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# ACT Transition to Net Zero Emissions – Stationary Energy/Buildings

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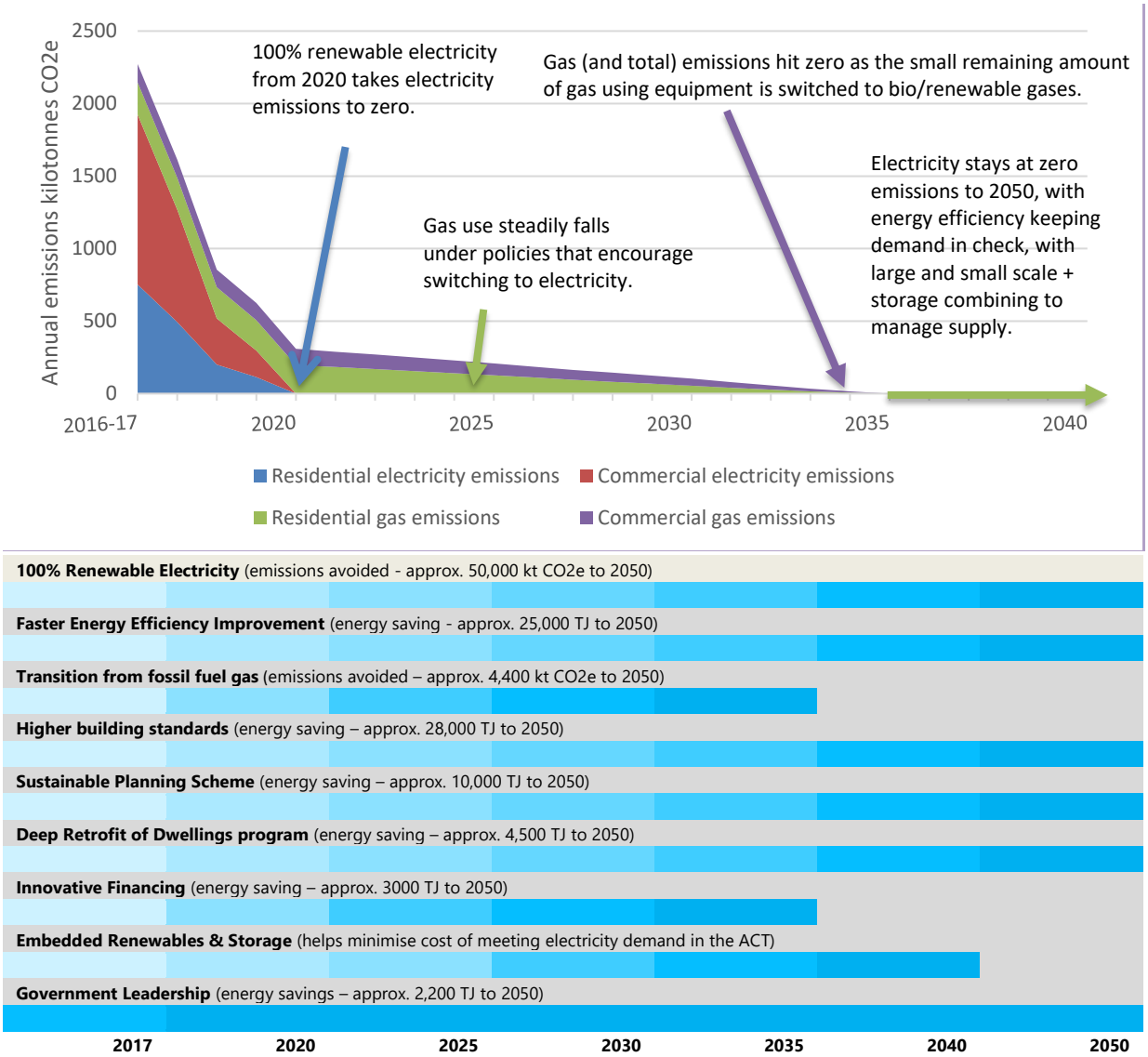
# Executive Summary

This Report aims to assist the ACT to determine how soon it would be feasible to attain net zero greenhouse gas emissions in the stationary energy sector and built environment. Our central policy case indicates that 2035 is a technically feasible date for zero emissions in this sector, but it could be as early as 2030 if stronger policies to eliminate the use of fossil methane (natural gas) are pursued - see Figure 1 below.[1] Note that the colour transitions in the Gantt chart below indicate an expectation of a progressive evolution in policy settings over time, as discussed in Chapter 5.

### Figure 1: ACT Stationary Energy Emissions Mid Policy Scenario - Zero Emissions by 2035




[1] We recommend that further analysis, including benefit cost analysis, is undertaken to identify the optimal suite and timing of policies and measures and to confirm the optimal date for reaching zero carbon emissions.

### *Key Issues*

The date at which the ACT's buildings and stationary energy sector could reach zero emissions is a function of just three major factors:

- the rate of growth in demand for energy services
- reaching and maintaining 100% renewable electricity supply (including with rising electricity demand)
- the rate of fuel switching from gas (and liquid fuels used for transport) to electricity or other renewable sources.

All three can be influenced by policy measures.

- ***Energy Services Demand***

The demand for energy services in the ACT – like lighting, heating, cooling and mobility – will firstly be driven by external factors (covered in our reference scenarios) such as:

- how rapidly the population and the economy grow (tending to push up energy service demand)
- national policy settings (a continuation of weak policy settings will tend to drive up demand; stronger settings would reduce it).

In addition, the demand for energy services will reflect the extent to which the ACT pursues ambitious energy efficiency policies, such as higher building energy performance standards, deep retrofits for the existing housing and building stock, and innovative incentives. This includes the extent to which the ACT builds on and strengthens existing measures, including the Energy Efficiency Incentives Scheme (EEIS). Efficiency improvements will:

- reduce pressure on (and the cost of) maintaining 100% renewable electricity cover
- offset other sources of increasing electrical demand, such as electric vehicles and fuel switching away from gas
- reduce costs for businesses and households
- improve equity for vulnerable households
- deliver greater resilience to extreme climate events, such as prolonged heatwaves.[2]

- ***100% Renewable Electricity***

Maintaining 100% renewable energy cover for electricity demand is critical to the ACT achieving and maintaining zero carbon emissions in the stationary energy sector.

Even with stronger energy efficiency policies, factors like the switch to electric vehicles and light rail (which is built into our reference scenarios) and fuel switching away from fossil methane – on top of factors like economic and population growth – may push up total (and potentially peak) demand for electricity. The ACT needs to ensure that its policy environment encourages local renewable energy investment and also delivers

[2] We use the term 'climate resilience' to refer to the intended outcome of adaptation to climate change. In practice, the terms 'resilience' and 'adaptation' are often used interchangeably.

sufficient flexibility in renewable electricity procurement to be able to accommodate possible demand (and peak demand) growth.

- ***Fuel Switching***

Fossil methane (natural gas) accounts for some 10% of current greenhouse gas emissions in the ACT, and there is a small additional consumption of LPG. As these are fossil fuels, their use will need to be phased out, or else offset, or potentially replaced by renewable gases – or some combination of these – in order to reach zero emissions.

Gas prices are generally rising in Australia, although the ACT has some of the lowest gas prices in Australia. This makes it less economic to switch away from gas. However, in some sectors like residential space heating, the switch to heat pumps is well underway and likely to continue, as the efficiency of these devices continues to increase and costs continue to fall. If distortions in building regulations that favour gas hot water are removed, as we recommend, then residential gas consumption – particularly for new houses – could fall quickly.

Also, as individual gas users reduce their consumption, the cost of connection to the gas network will become a rising share of their total costs, creating an incentive to switch away from gas altogether to avoid the connection cost. Similarly, for the increasing number of households and businesses with solar roofs, it is more valuable for these consumers to use their own generation, rather than to use gas and export surplus solar energy to the grid. The progressive rollout of batteries in households and businesses will extend the ability of consumers to cover their own electrical demand, and further reduce the incentive to use gas.

It is also necessary to consider the gas network perspective. As demand falls – whether from rising prices, technological change and/or policy incentives – the economics of operating and maintaining the gas distribution network will deteriorate. This could lead to rising prices, which may further curtail demand, or – at some point – trigger a need to shift to a different solution. This could include tanker/bottled delivery – although at a cost premium to the user, and without solving the greenhouse emission issue – or else moving to renewable gases, such as hydrogen or biomethane, if these present feasible and cost-effective solutions.

Overall, we can expect market forces to do some but not all of the work of phasing out the use of fossil fuel gases in the ACT. Some users will need incentives, or other policy measures, to induce them to switch, for example those who may have invested only recently in gas-using equipment, or those who have particular heat requirements.

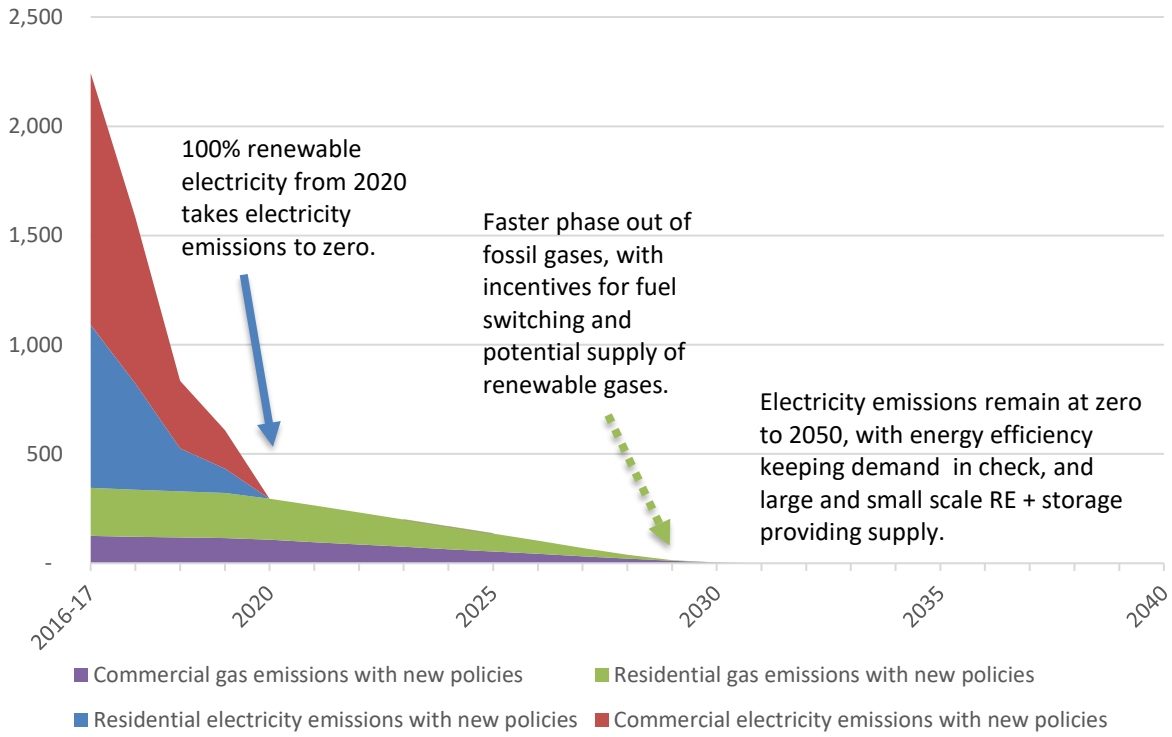
Unfortunately, there is little information in the public domain to understand who are the larger users of gas in the ACT, which energy service needs are being met with gas and why, what feasible substitution possibilities exist, how cost effective they are, and what transition issues may arise and require management. We therefore recommend that two key studies are undertaken, working closely with the gas sector:

