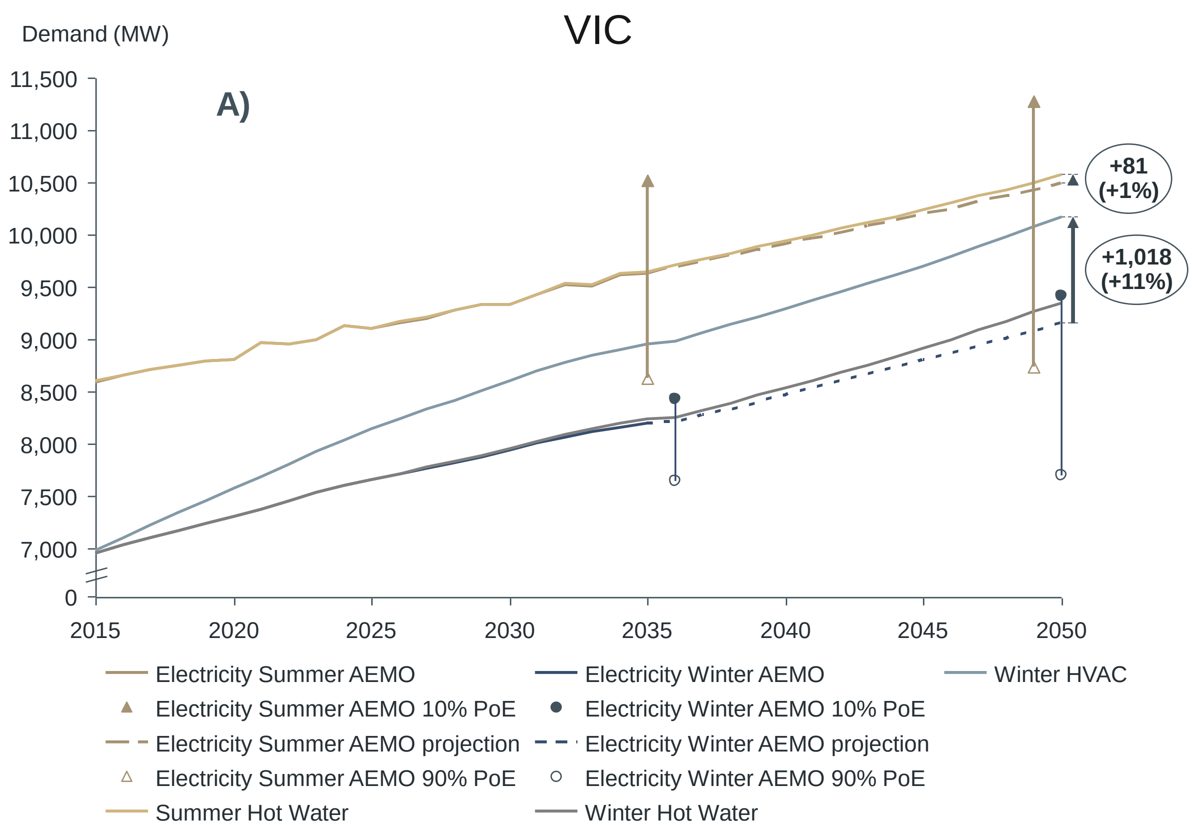
The estimated impact on summer demand is limited to shifts in hot water systems only. The impact resulting from shifts in HVAC, in particular space cooling, is not quantified for summer demand. This is due to the assumption that electrical space heating appliances are installed to replace gas space heating appliances. We were not able to quantify the cooling task associated with the switch to reverse cycle units, and was therefore not able to quantify the impact of these units on summer demand. The financial attractiveness was assessed for the heating task alone and any cooling benefit offered by the reverse cycle unit is incidental. Additional summer demand due to the higher penetration of reverse cycle HVAC units although not considered in this work is an area worthy of further investigation.

Summer demand
The impact of electrification on additional summer demand is most significant in Victoria with an additional 81 MW, followed by NSW and Western Australia, each with an additional 52 MW of demand in 2050. This amounts to approximately 0.8% of baseline summer demand in Victoria, 0.4% in NSW and 0.6% in Western Australia. South Australia sees 48 MW increased in maximum demand in summer in 2050, or approximately 1.6% of baseline winter demand.

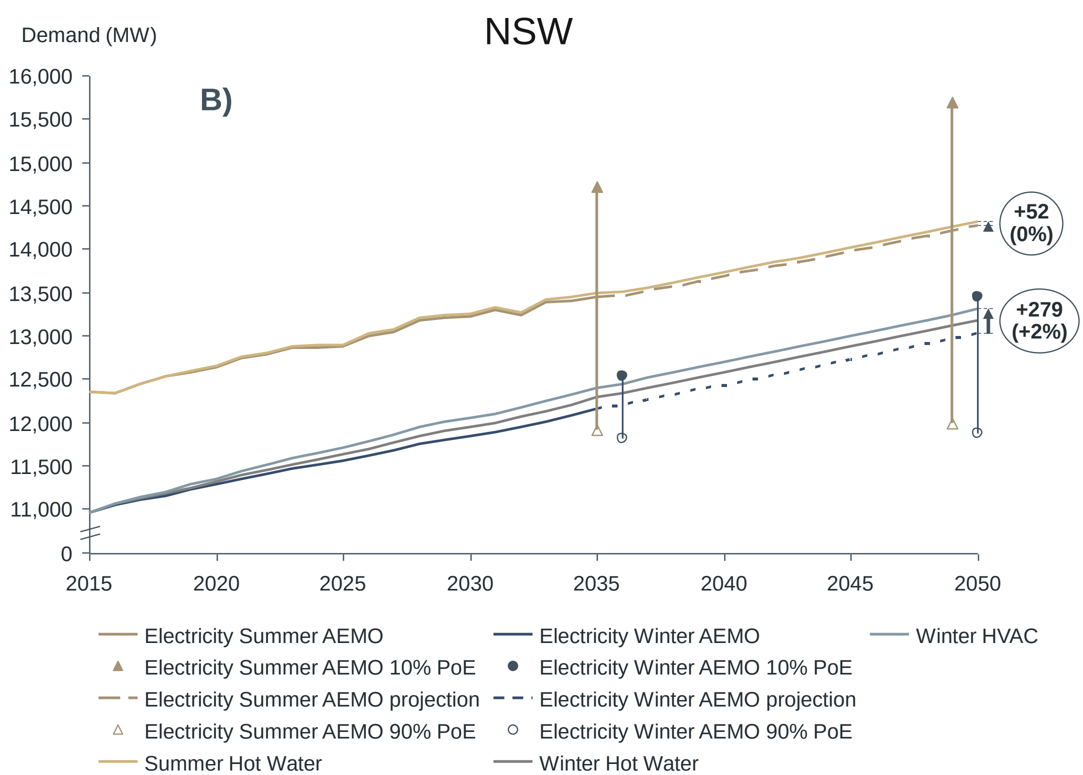
Despite having a larger increase, additional winter maximum demand does not exceed summer maximum demand in any state, except Tasmania. In Tasmania the greatest maximum demand occurs in winter, coinciding with the additional demand. The magnitude of additional capacity is limited however, with only 1.4 MW additional demand expected in 2050 from electrification.

The estimated impact on peak demands are relatively small compared to the range of peak demand forecasts for different confidence levels. For example, the impact on winter demand in Victoria (1018 MW) compares with 1709 MW, the difference between P10 and P90 bounds for forecasted winter demand in Victoria.