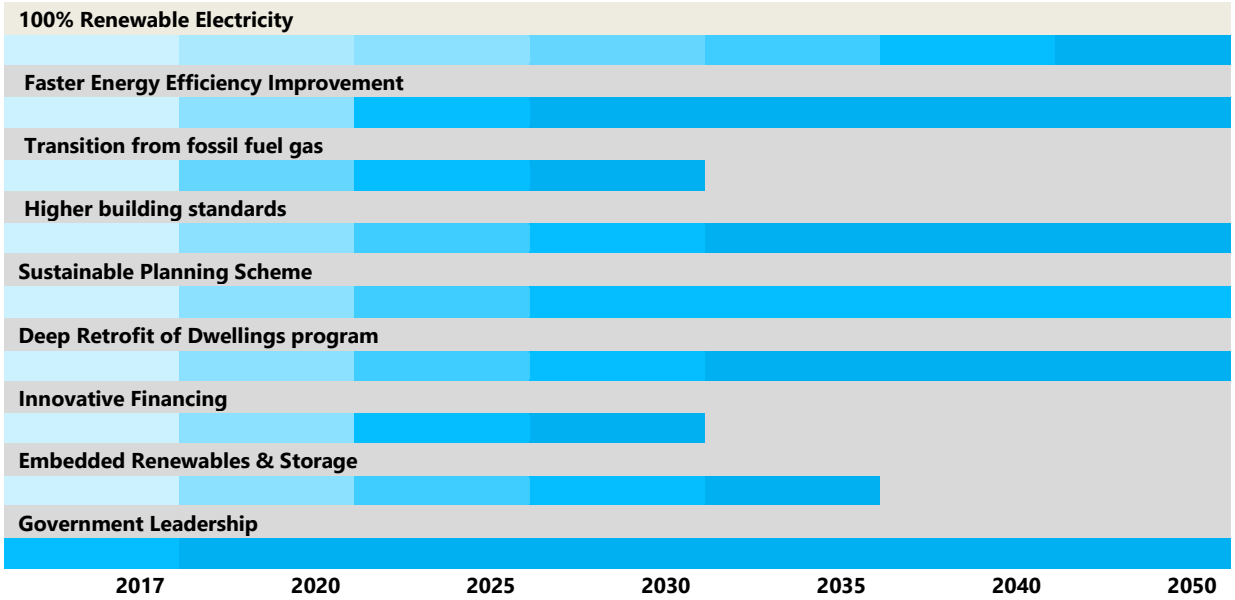
1. A detailed study of gas use in the ACT, focusing on larger commercial and (light) industrial users in particular – with the aim of understanding substitution possibilities and economics, and the feasible timing of switching;
2. A study of renewable gas supply (including generation and delivery) options in the ACT, their suitability for meeting customer demands (as mapped in study #1) and the cost effectiveness of those options from the customer's perspective, relative to other fuel switching options, including renewable electricity.

### *Zero Emissions by 2030?*

Our 'low emissions with policies' scenario indicates that the stationary energy sector in the ACT could reach zero emissions by 2030, and indeed it may be possible to reach that target even earlier – see Figure 2 below.

**Figure 2: Low Emissions Scenario - Stationary Energy Emissions with Policies, Reaching Zero Emissions by 2030**



Whether 2030 or 2035 is a feasible date for zero stationary energy emissions will depend upon the outcomes of the research projects recommended above, which together will enable the optimal transition path away from fossil gas consumption to be identified.

### *Reference Scenarios*

To put these issues into context, we briefly review the reference projections for stationary energy demand and greenhouse gas emissions in the ACT to 2050. In this report, we describe three reference scenarios:

- Low emissions (associated with higher ambition in national policies, and/or lower ACT population and economic growth than expected)
- Medium emissions (expected national policy settings and ACT growth rates)
- High emissions (lower than expected ambition in national policies, and/or higher than expected ACT population and economic growth).

Population growth is assumed to average 1.5% per annum in the medium case, and 0.9% and 2.3% per annum in the low and high cases respectively. Based on historical trends, economic growth (gross state product) is assumed to average 1.5 times the population growth rate in the medium case, and 0.25% points higher or lower in the other cases.

Other key assumptions are that the ACT's target of 100% renewable electricity supply is met and that this 100% cover is maintained through to 2050. This is fundamental to achieving a zero-carbon economy, however there are choices to be made about how this is to be achieved – for example, through accelerated energy efficiency improvements, additional rooftop or local solar, or additional purchases of remotely-generated renewable electricity. These are discussed further below.

Our scenarios anticipate an increasing demand for electricity for light rail and for a progressive uptake of electric vehicles. For the reference scenarios, we do not assume any production or use of renewable gases, although these are examined in policy scenarios. Overall, as discussed above, we expect considerable fuel switching away from gas, even without new policy incentives.

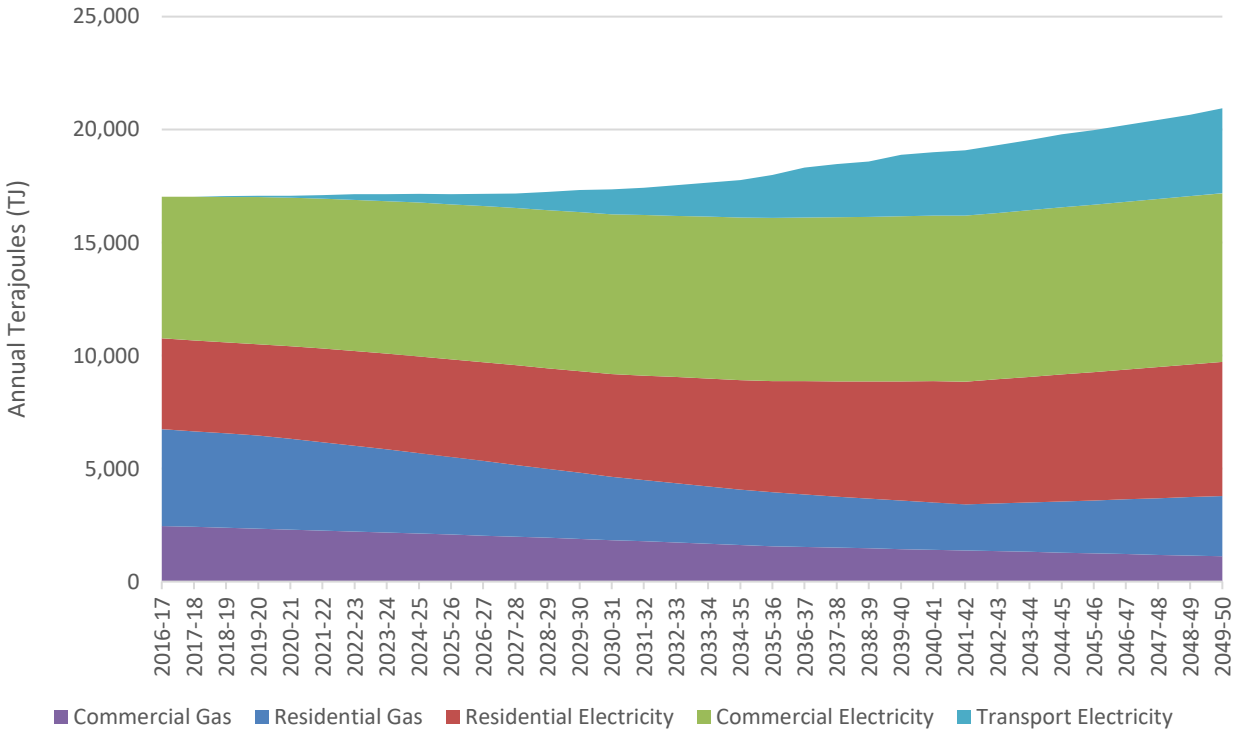
Finally, our reference scenarios assume some, albeit modest, progress in national emissions policy, including modest increases in the stringency of energy performance requirements in the National Construction Code and in energy performance standards for equipment and appliances.

- ***Reference Energy Demand***

Figure 3 below shows that, in the medium reference scenario, total energy consumption is projected to rise by 23%, or around 3.9 PJ, by 2050. This reflects the combined effect of an increasing population and economic activity, rising electricity demand for transport purposes (electric vehicles and light rail), but also switching from gas to electricity for space heating and other uses. The demand growth is offset by energy efficiency improvements driven by existing national policies (National Construction Code, minimum energy performance standards and labelling), existing ACT policies (eg, Energy Efficiency Incentive Scheme) and market-driven technological progress. Overall, the rate of growth in energy demand is less than half that of the rate of population growth (49% by 2050), and less than one third of the rate of economic growth (82% by 2050) in the mid-reference scenario, indicating that there is already significant decoupling of energy demand from these other growth drivers. Note that we model real demand for energy services, so the

contribution that rooftop PV makes to meeting demand is not counted in this Figure – rather, we treat rooftop PV as part of the energy supply.

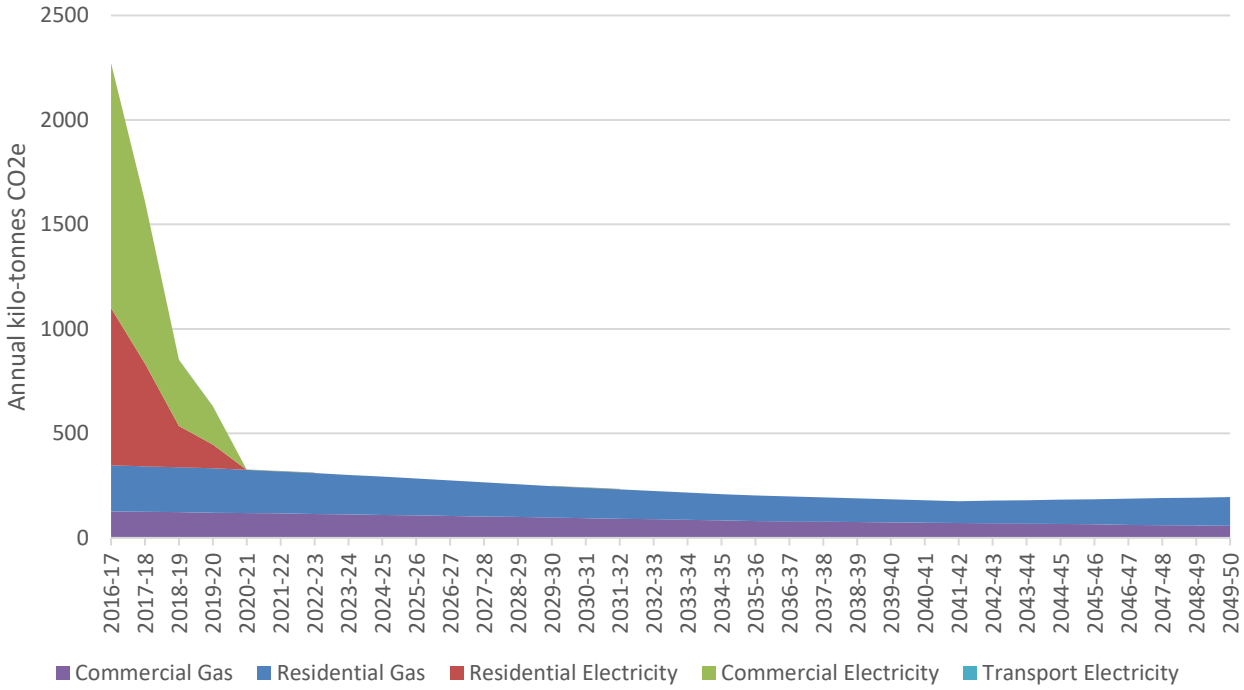
**Figure 3: Total Stationary Energy (and electric transport) Demand, ACT, Medium Reference Scenario, by Sector and Fuel**




- **Greenhouse Gas Emissions**

The outlook for greenhouse gas emissions in the reference scenarios is quite different from that for energy demand, due in large part to the expected achievement of 100% renewable electricity by 2020 – see Figure 4 below. This causes electricity related emissions to fall dramatically, as electricity moves from being the largest source of emissions in the ACT to none at all. As a result, emissions after 2020 are dominated by gas consumption in the residential and commercial sectors. As noted, we also assume further reductions in emissions associated with gas use due to fuel switching, even without policy incentives.

**Figure 4: Stationary Energy (and electric transport) Greenhouse Gas Emissions by Sector and Fuel, Medium Reference Scenario**




### *Further Abatement Potential*

While there is uncertainty about the rate at which particular technological break-throughs will occur, the effort to reduce greenhouse gas emissions – while accommodating high and rising living standards – is now truly global. The potential for further emissions abatement is therefore very large and growing all the time. This analysis explores the 'outer edge' of abatement potential, unconstrained by cost effectiveness considerations. As a result, not all of the abatement potential indicated will be cost effective in the short term, but the frontier of cost effective abatement is also being pushed out continually by research and economies of scale.

The analysis in this document (see Chapter 4 for details) is summarised by the charts shown below (Figure 5 and Figure 6). The figures are expressed as indices of energy use by end-use type per building, to facilitate comparison of the rate of change over time, starting from current ACT averages.

The charts indicate that, since there is a gap, on average, between current practices in the ACT and 'best available' technologies and practices, the potential exists, at least in principle, for rapid abatement by switching to best available technologies. Assuming that were to occur then, after that, the rate of change in abatement potential would slow down, reflecting the rate at which the 'frontier' of best practice improves globally. This is expected to vary for different technologies.

For example, the charts show that the greatest scope for improvement lies with on-site renewable energy generation storage, and secondly with heating, ventilation and air conditioning (HVAC), and heat pump technologies in particular. Note that the charts show potential per-building improvement in energy performance relative to 2015. The data is presented in energy units to avoid confusion with underlying changes in emissions intensity of energy use. If expressed in greenhouse emission units, the rate of reduction

would be even greater than shown below, due to rapidly falling greenhouse intensity of electricity use in the ACT.

In the residential sector, it would be possible to reduce per-building energy use by between 30% and 90%, depending upon the energy end-use, even by 2020, by adopting best available technologies. After 2020, the different technologies show further potential for improvement, in the 50% to 95% range by 2050. In the commercial sector, the same general pattern is evident, as the underlying technologies – LED lighting, very high-performance heat pumps, solar photovoltaics and storage – are similar.

**Figure 5: ACT Abatement Potentials – Residential Sector (index of energy use per dwelling)**

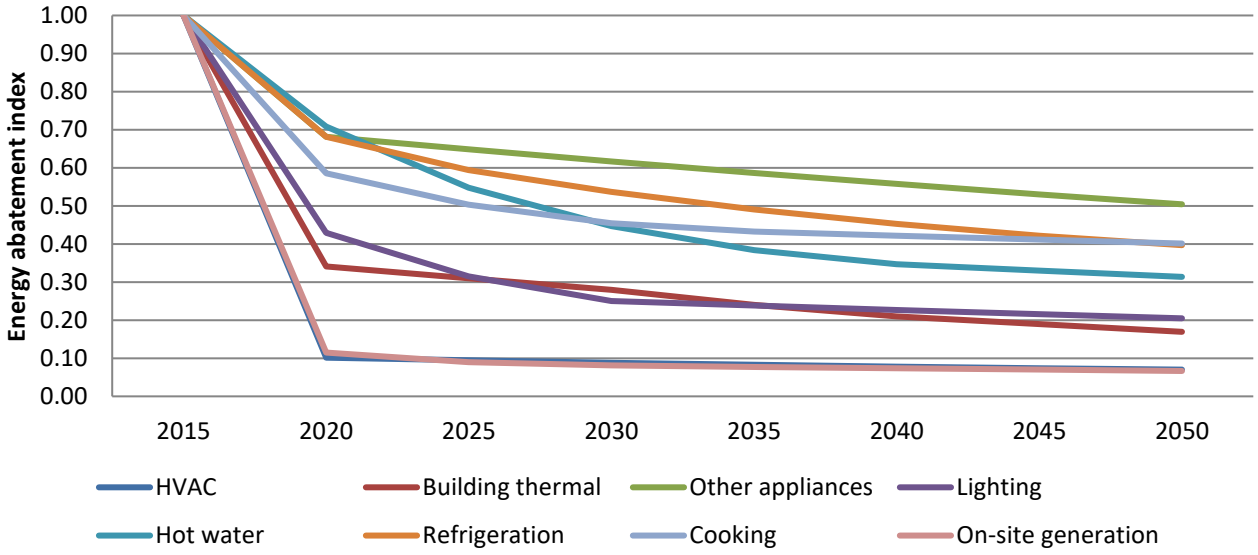
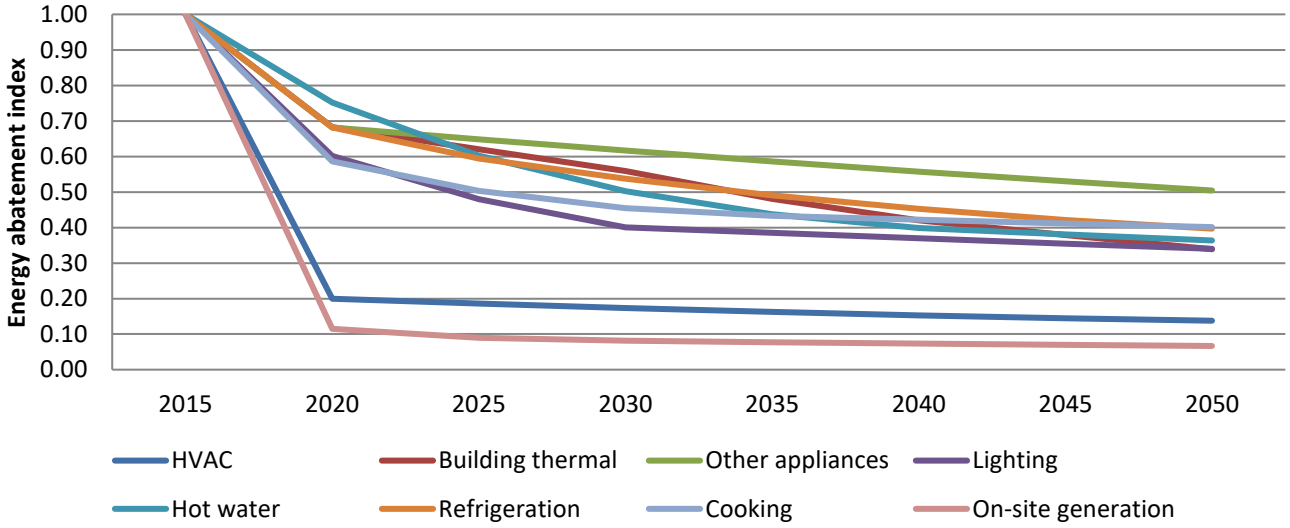



**Figure 6: ACT Abatement Potentials – Commercial Sector (index of energy use per building)**



In Chapter 4 we also examine the potential for technologies that may not currently be cost effective, including renewable gases such as biomethane and hydrogen, related technologies such as fuel cells, and a range of fuel delivery pathways, such as injecting hydrogen into methane supplies, or using hydrogen carriers such as ammonia. Some these options are being researched and promoted by major corporations and countries around the world, and the relative costs and performance of different technology pathways can change. We recommend that the ACT remains as flexible and technology-neutral as possible, with the overall aim of achieving and maintaining a zero-emission economy at the lowest possible cost.

### *Policy Potentials*

While the reference scenarios indicate the likely paths of emissions without new ACT policies, and the abatement potential scenarios above indicate what could theoretically be achieved, the policy scenarios below indicate the degree to which it is feasible, or likely, that different policies could reduce emissions from those shown in the reference case, including by inducing a faster rate of take-up of the abatement potential.