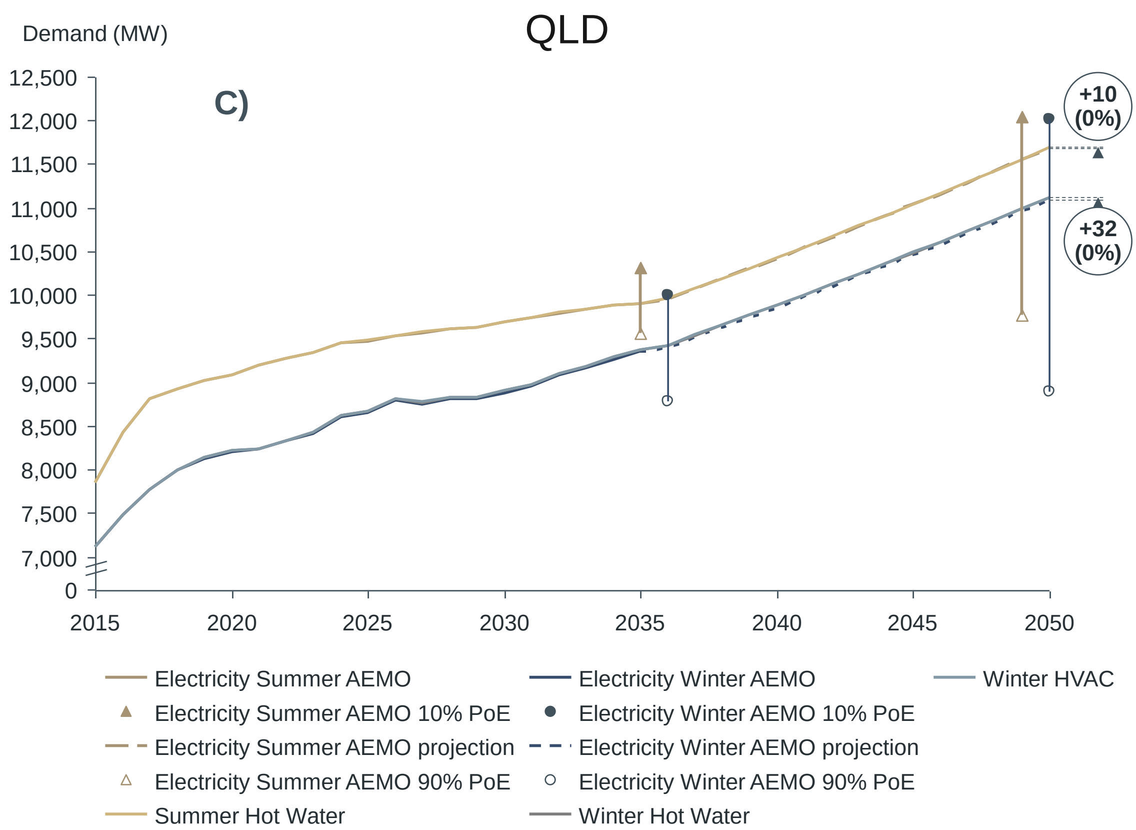
Projections for peak winter and summer demand for the states are provide in Figures 9 A-F.



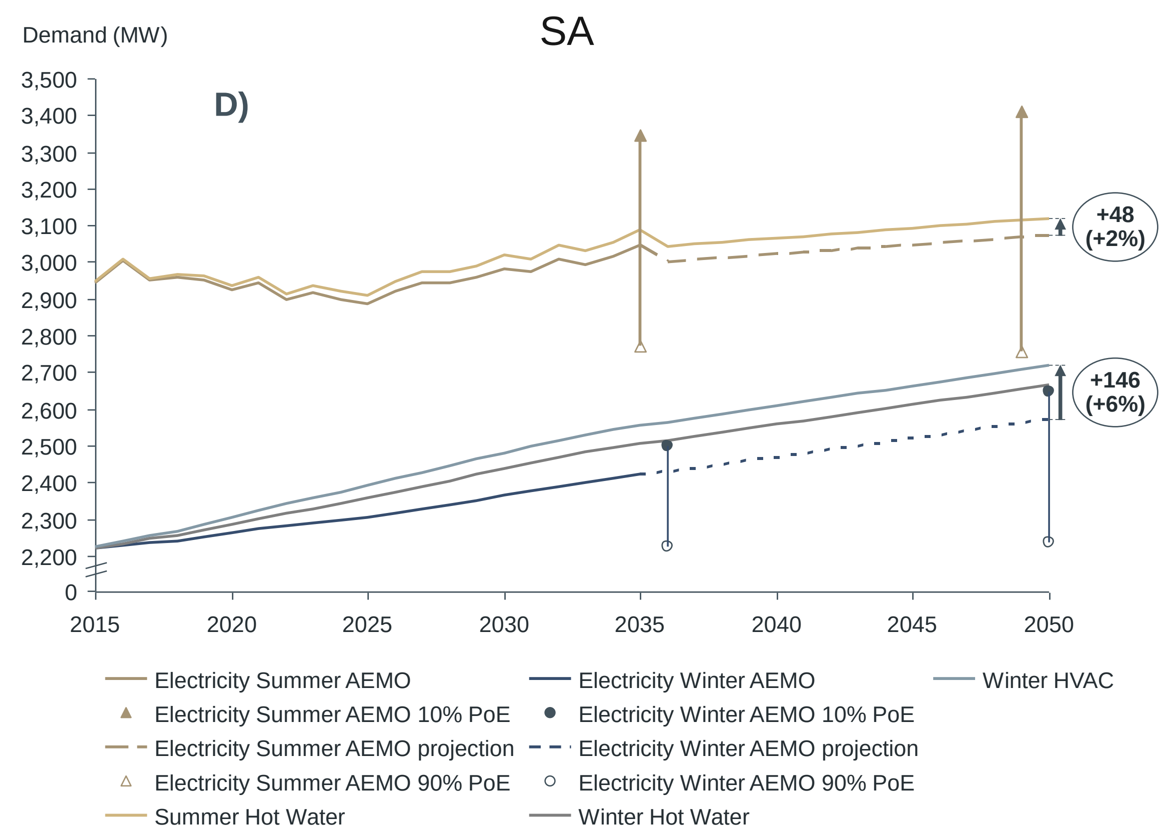
VIC
Demand (MW)
A)
11,500
11,000
10,500
10,000
9,500
9,000
8,500
8,000
7,500
7,000
0
2015
2020
2025
2030
2035
2040
2045
2050
+81
(+1%)
+1,018
(+11%)
Electricity Summer AEMO
Electricity Winter AEMO
Winter HVAC
Electricity Summer AEMO 10% PoE
Electricity Winter AEMO 10% PoE
Electricity Summer AEMO projection
Electricity Winter AEMO projection
Electricity Summer AEMO 90% PoE
Electricity Winter AEMO 90% PoE
Summer Hot Water
Winter Hot Water



NSW
Demand (MW)
B)
16,000
15,500
15,000
14,500
14,000
13,500
13,000
12,500
12,000
11,500
11,000
0
2015
2020
2025
2030
2035
2040
2045
2050
+52
(0%)
+279
(+2%)
Electricity Summer AEMO
Electricity Winter AEMO
Winter HVAC
Electricity Summer AEMO 10% PoE
Electricity Winter AEMO 10% PoE
Electricity Summer AEMO projection
Electricity Winter AEMO projection
Electricity Summer AEMO 90% PoE
Electricity Winter AEMO 90% PoE
Summer Hot Water
Winter Hot Water



QLD
Demand (MW)
C)
12,500
12,000
11,500
11,000
10,500
10,000
9,500
9,000
8,500
8,000
7,500
7,000
0
2015
2020
2025
2030
2035
2040
2045
2050
+10 (0%)
+32 (0%)
Electricity Summer AEMO
Electricity Summer AEMO 10% PoE
Electricity Summer AEMO projection
Electricity Summer AEMO 90% PoE
Summer Hot Water
Electricity Winter AEMO
Electricity Winter AEMO 10% PoE
Electricity Winter AEMO projection
Electricity Winter AEMO 90% PoE
Winter Hot Water
Winter HVAC



SA
Demand (MW)
D)
3,500
3,400
3,300
3,200
3,100
3,000
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
0
2015
2020
2025
2030
2035
2040
2045
2050
+48 (+2%)
+146 (+6%)
Electricity Summer AEMO
Electricity Summer AEMO 10% PoE
Electricity Summer AEMO projection
Electricity Summer AEMO 90% PoE
Summer Hot Water
Electricity Winter AEMO
Electricity Winter AEMO 10% PoE
Electricity Winter AEMO projection
Electricity Winter AEMO 90% PoE
Winter Hot Water
Winter HVAC

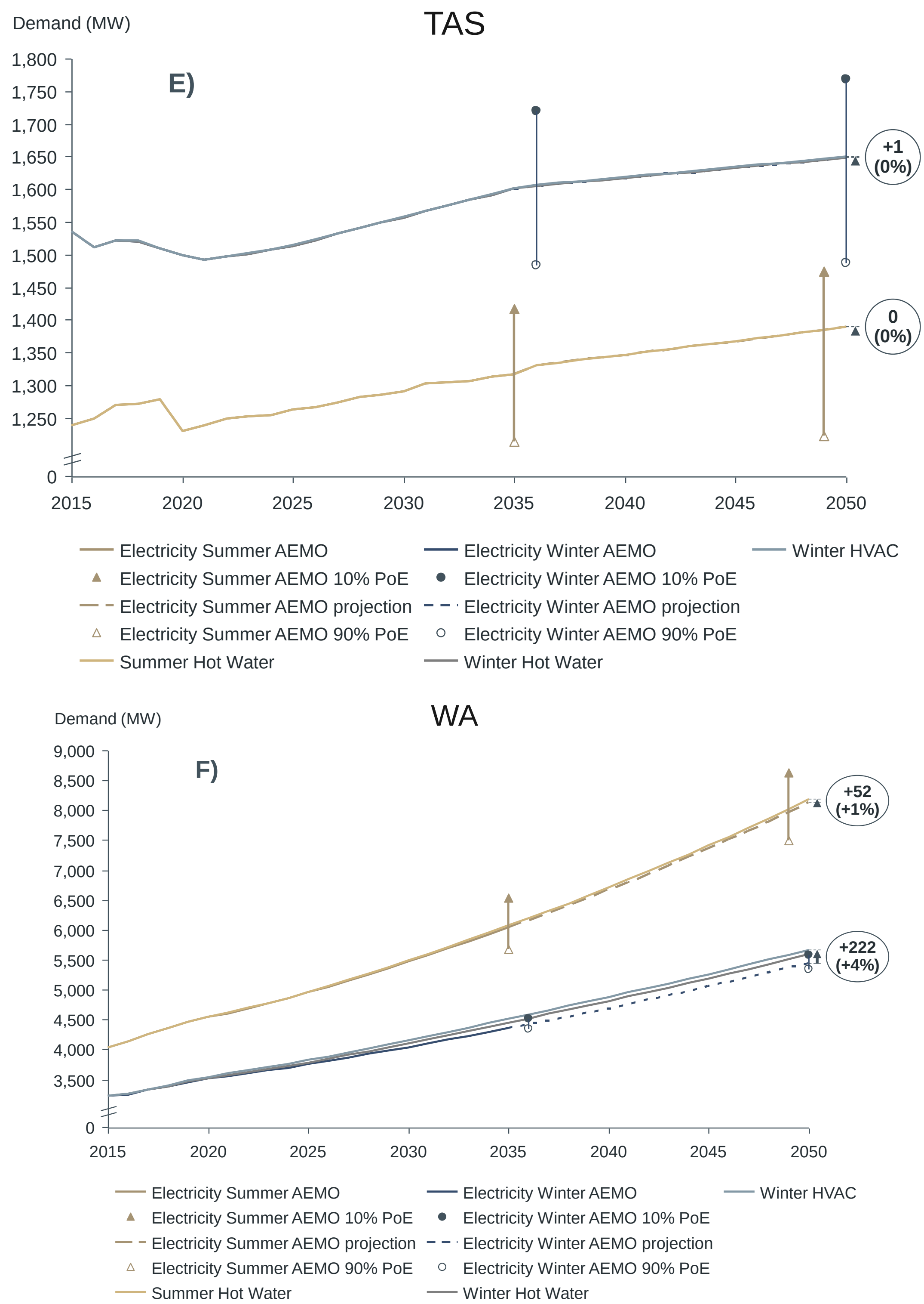


Figure 9: Figures A-F: Impact of electrification on peak electricity demand, relative to AEMO forecasts, by state. ***Note****: Estimated impact on summer demand is limited to shifts in hot water systems only. The impact resulting from shifts in HVAC, in particular space cooling, is not quantified for summer demand. Demand forecast for NT not available.*

In Industry, the shift to electricity is largest in non-ferrous metal ores and gas mining industrial subsectors, leading to 853 PJ electricity consumption in 2050. Industry electricity consumption potential is close to the amount across both residential and commercial sectors in 2050 after electrification.

While the residential and commercial sector analysis are new updated projections of likely gas-electricity switching, the industrial sector analysis draws upon existing projections from the Deep Decarbonisation Pathways Project (DDPP) which explored the upper potential of industry electrification to contribute greenhouse gas emissions reduction. As such the industry projections are at the high end of the plausible range of potential gas-electricity switching in this sector. The DDPP analysis was also high level in that it did not examine each state's individual circumstances but rather looked across subsectors of the industry sector.

The high level DDPP analysis was done for a number of industrial subsectors (listed in Table 1), representing industrial subsectors with the largest opportunity for electrification in 2050. These subsectors include Non-ferrous metal ores, Gas mining (extraction), Alumina, Other mining, Other food and drink products, Non-metallic construction materials (not cement) and Paper products.

Across these subsectors, the final electricity use in 2050 is 853 PJ, nearly the same as that expected in the residential and commercial sectors in 2050 (942 PJ), after electrification.

With significant growth in both the level of energy consumption and the degree of electrification expected in line with a decarbonised economy, non-ferrous metal ores is expected to have the highest electricity consumption (542 PJ). There is also substantial opportunity for electrification in the mining sectors, including gas mining and other mining, contributing 190 PJ of electricity consumption in 2050. These electrification opportunities are the result of a shift to electricity for heating processes and a shift in mining from trucks to electricity-based technologies, such as conveyors for materials handling[3].

The method[4] used to estimate impact of electrification on demand assumes 24/7 operation. This method is likely to provide a low estimate of demand given that industrial plants do often cycle up and down. It is, however, not uncommon for electricity providers to negotiate directly with large energy users to manage demand. Continuation of current trends towards decentralised and self-generated electricity would also reduce maximum demand.

The absence of available information at a more granular level and the scope of this project limits further investigation of this topic, however these constraints indicate that further investigation of this area would be beneficial.

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[3] ClimateWorks Australia and ANU (2014) *Pathways to Deep Decarbonisation in 2050: How Australia can prosper in a low carbon world.*

[4] See Industry subheading of methodology section for more information

Table 1: Summary of electricity use (PJ) and demand (MW) in selected industrial subsectors, 2012 and 2050

Sector	**2014 (OCE)**			**2050 (DDPP)**			**2050 electricity demand (MW)**
	Total energy consumption (PJ)	Electricity consumption (PJ)	Share of electricity (%)	Total energy consumption (PJ)	Electricity consumption (PJ)	Share of electricity (%)	
Alumina	403	132	33%	142	66	47%	2,102
Gas mining	216	18	8%	387	133	34%	4,218
Non-ferrous metal ores	184	60	33%	896	542	60%	17,176
Non-metallic construction materials (not cement)	100	16	16%	35	14	41%	455
Other food and drink products	154	21	14%	59	28	46%	872
Other mining	184	60	33%	147	57	39%	1,813
Paper products	53	14	26%	33	13	39%	402

**'Non-ferrous metal ores' and 'Other mining' are within the same ANZIC sub-division. See appendix for full detail on sector assignments.*

Methodology and approach used in analysis

This section provides an overview of the methodology and approach used in the analysis of the residential and commercial sectors, organised by steps shown in the schematic (Figure 10). Industry analysis was treated differently and explained further on in the document. The analysis was undertaken for the years 2015-2050.

The approach consisted of 5 main steps: 1) Developing a state-by-state baseline energy consumption trajectory for residential and commercial sectors, broken down by fuel type and end use; 2) Identifying relevant barriers and enabling factors that would affect electrification, and applying the segmentation accordingly; 3) Assess the drivers of electrification by undertaking

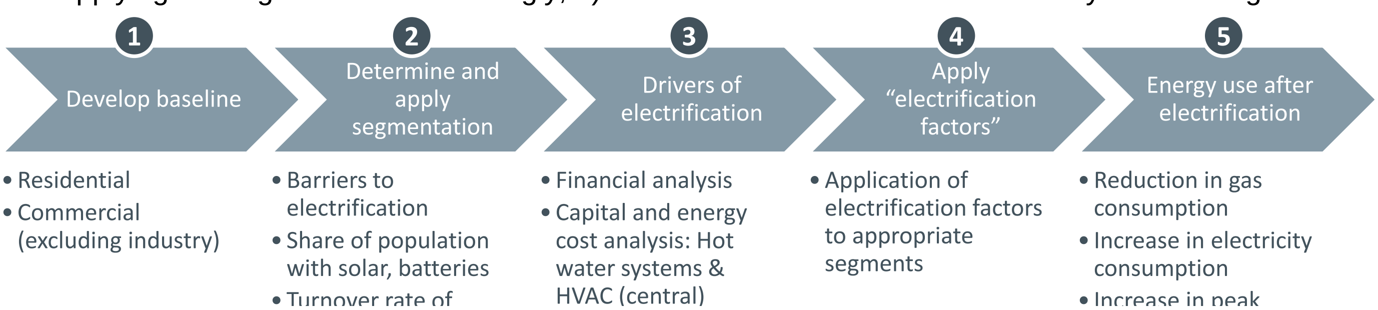

Figure 8: Schematic of methodology and approach used in the analysis

financial analysis ; 4) Applying the electrification factors informed by the drivers of electrification; and finally in 5) obtaining the changes in energy consumption and demand resulting from the electrification.