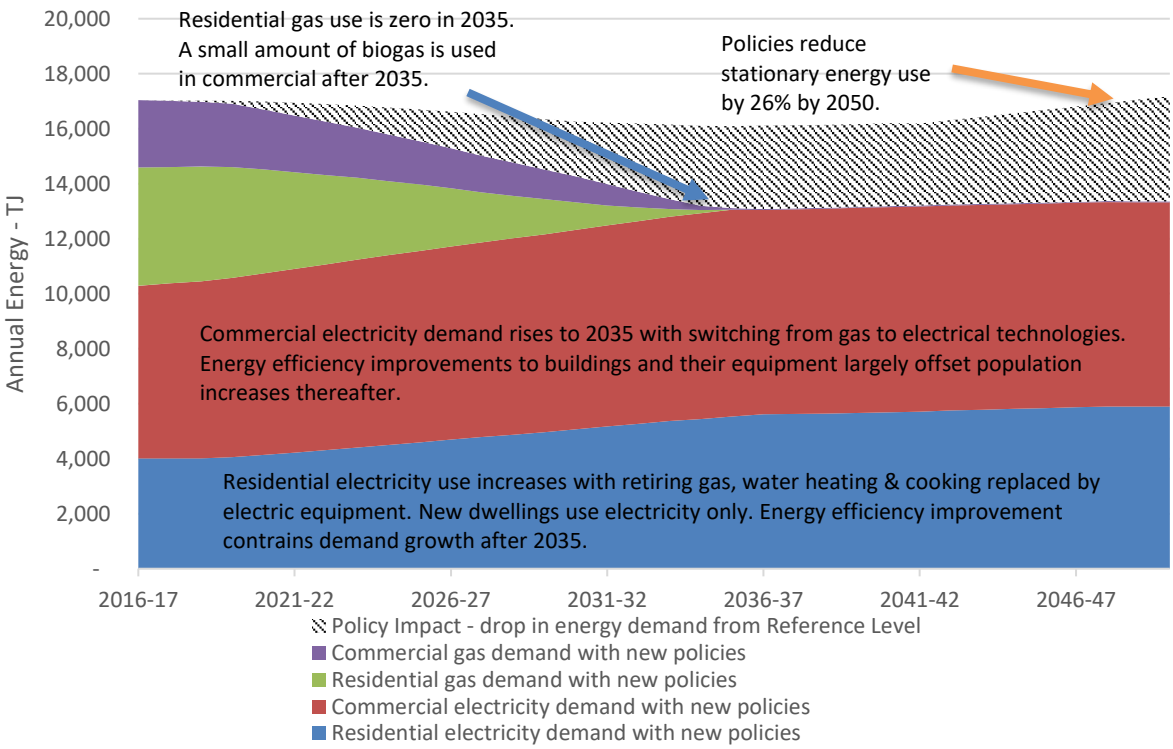
Key policy measures modelled in Chapter 5 include:

- **100% renewable electricity** – maintaining the commitment to 100% renewable electricity cover, including as electrical demand rises due to fuel switching.
- **Fuel switching from fossil fuels** – to renewable electricity and potentially renewable gases.
- **Building code** – lifting building requirements above the conservative settings in the National Construction Code is a key opportunity to reduce energy use, peak demand, energy costs and emissions in the building stock, while also improving thermal comfort and climate resilience.
- **Energy efficiency improvement** – a tailored incentives scheme is used to incentivise the uptake of high efficiency equipment and appliances; deep building retrofits (below); and fuel switching
- **Deep housing retrofits** – a number of policies and programs could target deep retrofits for houses that are unlikely to be retrofitted in the normal course of events, including low-income and tenanted dwellings. This would improve thermal comfort and climate resilience; reduce energy stress or poverty for low-income households; and also reduce the call on renewable energy PPAs to cover electricity demand. Measures could include minimum standards for rental properties, expansion of the Energy Efficiency Incentives Scheme or other targeted measures. These measures could also target the replacement of natural gas with (renewable) electricity.
- **Sustainable planning scheme** – to engender long term reductions in the emissions-intensity of ACT development, including encouraging more compact urban form, reducing urban heat island effect, avoiding the rollout of additional gas infrastructure, and accommodating more flexible working/living environments.
- **Innovative financing** – to provide market-based assistance to achieving the zero carbon goals, particularly where the required investments are cost effective and only require modest assistance.
- **Embedded renewables & storage** – while remote PPAs may be more cost effective, locally embedded renewables and storage will deliver important security and reliability outcomes, improved climate resilience, as well as improving social equity by targeting assistance to low income households.

- **Government Leadership** – government needs to set the example by procuring zero emissions buildings, vehicles and services; and by investing in high efficiency and climate resilient infrastructure, including LED traffic and street lights.

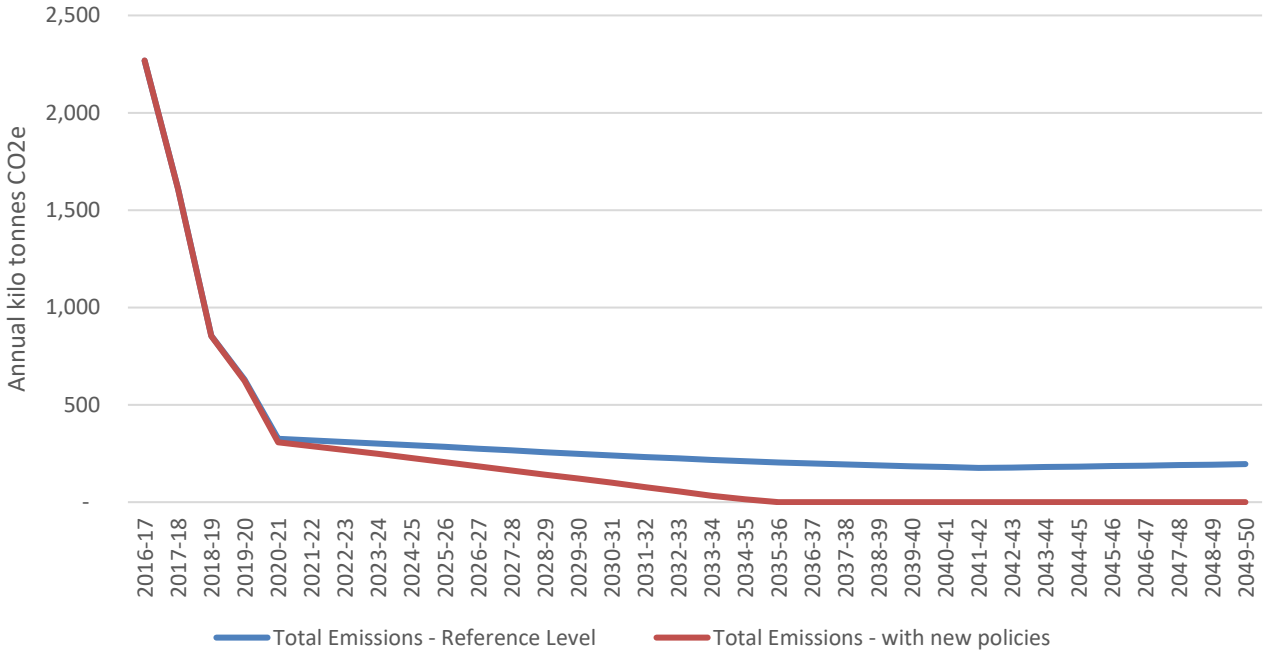
Overall, the effect of the modelled policies is to reduce energy demand in 2050 by around 26% in the medium scenario, as shown in Figure 7 below.

**Figure 7: Projected New Policy Impact and Remaining Stationary (non-transport) Energy Demand by Source and Sector, Medium Scenario**




The policy measures would enable the ACT to achieve zero emissions by 2035 in the medium scenario – see Figure 8.

**Figure 8: Stationary (non-transport) Greenhouse Gas Emissions With/Without New ACT Policies, Medium Scenario**




Note that similar figures for the low and high scenarios are shown at Figure 33 and Figure 36. We note that the differences between these scenarios are relatively small for, in the presence of 100% renewable electricity, total stationary emissions in the ACT are dominated by a single factor – the timing of phase out of fossil methane.

### *Comparison of Scenarios*

Figure 9 and Table 1 below provide succinct summaries of the scenarios modelled, while more details on each scenario can be found in the body of the report.

The high, medium and low reference scenarios differ only marginally when viewed in emissions terms, because the emissions associated with electricity consumption in each case are assumed to be zero from 2020 onwards, in line with existing ACT policy. Table 1 below shows that, despite this, total energy use in the three scenarios is significantly different, reflecting differing rates of economic and population growth and differences in the national policy environment.

For the 'with measures' scenarios – referring to new ACT Government measures – the primary difference between the scenarios is the timing of the phase out of fossil methane which, following the conversion of all electricity consumption to renewables by 2020, dominates stationary emissions thereafter. This date varies between 2030 and 2040, reflecting the strength and timing of ACT policy measures, overlaid on market effects (relative prices and differential rates of change in energy using product pricing and efficiency over time).

**Figure 9: ACT Stationary Energy Sector Greenhouse Gas Emissions by Scenario**

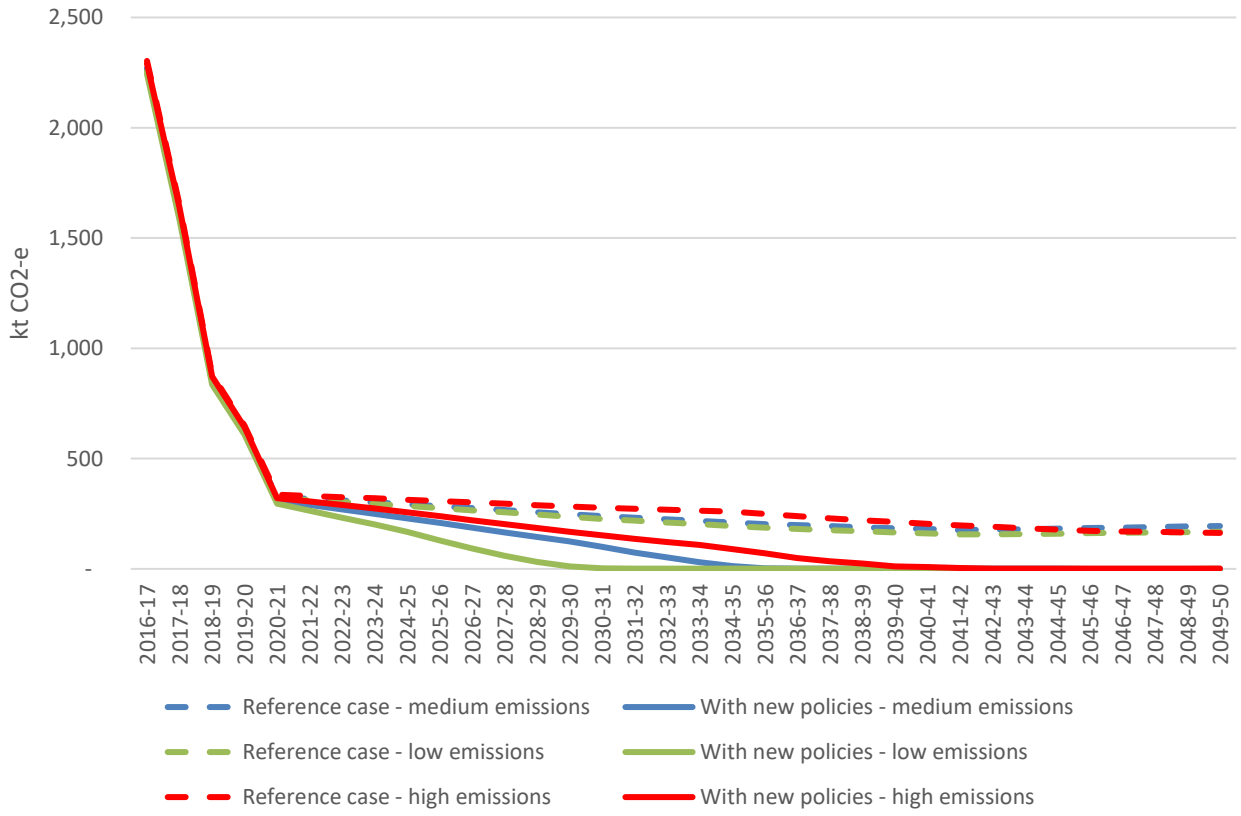



**Table 1: Energy and Emissions by Scenario – Selected Dates**

| Scenario | Energy in 2030 (TJ) | Energy in 2035 (TJ) | Energy in 2050 (TJ) | Emissions in 2030 (kt CO2e) | Emissions in 2035 (kt CO2e) | Emissions in 2050 (kt CO2e) |
|---|---|---|---|---|---|---|
| Reference - Medium | 16,322 | 16,181 | 17,171 | 239 | 204 | 195 |
| With New Policies - Medium | 14,294 | 13,076 | 13,369 | 100 | 0 | 0 |
| Reference - Low | 15,174 | 14,640 | 14,755 | 227 | 187 | 168 |
| With New Policies - Low | 12,055 | 12,496 | 11,819 | 0 | 0 | 0 |
| Reference - High | 18,667 | 19,483 | 23,107 | 277 | 249 | 258 |
| With New Policies - High | 16,901 | 16,843 | 18,045 | 136 | 73 | 0 |
| Transport Electricity - Reference Medium | 1,102 | 1,898 | 3,765 | 0 | 0 | 0 |

### *Conclusions and Recommendations*

- ***Zero emissions target date***

The ACT can attain zero emissions in the stationary energy sector by 2035, and it may also possible to reach that milestone by 2030 or potentially earlier.

The critical ingredients are:

- reaching and maintaining 100% renewable electricity
- promoting energy efficiency
- encouraging rapid switching away from the use of fossil gases.

Further research will be required to establish the feasible substitution possibilities for fossil gases, at the level of individual (larger) users, and the practicality and cost effectiveness of a range of renewable gas supply and distribution options. This process will require consultation with gas producers, distributors and customers.

- ***Detailed policy design***

This report outlines the policy measures that will enable the transition to zero emissions. Before the measures are finalised, we recommend that detailed benefit cost analysis is undertaken, to ensure that the least-cost choices are selected.

- ***Maximise ancillary benefits***

Policies such as 100% renewable electricity and zero emissions identify the ACT as a leader in this area. This is already bringing significant benefits beyond emissions reduction, such as investment, jobs and an enhancement of ACT's reputation as a centre of innovation and research capability. More broadly, education, construction, tourism, light manufacturing and transport sectors, are all more likely to thrive in conditions where sustainable innovation is incentivised. These benefits can be maximised through careful 'micro-design' of policies and effective communication of the ACT's strategic intent to major players such as technology providers.

- ***Maximise access to the benefits of a zero-carbon economy***

More energy efficient homes and buildings, solar energy, battery storage, electric transportation and other features of the zero-carbon economy offer significant financial benefits for households and businesses. They also offer benefits such as improved comfort, greater resilience to extreme climate events, and reduced morbidity and mortality. At the same time, the transition process requires investments that pay back over time. Those unable to access these benefits will be increasingly disadvantaged over time. It will therefore be important for ACT to design strategies and programs that enable everyone, including low income groups and tenants, to participate in and benefit from this transition.

- ***Integrate climate adaptation***

Climate projections indicate future increases in the extremity and frequency of heatwaves. Measures such as improving the thermal envelope of buildings, installing more efficient cooling systems, encouraging on-site generation and lower energy bills, paying attention to albedo effects, and reducing the 'urban heat island' will all contribute to healthier, cooler living conditions, as part of a wider climate adaptation program.

Opportunities such as the installation of PV panels to shade car parks and other public areas would help the ACT prepare for hotter weather, while delivering renewable energy benefits.

- ***Reform planning policy***

Planning regulations play a critical and often under-estimated role in shaping urban form over time, including its carbon- and energy-intensity. Planning can be a vehicle that encourages and supports the development of compact urban form; transit-oriented development around light rail and other public transit corridors; diverse, people-friendly and flexible working/living patterns, including multi-use buildings and attractive, liveable precincts. Planning can facilitate the shift to electric vehicles and the use of renewable sources of heat for industry and manufacturing.

- ***Remaining open to future innovation***

While choices and investments have to be made in the short term based on the options that are available today – and delaying the transition to zero carbon imposes opportunity costs on the community – the ACT should remain open to emerging and innovative technologies, for example by encouraging local investment by technology and solution-providers, and supporting trials.

### *Recommendations*

We recommend:

- In the next iteration of the ACT's climate change strategy:
    - Adopt a policy to maintain 100% renewable electricity from 2020 onwards
    - Set a target date for the elimination of fossil gases, such as 2035
    - Set targets for the adoption of electric and zero-emission vehicles in ACT.
- To the extent possible, set performance- and outcome-based targets, rather than prescriptive pathways.
- Conduct detailed studies of (larger) gas user needs and substitution possibilities, and also of options for replacing fossil gases with renewable gases such as hydrogen or biomethane, methanol, or other strategies.
- Consider innovation hubs for renewable industrial heat and mobile energy.
- Establish specific programs and regulations – with the detailed micro-design subject to benefit cost analysis – to target:
    - The highest cost-effective level of energy performance of new and refurbished buildings
    - Deep retrofits for existing buildings
    - Fuel switching to zero-emissions sources.
- Carry out benefit-cost analysis to support the micro-design of policies and programs.
- Ensure that there is universal access to the benefits of a zero-carbon economy.
- Balance least-cost approach with a portfolio approach which leaves options open for emerging technologies.

- Monitor progress and carry out thorough policy reviews every 3 to 5 years.

# 1. Background

## 1.1 Purpose

The ACT Government is currently in the process of updating its climate change strategy. This Report has been commissioned to model the ACT's transition to net zero emissions by 2050 at the latest, and to assist in setting firm interim targets. This report addresses stationary energy emissions (energy and buildings), together with an estimate of the electrical demand associated with light rail and electric vehicles. Key assumptions, such as population and economic growth rates, have been aligned with related projects addressing emissions from waste and land use in the ACT.

## 1.2 Background

The ACT is part of the international States and Regions alliance, and has recently signed up to the Under2MOU. The ACT is also a member of the Pathway to 2050 project. Other Australian States and Territories have also committed to the goal of net zero emissions by 2050, including NSW, Victoria and SA. The ACT is in conversation with other states and regions, both nationally and internationally, including California which has recently developed an emissions pathway strategy.

The recently signed ACT Government Parliamentary Agreement for the 9th Legislative Assembly specifically notes:

ACT Labor and the ACT Greens reconfirm their genuine commitment to protecting the local environment, and doing everything we can as a community and city to combat human-induced climate change. To meet these goals, the parties agree amongst other things to:

- Continue all necessary policy and contractual steps to achieve 100% renewable electricity by 2020;
- Sign the 'Under2MOU' and set firm interim targets to reach zero net emissions by 2050 at the latest;
- Conduct an assessment of a Sustainable Bonds scheme to fund sustainable infrastructure;
- Undertake a regulatory impact statement into setting minimum EER standards for rental properties by the end of 2017, with a view to implementing measures to improve energy efficiency of rental properties.

### 1.2.1 Climate Change and Greenhouse Gas Reduction Act 2010

The ACT's Climate Change and Greenhouse Gas Reduction Act 2010, sets emissions reduction targets of:

- Zero net greenhouse gas emissions by 2050;
- 40% below 1990 levels by 2020;
- Peaking per person greenhouse gas emissions by 2013;
- 100% renewable electricity by 2020.

### 1.2.2 The ACT's Climate Change Strategy - Action Plan 2

The ACT's current climate change strategy - Action Plan 2 (AP2) - released in October 2012, sets out a strategic pathway to guide the Territory to meet its 2020 greenhouse gas reduction targets and adapt to climatic changes. 15 of the 18 Actions are completed or ongoing, as reported in the six-monthly implementation status updates. The three outstanding actions (Actions 3, 4 and 10) may form the basis for the next iteration of the ACT's climate action strategy. These actions focus on low emissions transport, low emission buildings, and information sharing.

A review of AP2 also covered the ACT's greenhouse gas accounting method, and noted any future policy development should be compliant with the IPCC GHG Accounting Global Protocol for Communities. The method was formally amended in 2015 and is compliant with international account best practice.

The next iteration of the ACT's climate change strategy will involve a longer term view out to 2050, and will develop a blueprint for how the transition to net zero emissions can occur over that timeframe across all sectors. Although 'visibility' out to 2050 is poor, it is intended that future iterations of ACT's climate strategy will refine and update modelling, as 2050 comes more clearly into view.

### 1.2.3 Emissions Profile

Currently, electricity comprises up to 56% of the ACT's greenhouse gas emissions, followed by transport (26%) and natural gas (10%). These are the main sectors that the ACT Government will be targeting with its emission reduction actions. As fossil fuel generated electricity is replaced with renewable energy sources by 2020, it is projected that the transport sector will contribute around 60% of emissions, with natural gas approximately contributing 18% and waste, 5%. These three areas are expected to be the priority focus of the ACT Government's future carbon emissions reduction efforts. Consideration will also be made on ensuring the 100% renewable electricity target is maintained beyond 2020.

### 1.2.4 Zero emissions/ net zero energy buildings

The ACT participates in a range of national measures including the National Energy Productivity Plan and the National Carbon Offset Standards. The ACT also participates in the Australian Sustainable Built Environment Council (ASBEC) and other fora. These activities assist the ACT's pathway towards emissions reductions in the built environment.

Importantly, the ACT will be powered by 100% renewable electricity (RE) from 2020, which will need to be maintained through a combination of containing demand (including improving the energy performance of both new and existing buildings, for example), additional onsite solar PV and large scale renewable purchases, and other strategies. The 100% RE target changes the focus on zero carbon buildings, as by default, their electricity consumption will be zero emissions. The transition from gas to high efficiency electrical appliances for space heating, cooking and hot water will also need to be an important part of the consideration in the transition to zero emissions buildings.

## 1.3 Scope

Given the ACT is on track to being powered by 100% renewable electricity by 2020, a key focus for this project is maintaining that requirement over the coming decades through energy efficiency and other mechanisms. With gas emissions increasing to 18% of the ACT's emissions by 2020, the transition from gas to high

efficiency electrical appliances will be key to moving to zero emissions, making most of the opportunities from 100% renewable electricity.

The Project Brief may be found at Appendix A.

## 1.4 Context – Energy Disruption

The jury is in: the energy system – the way in which power is supplied and used – is in a state of transformation.