1. Develop baseline

Total baseline energy consumption from 2015 to 2050 was developed by applying activity growth rates to current energy use. Current energy use for each state was based on energy use data from Table F of the Australian Energy Statistics (OCE, 2015).

- Growth in **residential energy use** is based on the *total number of households*. This is informed directly by ABS[5] to 2031 and extrapolated based on ABS population forecasts[6] to 2050 by the assumed relationship between number of households and population.
- Growth in **commercial energy use** is based on *floor area.* This is informed by Pitt & Sherry[7] estimates of floor space for offices, retail, education, health accommodation, industrial and other buildings to 2020. It is extrapolated from 2020 to 2050 based on continuation of forecast trends.
- Baseline energy use for industrial sectors was not developed.

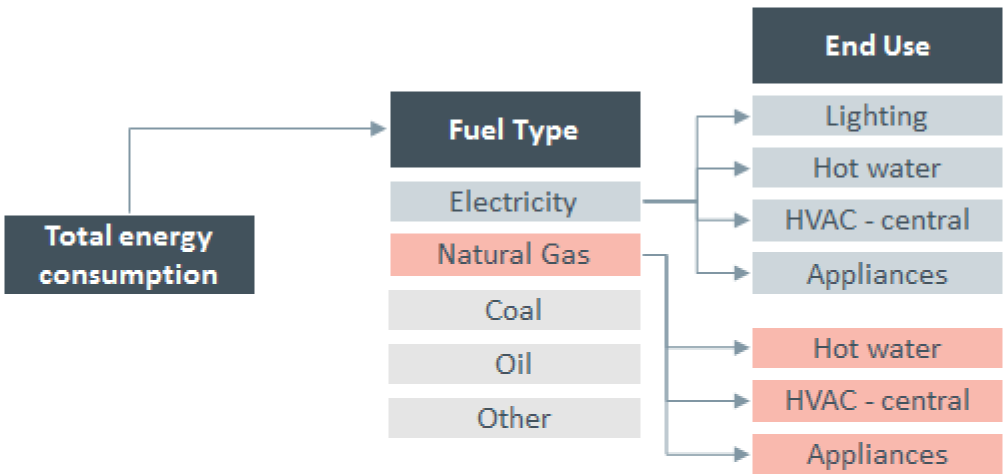

Figure 9: Schematic of modelling breakdown of energy consumption by fuel type and end use.

The split of total energy consumption **by fuel type** and the forecast change over time was informed by continuation of historic trends from Office of the Chief Economist's Australian Energy Statistics (2015).

[5] ABS, 2010, Projected number of households, Household type—2006 to 2031, "Series II". Available via: http://www.abs.gov.au/ausstats/abs@.nsf/mf/3236.0
[6] ABS, 2013, 3222.0 Population Projections, Series B, by State. Available Via: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3222.02012%20(base)%20to%202101?OpenDocument
[7] Pitt & Sherry, 2012, Baseline Energy Consumption and Greenhouse Gas Emissions In Commercial Buildings in Australia. Available via: http://www.industry.gov.au/ENERGY/ENERGYEFFICIENCY/NON-RESIDENTIALBUILDINGS/Pages/CommercialBuildingsBaselineStudy.aspx

Attribution of energy consumption **by end use** was at the state level using information from the Residential Baseline Study[8]. Similarly granular information was however not available for commercial buildings so national figures informed by Pitt & Sherry was used.

A turnover rate of 2% per year and 1.7% per year was applied to residential and commercial buildings respectively. This is consistent with a 50 and 60 year asset life respectively, assumed to come from demolition and substantial retrofit. This determined the split between new and existing buildings in each sector over time.

2. Determine and apply segmentation

The residential and commercial sectors were segmented based on two dimensions - barriers and energy costs.

A high level analysis was conducted to identify segments of the population that would face barriers to electrification. This is implemented in the modelling by reducing the amount of gas available for substitution in both residential and commercial buildings.

Residential barriers
The two barriers identified from ACOSS[9] to be most pertinent for residential are a) **split incentives (tenanted areas)** and b) **capital (low income households)**. The up-front cost would be the highest consideration when replacing an appliance for households with limited access to capital, even if that appliance is more expensive to run over the long-term. The modelling implication of the upfront costs is that this group of households would not follow the same rational purchasing decision assumed to influence uptake for other households.

For households that rent, it is assumed that the landlord has little or no incentive to outlay more capital for a high efficiency / electrical appliance, since the tenant bears the cost of operation. The modelling implication of this is that this group of households would not necessarily have rights or means to upgrade to an electrical appliance.

Commercial barriers
In lieu of similar information for the commercial sector, the rate of business exit was used as a proxy for businesses that are likely to face competing priorities and capital barriers. These businesses are likely to have competing priorities as they are more concerned about short term cash flows, and are therefore unlikely to be considering purchases requiring significant capital despite offering financial benefits over a longer time frame. Similarly, these businesses are likely to face capital barriers and therefore not have access to sufficient capital for these purchases.

Turnover rate of appliances
In addition to segmenting the residential and commercial sectors based on barriers, we have also assumed a 15 year life span which determines the proportion of existing gas appliances that are available for turnover at each year. This assumption meant that only 7% of gas HVAC

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[8] Energy consult, 2015, Residential Energy Baseline Study: Australia; Prepared for Department of Industry and Science on behalf of the trans-Tasman Equipment Energy Efficiency (E3) Program. Available via: http://www.energyrating.gov.au/document/report-residential-baseline-study-australia-2000-2030

[9] ACOSS, 2013, Energy Efficiency & People on Low Incomes. Available via: http://www.acoss.org.au/images/uploads/ACOSS_ENERGY_EFFICIENCY_PAPER_FINAL.pdf

and hot water heating systems are available for substitution each year, and was applied to both residential and commercial sectors.

End user electricity costs
Another segmentation category used across the residential and commercial sectors is the electricity costs paid by end users. For each state, we assumed the share of households and business with rooftop solar PV, with or without batteries. The remaining population was assumed to pay retail electricity prices[10].

The share of households and businesses with rooftop solar PV, with or without batteries, were approximated by the amount of electricity forecasted to be generated by rooftop solar PV (GWh) as a share of total electricity consumption in AEMO's National Electricity Forecasting Report[11]. This share of the market is assumed to have access to electricity costs that are lower than purchasing from the grid and hence would be more financially attractive to operate an electric appliance. Other enabling factors such as the imminent reduction/removal of feed in tariffs and emotional factors such as the desire to utilise self-generated electricity have the possibility to increase electrification but are not modelled here.

3. Drivers of electrification

Economic decision making by end consumers is assumed to be the main driver of appliance choice when replacing appliances at end of life or when purchasing a new appliance for a new premise. With the exception of those subject to barriers discussed above, households and commercial building owners are assumed to make rational economic decisions, purchasing the appliance that will lead to the lowest total cost of ownership over the life of the appliance. The total cost of ownership is a function of both **capital costs** of technology and the **operating costs** over the life of the appliance, determined by energy costs different consumers pay for electricity and gas.

Capital costs were modelled by annualising the typical upfront cost of different types of equipment (including installation cost) over a 15-year equipment life span. Operating costs were determined by taking the product of typical annual energy consumption and unit energy prices, for different appliances and regions where available. This provides an estimate of the year when the net operating cost of an electric heat pump appliance is lower than an equivalent gas appliance. Complete details of the financial assumptions and energy costs for each state are provided further in the report.

The financial analysis described above provides a year at which it becomes financially attractive to own and operate an electrical appliance over an equivalent gas appliance. Recognising, however, that not everyone will immediately adopt a new idea or technology (in this case, a high-efficiency electric appliance), the uptake of this new technology was modelled based on an S-curve or logistic function.

As seen in

[10] See Assumptions for detailed electricity prices for each state
[11] AEMO, 2016, National Electricity Forecasting Report (NEFR). Available via: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Electricity-Forecasting-Report

, the consumer adoption curve (in blue) is translated into an S-curve (in yellow) for our analysis. In doing so, the year at which electrification becomes attractive is used to inform the inflection point of the S-curve or the point at which 50% of the population (i.e. innovators, early adopters and early majority customer segments) chooses to replace/purchase a gas appliance with an electric equivalent. The rate of penetration (i.e. slope of the S-curve) is determined by historical technology diffusion rates (as seen in **Error! Reference source not found.**). In reviewing these historical technology diffusion rates, a typical rate of 0-100% adoption within 30 years was used.

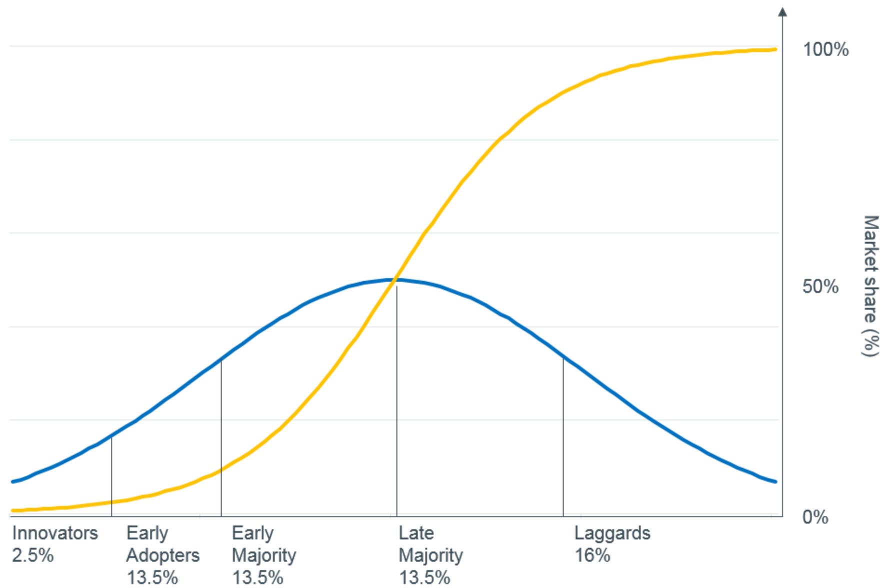

Figure 10: Customer segments of technology adoption: groups of consumer adopting a new technology in blue, and corresponding market share in yellow.

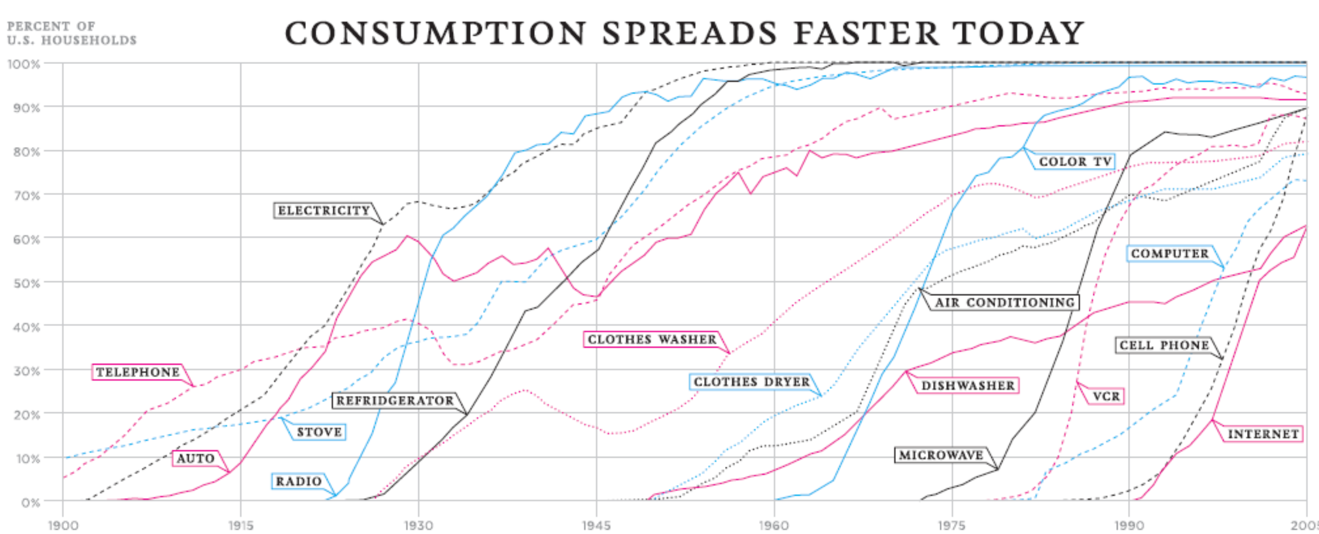

Figure 11: Rate of penetration of new technologies in US households, 1900-2005.
Source: http://www.nytimes.com/imagepages/2008/02/10/opinion/10op.graphic.ready.html
(c) Nicholas Felton; reproduced with permission

4. Applying "Electrification Factors"'

Combining the above parameters using a logistics function allowed us to create a time series of 'electrification factors' - the share of the population assumed to choose a high-efficiency electric model when considering the purchase or replacement of a space heating or hot water appliance. Three series of electrification factors were created and applied for each state, depending on the type of electricity prices end users were paying (e.g. retail, rooftop solar PV, and rooftop solar PV with batteries).

These shares were applied to the final gas use in residential and commercial sectors, after accounting for segments of these sectors that are facing barriers and so not likely to shift to electrical appliances (see above). In practice, these shares are 6% each year of the eligible market of about 60% - a number that varies by state.

State	Electricity price	Year	2015	2020	2025	2030	2035	2040	2045	2050
NSW	Grid	2018	23%	69%	94%	99%	100%	100%	100%	100%
NSW	Solar	2015	50%	88%	98%	100%	100%	100%	100%	100%
NSW	Solar+battery	2017	31%	77%	96%	99%	100%	100%	100%	100%
QLD	Grid	2017	31%	77%	96%	99%	100%	100%	100%	100%
QLD	Solar	2015	50%	88%	98%	100%	100%	100%	100%	100%
QLD	Solar+battery	2016	40%	83%	97%	100%	100%	100%	100%	100%
SA	Grid	2017	31%	77%	96%	99%	100%	100%	100%	100%
SA	Solar	2016	40%	83%	97%	100%	100%	100%	100%	100%
SA	Solar+battery	2016	40%	83%	97%	100%	100%	100%	100%	100%
TAS	Grid	2021	8%	40%	83%	97%	100%	100%	100%	100%
TAS	Solar	2017	31%	77%	96%	99%	100%	100%	100%	100%
TAS	Solar+battery	2019	17%	60%	92%	99%	100%	100%	100%	100%
VIC	Grid	2045	0%	0%	0%	0%	2%	12%	50%	88%
VIC	Solar	2024	3%	17%	60%	92%	99%	100%	100%	100%
VIC	Solar+battery	2033	0%	1%	4%	23%	69%	94%	99%	100%
WA	Grid	2022	6%	31%	77%	96%	99%	100%	100%	100%
WA	Solar	2015	50%	88%	98%	100%	100%	100%	100%	100%
WA	Solar+battery	2017	31%	77%	96%	99%	100%	100%	100%	100%
NT	Grid	2016	40%	83%	97%	100%	100%	100%	100%	100%
NT	Solar	2015	50%	88%	98%	100%	100%	100%	100%	100%
NT	Solar+battery	2015	50%	88%	98%	100%	100%	100%	100%	100%

Figure 12: Example of electrification factors for residential hot water system switching. Interim years are compressed for display.

5. Energy use after electrification

Consumption

The process described above allowed calculation of the amount of energy (PJ) switched from gas in a particular year from a given end-use and sector. This accumulates over time, given that the energy switched away from gas last year remains out.