The Finkel Review into the National Electricity Market has observed that the electricity system is transforming at rates not seen since the 1890's. The CSIRO, together with Electricity Networks Australia (an association of electricity network businesses) agree that the electricity system "is experiencing change on an unprecedented scale". Transformation is not restricted to electricity – the entire energy landscape – including gas, liquid fuels and other forms of power – is shifting.

### *Energy transformation is the result of powerful disruptive forces*

Three drivers are disrupting the energy system as illustrated below.

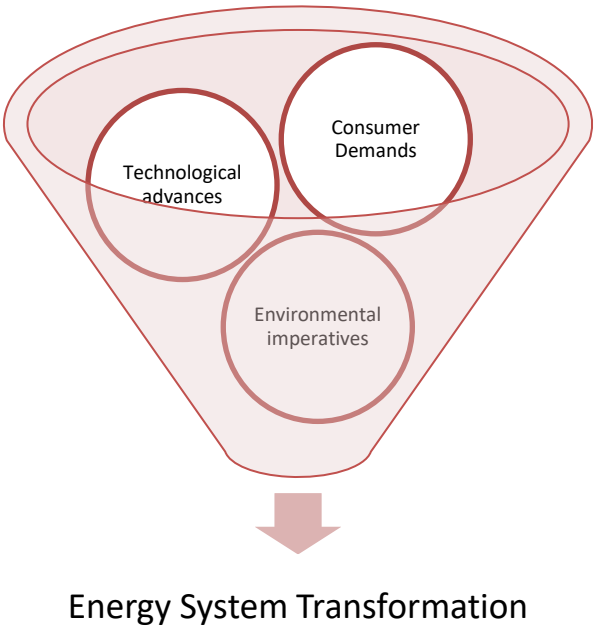



**Figure 10: Disruptive forces on the energy system**

Technological advances are impacting just about every way in which we harness, distribute and use energy. The so-called digital revolution and globalisation of supply chains are factors that speed the take-up of new technologies. For example, landline telephones were taken up by half of US households over a period of 76 years: smart phones achieved that market penetration in less than 10 years . Those same smart phones can now act as the remote control for energy supply and management systems that can improve energy

efficiency and lower network or peak demand. Section 4 details a multitude of technology advancements that will continue to disrupt the energy system in the coming decades.

Consumers are demanding more from energy systems – and are growing in numbers (Canberra is expected to have over 600,000 people by 2050). Energy is fundamental to our quality of life but we don't consume power as an end product. Rather we demand a huge range of energy services – and our expectations are growing and becoming more sophisticated. At the same time, we recognize that the community should have fair and affordable access to those services. These demands and expectations are not currently being fully met. A University of Sydney survey into the customer focus of infrastructure service providers found that schools, hospitals and ride sharing services were regarded as customer focused by 87% of respondents. Only 41% of respondents thought that energy utilities were responsive to customers – not much better than roads at 34%. This consumer dissatisfaction coupled with new choices – like electrification of heat and transport related energy services, PV, batteries, micro-grids, energy management systems, new business models - is a major disruptive force only just starting to gain momentum.

Humans are exerting immense pressure on the natural environment; it is imperative that we reduce the environmental impact of our activities. Biological diversity is plummeting, our water resources are under strain. Oceans will carry more plastic than fish by 2050 unless current trends are reversed. Climate change is happening far faster than we anticipated. The Svalbard Global Seed Vault was built just 9 years ago in 2008 in Arctic Norway under permafrost, thought to be an impregnable safeguard for millions of seeds that could be used to aid recovery from man-made and natural disasters. This year, with temperatures 7 degrees above average, rain rather than snow fell in spring, causing the frost to lose its permanence and flooding in the seed vault entry tunnels. Such events demonstrate the urgency of acting on the Paris Agreement, ratified by 148 countries, that global greenhouse gas emissions must peak then decline as soon as possible to limit global average temperature increase to well below 2 degrees above pre-industrial levels. The agreement encourages cities and regions to scale up efforts to reduce emissions. In the ACT, energy use in 2015/16 accounted for 92% of emissions (electricity 56%, transport 26%, gas 10%). This concentration of emissions in energy sources presents a huge opportunity for the ACT to lower its environmental impact.

### *The ACT has a track record of positively harnessing energy disruptions*

ACT is well on the way to achieving 100% renewably sourced electricity in 2020. In 2010 such a target would have been considered technically possible but unrealistic from a financial point of view. The global price of wind turbines in 1990 was about 2.5 million euros per MW. By 2000 this had fallen to about 1.3 million euros where the price stabilised for about 10 years until 2011. Prices then pushed considerably lower. Solar prices have fallen more steeply. These price falls coupled with the leadership of the ACT community have allowed the positive disruption of the ACT's electricity generation mix to be delivered on a win-win basis of lower wholesale electricity costs and lower environmental impact.

We can't precisely know the future impact of the disruptive forces – but transformation of the energy system will continue.

A key element of sending emissions, from building energy use, to zero will be the elimination of emissions from gas in the form of fossil fuel methane (other gases such as methane from waste or piggeries are zero emissions).

Our modelling suggests that even in the absence of active management, by the ACT Government for its community, gas use will decline significantly in the coming decades. This is largely for two reasons. With every

passing year, gas is getting more expensive while renewable electricity is getting cheaper. At the same time, most electrical devices are getting more efficient, and have more potential to do so in future, while most gas appliances have limited efficiency improvement potential. So, electrical equipment that can do the jobs previously performed by gas, like space and water heating, is becoming more attractive.

This is an example of the electrification of energy services – that has the potential to drive our need for electricity higher – posing the question of where the extra electricity will come from.

Our modelling suggests that the expected rate of switching from gas to electricity alone won't drive electricity demand higher as efficiency gains will compensate. However, two other forces will push overall electricity demand up. First population growth increases the need for energy services of all types. Second, some electrification of transport services is very likely. Trains, buses, cars and trucks can all be powered by electricity rather than liquid fuels. The running costs of electric vehicles (EVs) are already much lower than their petrol and diesel fuelled counter-parts – it is likely that EV range will increase and that up-front purchase costs will fall sufficiently to make EVs an attractive option in the next decade or two at the outside.

### *Active management of disruption has the best chance of delivering widely beneficial transformation*

These ongoing disruptions pose at least three related challenges for the ACT Government and its community to grapple with.

1) Electrification of building services like heating and transport services will probably reduce, but not eliminate, emissions from fossil fuel gas and liquid fuels in the absence of new ACT policies. The ACT will have to take active steps if energy use in the ACT is to hit zero emissions in 2050 or earlier.

2) The transition for the fossil gas industry and its customers will need to be managed actively and with due consideration for the sunk costs in existing infrastructure and equipment.

3) Growing electricity demand together with consumer desires for action on climate change, affordable, reliable and customer focused energy services creates, in the head of AEMO's words, 'a community of interest' in addressing the challenge of how to develop a fair, responsive, low-cost and environmentally responsible energy system.

This third challenge is all-encompassing. Such a transformation will only be achieved with the implementation of forward looking policy developed in close consultation with the ACT community.

# 2. Approach and Methodology

## 2.1 Approach

Our overall approach to this brief was to:

1. create an up-to-date, detailed and evidence-based projection of ACT stationary energy emissions to 2050, in three reference scenarios, based on a highly detailed model of energy use by sector, fuel and end-use, and anticipating likely take-up of abatement potential as a result of market and national policy settings
2. examine the technical emissions abatement potential by sector, fuel and end-use (noting that certain technologies cut across the sectors)
3. model the additional take-up of the technical emissions abatement potential that could be expected with a range of additional ACT policy measures in place.

In such analysis, uncertainties abound. The rate at which new technologies are developed and commercialised, the extent to which national governments strive for faster abatement with stronger abatement policies, the timing of national policy changes, and also the strength of underlying emissions drivers in the ACT – like population and economic growth – are all uncertain. Of course, uncertainty does not justify inaction: rather, it requires us to design strategies that remain robust and cost effective through a range of plausible futures. For this reason, we identify a range of scenarios, which are described more formally in Chapter 3.

In discussion with the ACT, we adopted the use of 'reference' rather than 'business as usual (BAU)' scenarios for this task. This reflects the practice of the International Energy Agency *inter alia* since 2016, and recognises that the conventional BAU scenario approach – which reflects frozen national policy settings and, by implication, non-achievement of Paris Climate Agreement targets – is not a realistic basis for making longer term projections, as countries including Australia have international legal obligations to meet these targets. A reference scenario is therefore able to anticipate future policy changes, while a business as usual scenario assumes constant policy settings. A reference scenario also aims to incorporate the effect of emerging changes in technologies, economic drivers and consumer behaviour. Of course, there is considerable uncertainty about future policy settings, amongst many other factors that will affect emissions in a reference scenario, and for this reason we develop high, medium and low versions of the reference scenario, to illustrate the effect of a range of plausible sources of variation on emissions to 2020 to 2050.

Second, we aligned our scenarios with those being created in the waste and land use sectors, specifically by adopting a common conceptual basis for framing the scenarios. This approach extends the high, mid and low approach to reference scenarios, scenarios for abatement potential and for ACT policy. In effect, this generates a 3-by-3 grid of scenarios, as follows:

**Table 2: Scenario Characterisation**

| Scenario | High Emissions | Medium/Mid Emissions | Low Emissions |
|---|---|---|---|
| **Reference** | • Higher population growth<br>• Higher economic growth<br>• Weaker national policy settings | • Expected population growth<br>• Expected economic growth<br>• Expected national policy settings | • Slower population growth<br>• Slower economic growth<br>• Stronger national policy settings |
| **Abatement Potential** | • Expected potential | • Expected potential | • Expected potential |
| **ACT Policy** | • Greater implementation delays | • Expected implementation timeline | • Faster implementation timeline |

These terms are defined in Chapter 3, but high emissions in a reference scenario are associated with low ambition in national policy settings, but also with faster economic and population growth. The potential for greenhouse gas abatement we model as independent of local factors, given that technology markets are increasingly global. What varies is the extent to which this potential is taken up in the ACT, and that will reflect a hybrid of national and local factors.

Given the ACT's target of reaching net zero emissions by 2050 at the latest, ACT policy scenarios are assumed to be as ambitious as practically feasible, and therefore not to vary by scenario. However, despite best intentions, implementation delays can arise, whether due to process issues, funding or extended consultations.

In a low emissions scenario, (eg, stronger national abatement policies, slower local economic or population growth), the ACT will be able to reach zero emissions in the stationary energy sector more quickly than it would in a high emissions scenario. Note that, perhaps paradoxically, the abatement effect of a given policy design is generally lower when emissions are lower, and higher when emissions are higher, because the extent of cost effective opportunity for abatement that is able to be captured by the policy differs in each case.

In certain key areas – such as the specific opportunities and barriers to phasing out the use of fossil gases such as methane, and to producing and distributing renewable alternatives – we identify a need for further and much more detailed studies. Little is known about commercial end-uses of methane in the ACT, for example, yet successful strategies to move away from such uses must be found if the ACT is to reach zero net emissions. Also, the feasibility of producing commercial quantities of different bio- or renewable gases, in or near the ACT, that are suitable for the needs of ACT customers, requires further and careful analysis.