The total amount of energy required to service the different end use in each sector and state is determined in the baseline. We assume that the task still needs to be completed: i.e. the same amount of hot water output is still required, proportional to the amount of energy used for hot water in baseline; however this can be done by using electricity rather than gas. Electric heat-pump systems require less input energy to create the same amount of output, due to the higher coefficient of performance (CoP). The CoP improves over time for electric appliances and gas appliances are assumed to remain constant. The resulting electricity energy consumption is a fraction of the original gas energy consumption, proportional to the ratio of CoP.

As above, the amount of additional electricity consumption also accumulates over time as the energy required to perform the heating or cooling task from an electrical appliance switched last year continues to demand electricity for the 15 year life of the appliance.
See Assumptions and Sources for further information and the values used.

Peak demand

This analysis did not seek to conduct time of use modelling per appliance, on a per-premise basis. Rather, the Conservation Load Factor (CLF)[12] concept was used to quantify the increase in peak demand (MW) due to additional electricity consumption (PJ) from gas-electricity switching. CLF for different end uses (i.e. HVAC and hot water heating) were available for different times of the year (i.e. winter and summer demands).
According to Langham, et al. (2010), "The CLF, determined through simulation or measurement, depends on the diversity and shape of the baseline profile related to the end use application impacted by an energy conservation measure as well as the coincidence of energy savings with winter/summer peak periods." Further detail on the CLF is provided in the Assumptions and Sources section.

Industry

Industry analysis was informed by the analysis that was done nationally as part of the *Pathways to Deep Decarbonisation in 2050*. Industrial subsectors that had a large shift towards electricity as share of total energy use in 2050 compared to 2012 and also had sizeable electricity consumption (>10PJ) were identified.

The conservation load factor approached used in residential and commercial could not be applied to industrial subsectors since no information was available. The total electricity demand (MW) in 2050 is determined from the consumption figure, assuming 24/7 operation.

Assumptions and sources

Limitations

The modelling done has not accounted for the impact of future changes to climate and temperature. AEMO has indicated that future NEFR forecasts will address this which could be considered in future analysis around electrification. The implication of excluding this in the analysis could mean that winter demand is overstated while summer demand might be understated.

[12] Langham, E., Dunstan, C., Walgenwitz, G., Denvir, P., Lederwasch, A., and Landler, J. 2010, Reduced Infrastructure Costs from Improving Building Energy Efficiency. Prepared for the Department of Climate Change and Energy Efficiency by the Institute for Sustainable Futures, University of Technology Sydney and Energetics.

In estimating the amount of new buildings in residential and commercial sectors, we have assumed that building performance remains the same. This would, in effect, reduce the amount of heating and cooling requirements of buildings as the building envelope in new builds improves over time.

Develop baseline

Autonomous rate of increase in energy use

Residential energy consumption growth is informed by the number of residential households:

- 2015-2036: ABS Household and Family Projections, Australia, Series II total households. [3236.0 - Household and Family Projections, Australia, 2011 to 2036]
- 2036-2050: Extrapolated number of households from2015-36 based on ABS population projections [3222.0 - Population Projections, Australia, 2012 (base) to 2101]
- “Existing” building stock reduces at 2% p.a., consistent with a 50 year asset life assumed to come from demolition and substantial retrofit

Commercial energy consumption is informed by floor area (m^2) in commercial buildings: [CBBS]

- This is informed by Pitt & Sherry estimates of floor space in each state for the following types of buildings: Stand alone offices, Non-stand alone offices, Hospitals, Hotels, TAFEs, Universities, Schools, Shopping centres, Supermarket, Retail strip, Public building, Law court and Correctional centre.
- The additional floor area for Restaurants, cafes, pubs, bars, clubs was estimated to be 75% of Hotels floor area.
- “Existing” building stock reduces at 1.7% p.a., consistent with a 60 year asset life assumed to come from demolition and substantial retrofit

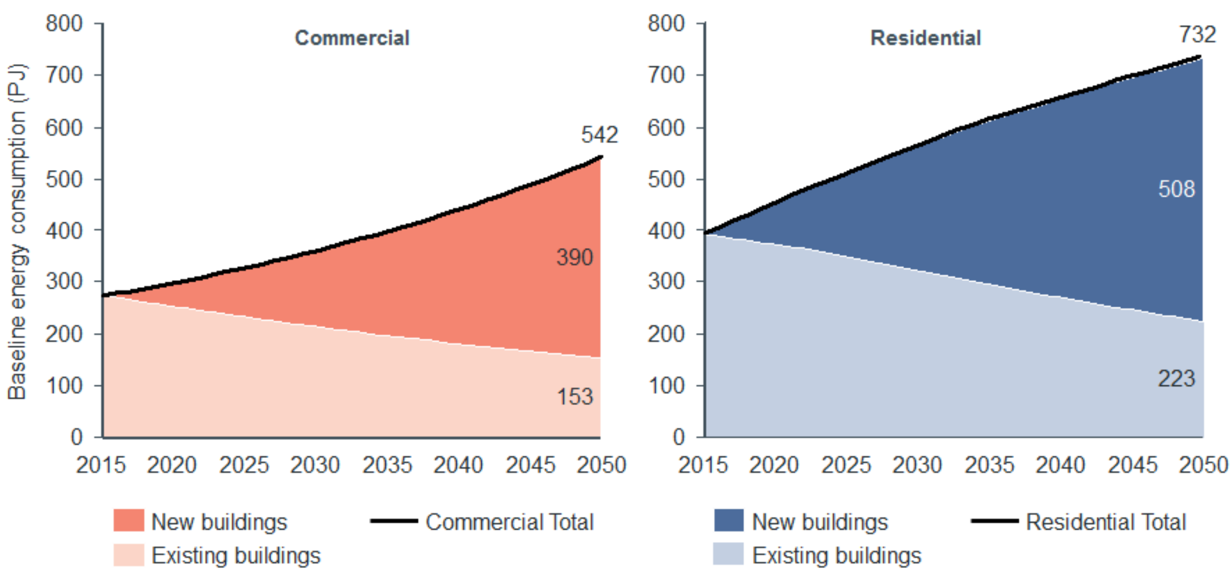

Figure 14) Energy consumption in commercial (left) and residential (right), showing the split of new and existing buildings over time

Breakdown of energy consumption by fuel type

Fuel type by state for the residential sector was aligned to 2014 values of, and historical rate of change in fuel use (1975-2014) according to Office of the Chief Economist, Table F for 2015-2050.

NSW	2014 share	Change % p.a.
Coal	0%	-0.04%
Electricity	63%	0.55%
Gas	20%	0.28%
Oil	4%	-0.37%
Other	13%	-0.42%

VIC	2014 share	Change, % p.a.
Coal	0%	-0.20%
Electricity	24%	0.07%
Gas	65%	1.10%
Oil	2%	-0.47%
Other	9%	-0.50%

QLD	2014 share	Change, % p.a.
Coal	0%	-0.01%
Electricity	80%	0.90%
Gas	5%	0.10%
Oil	7%	-0.18%
Other	7%	-0.78%

WA	2014 share	Change, % p.a.
Coal	0%	0.00%
Electricity	58%	0.87%
Gas	25%	0.63%
Oil	5%	-0.68%
Other	12%	-0.82%

TAS	2014 share	Change, % p.a.
Coal	0%	0.00%
Electricity	61%	0.85%
Gas	1%	0.04%
Oil	4%	-0.50%
Other	35%	-0.35%

NT	2014 share	Change, % p.a.
Coal	0%	0.00%
Electricity	86%	1.15%
Gas	0%	0.00%
Oil	11%	-0.46%
Other	3%	-0.68%

SA	2014 share	Change, % p.a.
Coal	0%	0.00%
Electricity	49%	0.37%
Gas	32%	0.30%
Oil	4%	-0.39%
Other	14%	-0.28%

To account for the trend away from stand-alone houses and the increased likelihood that new apartments won't have a gas connection, a proportion of "new" buildings that are apartments are assumed to be all-electric. This proportion is determined from building approvals statistics from ABS[13] [8731.0 - Building Approvals, Australia, Sep 2015]

For commercial sector, the fuel type split is held constant according to 2014 figures of Office of the Chief Economist, Table F.

Split of energy consumption by end use

For the residential sector, state by state information of split of energy use by end use and fuel type was drawn from the Residential Baseline Study for 2015 and assumed constant over time. Commercial energy use by end use and fuel type was drawn from the Commercial Buildings Baseline study, with national values used for all states in the absence of more granular state-based information being available.