For example, in Chapter 4 we examine the opportunities such as the generation of hydrogen from renewable electricity and water, and then the subsequent issues regarding storage, transportation and use of this fuel. We note that there are multiple potential pathways. Japan and Korea in particularly are investing heavily in hydrogen and related technology pathways, such as fuel cells, while others are investing in different battery

storage technologies and using electricity, rather than renewables gases, as an energy carrier. It is possible to combine hydrogen with other fuels, such as renewably-generated methane. The rate at which these different technology pathways develop over time, and the resulting timeliness and cost effectiveness of the abatement opportunities, will remain uncertain and must be constantly monitored.

Overall, we recommend an insurance- and portfolio-based approach, whereby the ACT weights its abatement strategies and policy measures towards those that are most available and most cost effective in the short term, but also retains some focus on and investment in plausible alternative, or 'blue-sky' pathways. In addition to ensuring that the ACT is positioned to respond rapidly and flexibly over time to changing technological opportunities, we note that there are also direct economic benefits – such as investment, jobs and linkages to the ACT's tertiary education and research capabilities – from engaging in a basket of abatement technology pathways, rather than attempting to pick the one 'winning' pathway. This approach is elaborated upon below.

## 2.2 Blue-Sky Potentials

We can anticipate the broad direction of some technological change pathways. For example, we can be confident that renewable electricity generation and storage will continue to become more efficient, more effective and more affordable, because these outcomes are the focus of very many well-resourced technology development efforts by businesses, governments and researchers world-wide. Other technological developments, along with social and attitudinal changes, that will take place by 2050, are harder to anticipate. The following established policy principles can handle this challenge.

- *Calibrate policies to overarching goals – climate change mitigation and adaption + social and economic well-being.* This helps prevent the policy focus from becoming too narrow – and reduces the risk of making policy that becomes redundant or even counter-productive.
- *Set performance-based or outcome-based targets not prescriptive pathways.* This reduces the risk of backing the wrong horse – which leads to forgone opportunities and the creation of incumbents that demand compensation when circumstances change.
- *Scan and fine tune constantly. Review and evaluate often.* Policy makers should be scanning and tweaking policy design on an ongoing basis. Thorough reviews can occur periodically (every 3 to 5 years).

### 2.2.1 Actively Fostering Innovation

Forward looking regional governments are seeking to maximise the opportunities offered by a rapid transition to zero emissions. South Australia and California are examples of states that are aggressively chasing emissions reductions while maximising the extent to which economic activity (in support of the transition to zero emissions) occurs within their region. Cities are doing the same: Freiburg in Germany has long positioned itself as a centre of sustainability innovation.

A key method of maximising the economic benefits of the zero emissions transition is to encourage locally based innovation. ACT based innovation can boost local development and delivery of energy efficiency and renewables services. More broadly, education, construction, tourism, light manufacturing and transport sectors, are all more likely to thrive in conditions where sustainable innovation is incentivised.

How might the ACT support local, specific examples of innovation within a blue-sky policy framework that is broad and far sighted? Can a government pick innovation winners in a policy setting that focuses on targets and performance outcomes rather than prescriptive pathways?

The solution is to identify specific areas where prospects are strong, then incentivise organisations to innovate in those areas. In other words, government can play an active role in looking for opportunities, then encourage business and other organisations (schools, hospitals, etc) to realise those opportunities.

### 2.2.2 Innovation Examples

A few examples of specific rapid-transition and innovation-enabling policies are presented below under three themes:

***Expand the reach of renewables***

The legislated 2020 target for 100% renewable electricity already makes the ACT an international leader in the use of renewables for electricity.

These laurels shouldn't be rested upon. There remains plenty of potential for renewables to move beyond the electricity generation sector to further speed and minimise the cost of the transition to zero emissions.

As the IEA's Executive Director Fatih Birol has said:

> *The next frontier for the renewables story is to expand their use in the industrial, building and transportation sectors where enormous potential for growth exists*[3]

This means using renewable energy not only for electricity but for process heat, space heating and cooling, and other end uses.

***Facilitate the creation of a Renewable Industrial Process Heat and Mobile Energy Source Hubs.***

Industrial scale laundries and commercial kitchens commonly use process heat; supplied most commonly at present with gas not electricity. Renewable alternatives to fossil fuel gas such as solar thermal and ground source heat-pumps can be used to reduce the energy load while renewable sources such as biogas and solar thermal can supply the necessary heat.

This would occur most efficiently within a precinct – where process heat could be supplied at scale and used by numerous end use customers. Hydrogen, biofuels, biogas etc for heavy transport and other uses could also be supplied from the same hub. A renewable gas peaker-plant could also be located at the same hub as a component of ACT's energy security strategy.

The hub could be set up using a combination of push and pull incentives for energy suppliers and users.

***User and environmentally friendly buildings***

Buildings provide shelter, comfort, and security, and are the location for countless forms of economic activity. The vast bulk of ACT's stationary energy use occurs in buildings. Buildings also are associated with water use and material use generally.

[3] See https://www.iea.org/newsroom/news/2016/november/world-energy-outlook-2016.html, viewed 30/06/2017.

***Promoting a zero emissions culture***

Social attitudes will affect the ability of the ACT to hit zero emissions earlier than 2050. Attitudes can't be regulated but they can be influenced by government policy – including regulations. Policies across the board can be designed with holistic prosperity in mind (which must include looking after the environment in which we live). A comprehensive policy framework should explicitly intertwine environmental, social and economic goals – making the achievement of zero emissions and material efficiency a core activity of Canberrans.

The ACT Government can lead by demonstrating behaviour and using services that involve best practice emissions, energy and material efficiency.

## 2.3 Further Analysis

Finally, it is important to note that this study identifies potentials and broad technical and pathways and timelines for achieving zero net emissions. It does not subject these pathways to detailed benefit cost analysis, nor do we attempt the level of 'micro-design' of policies and measures that will be necessary before final decisions are made. We recommend an approach whereby this (and other) assessments of abatement potentials and pathways are reviewed, and the collective appetite for different policy approaches and measures judged, prior to detailed development and optimisation of individual measures using benefit cost analysis and, where needed, additional targeted research.

# 3. Reference Projections

## 3.1 Reference Case Scenarios: brief explanatory narrative

Reference scenarios projecting ACT stationary energy use and related emissions have been developed. Three scenarios – Low, Medium and High - show different levels of energy consumption, and related emissions, through to 2050.

The terms low, medium and high refer to the quantity of emissions and stationary energy consumption (electricity and gas) under each scenario. The low reference scenario shows the smallest level of energy and emissions while the high scenario represents circumstances where larger levels of energy use occur.

Electricity use for transport does not, at first glance, perfectly fit this framework because the low scenario shows the highest electricity use for transport. This is because by increasing the use of electricity, instead of liquid fuel, to power vehicles; overall ACT transport sector energy use and emissions will be lowered. Electric vehicles are more fuel efficient and able to run on zero emissions electricity.

A key assumption for all Reference scenarios is that the ACT Government does not take any new policy action to meet a mitigation goal. Current ACT energy efficiency policies and programs are assumed to continue.

Key variables under the three scenarios are explained in turn below.

## 3.2 Reference Case – Medium Scenario Projections

### 3.2.1 Key Variables and Assumptions

***Population***

The population projection provided by the Directorate was used. This extends only to 2041, and for this study has been extrapolated to 2050. The figures show population growing at a linear (arithmetic) rate, rather than an exponential or geometric rate, and they also show a roughly constant year on year increase over the entire period. The extrapolation results in an estimated population of 609,000 in 2050 under this scenario.

***Economic Growth***

Projections of gross state product (GSP) are linked to the population projections. In the past, the relationship between population growth and GSP growth has shown considerable year to year variation. However, on average over the period from 2004 to 2016 inclusive, the ACT's GSP has grown at a rate which is approximately 1.5 times the rate of population growth. It has been assumed that this relationship will persist over the entire projection period, i.e. that GSP will rise 1.5 times faster than population.

***National Policy settings***

Under this medium scenario there is an assumption that existing policy positions at both national and ACT levels will continue, but no new or more ambitious policy settings will be implemented. Key policy settings include:

- ACT electricity will remain 100% renewable and emissions free from 2020 (the current legislated target) through to 2050 (not yet legislated)

- current energy provisions of the National Construction Code, as they affect new construction and major refurbishments of both residential and non-residential buildings, and
- all Minimum Energy Performance Standards (MEPS) currently in force, affecting a wide range of electric appliances and equipment.

***Base year reconciliation***

Separate models were developed for residential and non-residential (henceforward termed commercial) consumption. Both models use a bottom up approach, in which consumption is disaggregated by type of electricity and gas service/equipment and/or category of consumer.

In both cases, the modelled consumption for both the most recent complete years (2014-15 and 2015-16) was reconciled with actual electricity consumption for those years.

Consumption of electricity was measured as the sum of electricity supplied by ActewAGL Distribution, as specified in the annual AER RIN template reports, and estimated behind the meter consumption of electricity from rooftop PV. The latter estimates were made by comparing estimated output of rooftop PV installed in the ACT, using installation data from the APVI Live Solar Map website, with reported electricity supplied to ActewAGL Distribution by embedded generation at the premises of residential and non-residential consumers, as specified in the annual AER RIN template reports.

Use of base year electricity consumption inclusive of behind the meter consumption of electricity supplied by rooftop PV means that all projected electricity consumption represents, when totalled, electricity consumed on customer premises for all activities, regardless of the source of that electricity; in previous studies we have used the term consumption of electricity services, to distinguish this quantity from consumption of electricity supplied though the meter from a local electricity distribution network. This approach is consistent with the approach used to calculate total renewable electricity consumption in the ACT. The approach avoids the need to estimate future behind the meter consumption of distributed electricity generation, and thus avoids adding another layer of uncertainty to what are already unavoidably uncertain projections of future electricity consumption.

For gas, comparable data are not available. ActewAGL Distribution's network covers Queanbeyan and Bungendore, as well as Canberra, and it is only able to provide data for the network as a whole, which it does not, or cannot, separate into residential and other. It has consistently advised that it estimates Canberra to account for 90% of gas supplied through its network. This assumption is used, together with historic data published in the ICRC's now discontinued utility Compliance and Performance Reports, to make estimates of current residential and non-residential gas consumption in the ACT.

A complete listing of all the assumptions and parameter values used for all three Reference scenarios, and also for the three Policy scenarios, will be found in Appendix A.

### 3.2.2 Residential Sector Projection Model

Modelling was undertaken in three components: space heating and cooling, water heating, and all other energy consumption.