[13] ABS, 2015, 8731.0 - Building Approvals, Australia, Sep 2015. Available at: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/8731.0Sep%202015?OpenDocument

Residential

VIC	Electricity	Direct Fuels
Lighting	15%	0%
Hot water	12%	21%
HVAC - central	16%	77%
Appliances	58%	3%

QLD	Electricity	Direct Fuels
Lighting	11%	0%
Hot water	24%	52%
HVAC - central	17%	14%
Appliances	48%	34%

NSW	Electricity	Direct Fuels
Lighting	12%	0%
Hot water	22%	38%
HVAC - central	17%	48%
Appliances	49%	14%

SA	Electricity	Direct Fuels
Lighting	13%	0%
Hot water	15%	48%
HVAC - central	19%	43%
Appliances	53%	9%

WAS	Electricity	Direct Fuels
Lighting	13%	0%
Hot water	9%	49%
HVAC - central	23%	42%
Appliances	54%	9%

TAS	Electricity	Direct Fuels
Lighting	9%	0%
Hot water	23%	4%
HVAC - central	34%	89%
Appliances	35%	6%

NT	Electricity	Direct Fuels
Lighting	11%	0%
Hot water	19%	32%
HVAC - central	22%	9%
Appliances	48%	60%

Commercial	Australia	Electricity	Direct Fuels
	Lighting	24%	0%
	Hot water	2%	14%
	HVAC - central	44%	39%
	Appliances	30%	47%

Determine and apply segmentation

The barrier data was sourced from ABS[14], and used the 2013-14 figures held constant over time.

Residential barriers

A. Split incentives (tenanted areas)
Proportion of households with characteristic: 'Tenure and landlord type: *Renter, Private landlord.'*

B. Capital (low income households).
Proportion of households with the following characteristics: 'Equivalised disposable household income: *Lowest quintile'* and subtracting 'Tenure and landlord type: *Renter, State/territory housing authority'*

	Barrier A	Barrier B
	Split incentives	**Capital**
State	**%**	**%**
NSW	25.5%	21.0%
VIC	24.7%	21.6%
QLD	30.0%	21.9%
SA	21.9%	20.3%
WA	24.5%	16.4%
TAS	18.9%	27.1%
NT	30.3%	4.8%
ACT	23.5%	4.2%

Commercial barriers

- Using a business exit rate of 12%, informed by ABS[15] data. [8165.0 - Counts of Australian Businesses, including Entries and Exits, Jun 2011 to Jun 2015]

[14] ABS, 2015, 4130.0 - Housing Occupancy and Costs, 2013-14. Available at: http://www.abs.gov.au/ausstats/abs@.nsf/mf/4130.0

[15] ABS, 2015, 8165.0 - Counts of Australian Businesses, including Entries and Exits, Jun 2011 to Jun 2015. Available at: http://www.abs.gov.au/ausstats/abs@.nsf/mf/8165.0

Drivers of electrification

The key economic factors that drive the rate of electrification are the capital costs, discount rate, turnover rate, energy consumption and end user energy costs. The assumptions are listed here:

Capital costs
The capital cost of appliances used in the financial analysis are as follows. These prices are assumed to include installation.

Source: CWA analysis

Appliance	Gas	Electric
Hot water	$3,070, constant	$3,916 in 2015, linear drop to $2,327 in 2050
HVAC (constant 2015-2050)	$1,836	$5,328

Discount rate

Sector	Value	Rationale
Residential	5.5%	Home loan rate
Commercial	10%	Typical weighted average cost of capital for businesses

Turnover rate of appliances
Hot water systems and HVAC appliances are assumed to be turned over every **15 years** due to equipment failure.

Energy consumption

Appliance		Gas	Electric
Hot water		11,400 MJ, constant	1,664 kWh in 2015, linear drop to 989 kWh in 2050
HVAC Constant 2015-2050	NSW	25,613 MJ gas + 69 kWh electricity	1,270 kWh
	SA	15,497 MJ gas + 38 kWh electricity	703 kWh
	VIC	45,853 MJ gas + 235 kWh electricity	1,429 kWh

Source: ATA[16]; Table 7-13: Annual RC Air Con Energy Use by Climate Location & Household Scenario.

End user energy costs
Gas prices depend on the customer type and State location. However, the price that end users pay for electricity is also determined according to whether the user has adopted solar or a solar + battery bundle. Gas and electricity tables are provided below.

Recognising the misalignment of electricity production from rooftop solar PV and consumption of appliances, the electricity cost incorporates a proportion of electricity purchased from the grid. As for HVAC, 90% is assumed to be purchased using grid electricity for premises with solar and 80% for premises with solar + battery. The ratio for hot water systems is much higher (20%) because we assumed that these can be more easily be controlled to coincide with times of peak solar production.

<u>Gas</u>

Gas price, c/MJ										
Scope	**State**	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Commercial	NSW	c/MJ	2.79	3.85	3.94	4.06	4.21	4.42	4.68	5.04
Commercial	NT	c/MJ	3.35	4.22	4.32	4.48	4.61	4.82	5.05	5.37
Commercial	QLD	c/MJ	3.35	4.22	4.32	4.48	4.61	4.82	5.05	5.37
Commercial	SA	c/MJ	3.82	5.04	5.12	5.23	5.36	5.54	5.78	6.09
Commercial	TAS	c/MJ	2.78	3.71	3.78	3.89	4.01	4.18	4.40	4.69
Commercial	VIC	c/MJ	1.25	1.91	1.99	2.12	2.25	2.44	2.67	2.99
Commercial	WA	c/MJ	2.81	2.97	2.92	3.07	3.21	3.39	3.64	3.96
Residential	NSW	c/MJ	4.02	4.91	5.00	5.12	5.27	5.48	5.74	6.10
Residential	NT	c/MJ	4.45	5.12	5.22	5.38	5.51	5.72	5.96	6.27
Residential	QLD	c/MJ	4.45	5.12	5.22	5.38	5.51	5.72	5.96	6.27
Residential	SA	c/MJ	4.47	5.43	5.51	5.62	5.75	5.93	6.17	6.48
Residential	TAS	c/MJ	3.36	4.41	4.48	4.59	4.71	4.88	5.10	5.39
Residential	VIC	c/MJ	1.84	2.50	2.58	2.71	2.84	3.03	3.26	3.58
Residential	WA	c/MJ	3.86	3.95	3.90	4.05	4.19	4.37	4.62	4.94

NB: NT marked in grey to reflect we have assumed QLD prices due to lack of data

[16] ATA, 2014, Are we still cooking with gas? Available at: http://www.ata.org.au/wp-content/projects/CAP_Gas_Research_Final_Report_251114_v2.0.pdf

Attribution of energy use to different costs

Electricity

Electricity Price, Retail, $/kWh										
State	Scope	Unit	2015	2020	2025	2030	2035	2040	2045	2050
NSW	Residential	$/kWh	0.22	0.25	0.28	0.30	0.33	0.38	0.39	0.41
NT	Residential	$/kWh	0.24	0.18	0.19	0.22	0.18	0.22	0.24	0.25
QLD	Residential	$/kWh	0.27	0.26	0.27	0.30	0.30	0.36	0.36	0.36
SA	Residential	$/kWh	0.23	0.25	0.28	0.30	0.34	0.35	0.33	0.35
TAS	Residential	$/kWh	0.23	0.26	0.28	0.30	0.24	0.30	0.33	0.33
VIC	Residential	$/kWh	0.20	0.24	0.27	0.31	0.29	0.34	0.32	0.33
WA	Residential	$/kWh	0.21	0.21	0.22	0.25	0.30	0.27	0.30	0.31
NSW	Commercial	$/kWh	0.21	0.36	0.39	0.46	0.54	0.68	0.67	0.70
NT	Commercial	$/kWh	0.10	0.18	0.20	0.23	0.27	0.34	0.34	0.35
QLD	Commercial	$/kWh	0.12	0.21	0.23	0.27	0.31	0.39	0.39	0.41
SA	Commercial	$/kWh	0.07	0.13	0.14	0.17	0.20	0.25	0.24	0.25
TAS	Commercial	$/kWh	0.15	0.27	0.29	0.34	0.40	0.50	0.50	0.52
VIC	Commercial	$/kWh	0.17	0.30	0.33	0.39	0.45	0.57	0.56	0.59
WA	Commercial	$/kWh	0.12	0.21	0.23	0.28	0.32	0.40	0.40	0.42

Electricity price, Solar, $/kWh										
State	Scope	Unit	2015	2020	2025	2030	2035	2040	2045	2050
NSW	Residential	$/kWh	0.13	0.10	0.07	0.07	0.10	0.08	0.08	0.08
NT	Residential	$/kWh	0.11	0.09	0.06	0.06	0.09	0.07	0.07	0.07
QLD	Residential	$/kWh	0.12	0.09	0.07	0.07	0.09	0.08	0.07	0.07
SA	Residential	$/kWh	0.12	0.09	0.07	0.07	0.09	0.08	0.07	0.07
TAS	Residential	$/kWh	0.15	0.12	0.09	0.09	0.11	0.09	0.09	0.09
VIC	Residential	$/kWh	0.15	0.11	0.09	0.09	0.11	0.09	0.09	0.09
WA	Residential	$/kWh	0.11	0.09	0.06	0.06	0.09	0.07	0.07	0.07
NSW	Commercial	$/kWh	0.10	0.08	0.06	0.06	0.09	0.07	0.07	0.07
NT	Commercial	$/kWh	0.09	0.07	0.05	0.05	0.08	0.06	0.06	0.06
QLD	Commercial	$/kWh	0.10	0.07	0.05	0.05	0.08	0.07	0.07	0.06
SA	Commercial	$/kWh	0.10	0.07	0.05	0.05	0.08	0.07	0.07	0.06
TAS	Commercial	$/kWh	0.13	0.10	0.07	0.07	0.10	0.08	0.08	0.08
VIC	Commercial	$/kWh	0.12	0.09	0.07	0.07	0.09	0.08	0.08	0.07
WA	Commercial	$/kWh	0.09	0.07	0.05	0.05	0.08	0.06	0.06	0.06

Electricity price, Solar + battery, $/kWh										
State	Scope	Unit	2015	2020	2025	2030	2035	2040	2045	2050
NSW	Residential	$/kWh	0.22	0.17	0.14	0.13	0.16	0.14	0.13	0.13
NT	Residential	$/kWh	0.20	0.15	0.12	0.12	0.14	0.12	0.12	0.12
QLD	Residential	$/kWh	0.21	0.16	0.13	0.12	0.15	0.13	0.12	0.12
SA	Residential	$/kWh	0.21	0.16	0.13	0.12	0.15	0.13	0.12	0.12
TAS	Residential	$/kWh	0.26	0.20	0.16	0.16	0.17	0.15	0.15	0.14
VIC	Residential	$/kWh	0.25	0.19	0.16	0.15	0.17	0.15	0.14	0.14
WA	Residential	$/kWh	0.20	0.15	0.12	0.12	0.14	0.12	0.12	0.12
NSW	Commercial	$/kWh	0.20	0.15	0.12	0.12	0.14	0.13	0.12	0.12
NT	Commercial	$/kWh	0.18	0.13	0.11	0.10	0.13	0.11	0.11	0.11
QLD	Commercial	$/kWh	0.19	0.14	0.11	0.11	0.13	0.12	0.12	0.11
SA	Commercial	$/kWh	0.19	0.14	0.11	0.11	0.13	0.12	0.12	0.11
TAS	Commercial	$/kWh	0.23	0.18	0.14	0.14	0.16	0.14	0.14	0.13
VIC	Commercial	$/kWh	0.23	0.17	0.14	0.14	0.16	0.14	0.13	0.13
WA	Commercial	$/kWh	0.18	0.13	0.11	0.10	0.13	0.11	0.11	0.11

Apply “Electrification Factors”’

Share of premises with grid, solar or solar + battery

The percentage of premises assumed to have rooftop solar, and therefore pay the associated electricity price, are shown in the tables below. These have been calculated from AEMO 2016 NEFR projections, extended to 2050 by continuing historic trends.

One in five (20%) of premises with Solar are assumed to have a solar + battery storage bundle.

Rooftop Solar PV generation as % of total GWh for Residential

State	2015	2020	2030	2040	2050
NSW	6%	8%	14%	18%	20%
QLD	14%	18%	29%	32%	33%
SA	19%	23%	30%	30%	30%
TAS	5%	8%	17%	23%	25%
VIC	8%	11%	20%	24%	24%
WA	3%	5%	9%	14%	21%

Rooftop Solar PV generation as % of total GWh for Commercial

State	2015	2020	2030	2040	2050
NSW	0%	1%	4%	5%	7%
QLD	0%	1%	3%	5%	8%
SA	1%	2%	8%	10%	12%
TAS	0%	0%	1%	1%	2%
VIC	0%	1%	3%	4%	6%
WA	3%	5%	9%	14%	21%

Appliance turnover rate

Hot water systems and HVAC appliances are assumed to be turned over every 15 years due to equipment failure. Therefore the modelling specifies that 6.7% (1/15) of energy consumption in each year to be eligible for switching.

Note on HVAC electrification factors

Comparable HVAC energy consumption figures were only available for NSW, SA and VIC. The calculations determined that an electric appliance was already cost effective in all of these states, regardless of alternative electricity prices - as a result the electrification factors are the same in all states. Because of this we determined that it would be reasonable to use these factors for other states, where data was not available.

Energy use after electrification

For energy consumption switched from gas to electricity, the following values were used for Coefficient of Performance (CoP) to account of the increased efficiency of electric appliances.

CoP - Unit of heating output per unit of energy input	**From 2015 to 2030**	**2030 onwards**
Hot water systems	2.5	4
HVAC	3	7

The rebound effect of switching to more energy efficient electric appliances assumed to be an increase in electricity consumption of **20%** of the energy savings based on mid-range of reviewed literature (for example SKM MMA[17]).

The following conservation load factors were used to determine the impact on peak demand from increased consumption.

	Residential		**Commercial**	
Equipment	**Summer**	**Winter**	**Summer**	**Winter**
HVAC	N/A	0.79	N/A	1.5
Hot Water Systems	2.08	0.64	34 MW/PJ*	59 MW/PJ*

* Note: CLFs for commercial Hot water systems were not provided, these figures were used. These are sourced from EMET[18] (that was used to inform the Langham et al. 2010 report).

An extract from Langham, et al. (2010) "For an energy conservation measure impacting an end-use application with a flat base load shape the CLF is high (i.e. close to 1). This indicates that the peak demand reduction resulting from the energy conservation measure is close to the average demand reduction across the year. A refrigerator for example has, typically, a CLF of around 0.8. On the other hand, for energy conservation measures applying to a peaky end-use technology, the CLF is lower. A conservation measure applied to air-conditioners, which are peak coincident end use, will result in large peak demand savings during hot summer days relative to the energy saved. The CLF for air-conditioners is typically below 0.3. Note also that the CLF may exceed 1 if a conservation measure saves energy mostly during off-peak periods."

$$CLF = \frac{\frac{Annual\ energy\ savings\ (MWh)}{8760\ hours}}{Peak\ demand\ reduction\ (MW)}\ for\ electricity$$

$$CLF = \frac{\frac{Annual\ energy\ savings\ (GJ)}{365\ days}}{Peak\ demand\ reduction\ \left(\frac{GJ}{day}\right)}\ for\ natural\ gas$$

[17] SKM MMA, 2013, Assessment of Economic Benefits from a National Energy Savings Initiative, Final Report. Available via: www.industry.gov.au/Energy/IndustrialEnergyEfficiency/NationalEnergySavingsInitiative/Pages/ConsultantReports.aspx

[18] EMET Consultants, 2004, The IMPACT of COMMERCIAL AND RESIDENTIAL SECTORS' EEIs on ELECTRICITY DEMAND; SUSTAINABLE ENERGY AUTHORITY OF VICTORIA.

Industrial

The following table provides the sector assignment between that used in the Deep Decarbonisation Pathway Project and Office of the Chief Economist data.

Sector (DDPP)	***Comparable ANZIC code from OCE Table F-1***
Alumina	*213-214 Basic non-ferrous metals*
Gas mining	*07 Oil and gas extraction*
Non-ferrous metal ores	*08-10 Other mining*
Non-metallic construction materials (not cement)	*20 Non-metallic mineral products*
Other food and drink products	*11-12 Food, beverages and tobacco*
Other mining	*08-10 Other mining*
Paper products	*15-16 Pulp, paper and printing*

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Published by ClimateWorks Australia
Melbourne, Victoria, September 2016

ISBN 978-0-9941725-3-2