### *Stock model*

Both the space heating and cooling and the water heating components are based on a detailed stock model of ACT dwellings. All dwelling numbers modelled are occupied dwellings, as defined in the Census. Numbers of occupied dwellings are less than total dwelling numbers, and considerably less than the number of individual residential consumers of electricity. The stock of dwellings is allocated into the three main categories specified in the National Construction Code (NCC): Class 1A (separate/detached houses), Class 1B (town houses) and Class 2 (apartments, including both low rise and high rise). Using Census data, other ABS data, and data provided by the Directorate, a model of stock and stock turnover in recent years was constructed. The model had to go back some years in order to estimate numbers of dwellings falling into each of the four successive energy star rating classes now in the ACT housing stock: pre-4 star (assumed to be 2-star on average), 4 star, 5 star, and 6 star. For each of the three dwelling Classes the model includes, on a cumulative year by year basis: demolition and rebuild of a new dwelling of the same Class, demolition and rebuild of a new dwelling of a denser Class, greenfields new build, and rating upgrade through major refurbishment.

For the future, the model is driven by population, overall average dwelling occupancy (persons per occupied dwelling), and the expected future share of the three dwelling classes, as advised by the Directorate. For each of the three dwelling Classes the model provides projections of total dwelling numbers in each year of each of the four energy efficiency ratings: 2-, 4- , 5- , and 6-star. In addition, the Mid and Low Reference cases assume future increases in minimum energy efficiency to 7, 7.5 and 8 star.

### *Space heating and cooling*

For the space heating and cooling sub-model, annual heating and cooling thermal loads are calculated for an average individual dwelling in each dwelling Class and energy star rating, using NatHERS modelling results. Thermal loads are determined by the combination of thermal energy per m2 of floor space and conditioned floor area; the latter is largest for Class 1 dwellings and smallest for Class 2. Note that these results show that cooling thermal load is only one tenth of the heating load in an average dwelling in Canberra. The model includes no shift over time in conditioned area, the assumption being that the historic shift over several past decades, from single room heating to most of dwelling heating, has been effectively completed.

A mix of heating and cooling equipment types is then estimated for each of the three dwelling Classes, drawing on successive ABS triennial energy use survey data. Finally, a table of energy efficiency of each equipment type is constructed. Four vintages are assumed for both equipment shares in each dwelling Class and successively increasing efficiency of equipment. For each new dwelling in each Class falling into each of the four vintages, equipment type weighted average consumption of electricity and gas for heating is then calculated, together with an equipment type weighted average consumption of electricity for cooling.

These detailed input data allow for differing mixes of equipment in the different dwelling Classes (more electricity, less gas in Classes 1B and 2, compared with Class 1A), and a shift over time (past and future) away from both gas and electric resistance heating and towards RCAC heating.

Finally, the model includes replacement of heating equipment in older dwellings at the end of an assumed life of 25 years. For heating, the share of gas in the replacement equipment is much lower than in the equipment being retired. It is assumed that after 2020 the gas share falls to zero, as all new equipment is RCAC.

Overall, future electricity use for heating and cooling will be increased by: population growth, a shift to active heating and cooling in all dwellings, and a shift from gas heating to RCAC. Electricity use will be decreased by: increased thermal efficiency of the dwelling stock, and increased energy efficiency of heating and cooling equipment. The modelling shows that the latter factors outweigh the former, so that total electricity consumption for residential heating and cooling gradually declines. Incidentally, gas consumption declines much faster.

### *Water heating*

For the water heating sub-model, annual requirements of electricity and gas for each type of water heater and each hot water load are taken from simulation modelling results. ABS survey data are used to estimate the water heating equipment type shares in the existing stock in each of the three dwelling Classes. These shares are applied to the simulation modelling results for the applicable annual hot water load to calculate equipment type weighted average per dwelling consumption of electricity and gas for water heating in the existing stock of dwellings in each Class.

Since 2013 the installation of large electric resistance storage water heaters in new dwellings has been prohibited under the NCC. This has led to much greater use of instantaneous gas and solar/heat pump water heaters in new Class 1A and 1B dwellings. The effect has been less in Class 2 dwellings, because they use small electric water heaters, which are not prohibited. In addition, most high rise apartment buildings in the ACT use reticulated hot water, supplied from a central gas boiler. This consumption is included with commercial energy demand. It follows that the weighted average per dwelling consumption of electricity and gas in new Class 1A and 1B dwellings changed decisively away from electricity and towards gas in 2013.

The model also allows for the turnover of water heating equipment after an assumed average life of 18 years. Since the NCC does not currently prohibit like for like replacement of old electric resistance water heaters, the replacement stock is assumed to have a lower, but non-zero share of this type, compared with what is being replaced.

Finally, limited available data suggest that, over the past two or three decades, adoption of more water efficient technologies, such as low flow showerheads and front-loading clothes washers, has greatly reduced residential hot water consumption. This modelling, however, assumes no further reductions in average per household hot water consumption.

### *Other residential loads*

Other loads were separately identified as lighting, refrigeration, cooking, and all other plug loads for electricity, and cooking and pool and spa heating for gas. Base year per dwelling values (MWh per dwelling per year) for each service were initially set equal to those prepared several years ago by Energy Efficient Strategies for use in a major study by BZE. These input values are single values for each end use load type for the whole of Australia. Some very small adjustments were made to these values, so as to achieve reconciliation of modelled total residential energy consumption with actual values for 2014-15 and 2015-16.

Projections for each load type were primarily driven by household numbers, taken from the stock model. All three of these electricity use categories are strongly affected by the substantial consumption reductions resulting from national Minimum Energy Performance Standards (MEPS) already in place and applying to purchases of new lighting, refrigerators, televisions, clothes washers, dishwashers and a few smaller equipment categories. The quantum of electrical energy against each equipment type was based on national

estimates, prepared a few years ago for the (now) Department of Environment and Energy, and used by the consultant team in previous studies for that Department and for the Australian Energy Market Operator (AEMO). For this report, the national savings estimates were pro-rated to the ACT in proportion to population.

Although it uses much less energy than either HVAC or hot water, cooking is the third important use of gas in ACT households. We estimate that about 60% of ACT households currently use gas cooktops, while almost all use electric ovens (conventional electric resistance and/or microwave). Limited available data suggests that ovens are used much less frequently than cooktops and so use less energy in total. As with HVAC, a cost effective, high performance electric alternative to the gas cooktop, in this case the electric induction cooktop, has emerged in recent years and is steadily gaining acceptance. As with alternatives to gas water heating, higher capital cost is currently an impediment to wider adoption of induction cooktops. The model explicitly incorporates a steady shift from gas to electric induction in new dwellings and also in replacement cooktops in existing dwellings, based on the effect of assumed higher retail gas prices and falling induction capital costs. The assumed replacement rates are not sufficient to reduce gas consumption to zero by 2050, partly because consumers with a strong preference for gas cooking have a simple and readily available alternative option, in the form of LPG (currently provided by exchange of 45 kg bottles).

Cool and spa heating was modelled by a simple annual rate of switch from gas to electricity, using the same relative performance factors as applied to water heating, thus implying that the electric alternative is either heat pump or solar.

Finally, all modelling for the residential sector includes estimates of savings realised through the ACT Energy Efficiency Improvement Program (EEIP), calculated from data provided by the Directorate.

### 3.2.3 Commercial (Non-Residential) Sector Projection Model

Modelling energy consumption in the commercial sector was more challenging than the residential sector, both because much less data is available about how much energy is used and what activities it is used for, and because of the greater diversity of activities of the energy using activities. As is the case with residential energy, HVAC is an important category of energy use, closely associated with building types and performance, but information about the stock of non-residential buildings in the ACT is fragmentary, at best. The Directorate provided very detailed data on energy use by the ACT government in its complete stock of buildings and facilities; this was a very valuable starting point for understanding non-residential energy use.

Professional judgement was applied to these data, as less detailed data from a variety of other sources, to construct estimates of 2015-16 electricity and gas consumption in each of the following user categories (some of which do not use gas):

- office light and power
- office central services
- public buildings
- data centres
- schools
- universities and laboratories

- hospitals and other health facilities
- aged care facilities
- retail, including cafes and restaurants
- non-retail, i.e. “upstream” cold chain refrigerators and freezers
- hotels and accommodation
- miscellaneous other ACT government buildings and facilities
- street and traffic lighting, pumping
- water heating and other central services in apartment buildings
- other (undefined) large uses of (mainly) gas.

For each category, energy consumption was allocated between up to five end use types for electricity and three end use types for gas.

The end use types for electricity are:

- HVAC
- hot water/cooking
- lighting
- machinery and equipment, including motors and electronic equipment
- refrigeration equipment

The end use types for gas are:

- HVAC
- hot water/cooking
- machinery and equipment

For HVAC and hot water, what we have termed ‘synthetic’ stock models were constructed. As with the actual stock model used for residential sector modelling, these models represent the mix of equipment stock of different vintages in each future year. They also estimate, for the purpose of accurately modelling stock replacement, the stock and average performance (efficiency) in past years, based on assumptions about past rates of stock growth and efficiency improvement. This allows the models to represent changes in the efficiency of equipment and to represent policy changes in the form of changing requirements for new stock, replacement stock and upgraded stock. Replacement changes are based on specified equipment lives, i.e. specified turnover rates, which are different for HVAC and water heating (and can also be varied if desired). The models also represent fuel switching from gas to electricity, and allow rates of switching, in both new buildings and equipment replacement in existing buildings, to be varied.

For HVAC, the efficiency of the buildings themselves, as well as of the equipment, is of course highly relevant. The modelling represents the increasing efficiency of net additions to building stock. However, lack of data about the current building stock, such as vintage, mix of different energy efficiencies and average energy efficiency, not to mention floor area, precludes explicit modelling of demolitions, replacements and major

refurbishments of existing buildings. For most building types, such as public buildings, schools and hospitals, turnover, in the sense of demolition and complete replacement, is rare. That is not the case, however, for office buildings. The model therefore includes an approximate representation of stock removal, e.g. by demolition or conversion to apartments, and replacement, by assuming that, from the mid-2020s, 5% of the current stock, with historic efficiency, is removed and replaced by new stock which meets the required minimum energy performance levels. Overall, this approach probably underestimates the possible improvement of the average efficiency of the building stock, and hence over estimates energy consumption in the future, all else being equal.

With the exception of the treatment of building stock, just described, separate, similarly structured models, though, in some cases, slightly different parameter assumptions are, used for each of the building categories listed above. The models are synthetic, in that they do not represent the actual stock of HVAC equipment, but are scaled against actual energy consumption in the base year (2015-16). The models allow for the fact that base year energy consumption is derived from a mix of existing equipment of different vintages with different efficiencies, and that this will continue into the future, but evolve as old equipment is replaced.

For the other three end use types, a simpler approach was adopted. The combined effects of increasing energy efficiency of new equipment and the turnover of stock were modelled by applying annual reductions in energy consumed per unit of energy service delivered of either 1% or 2% per annum, depending on end user category.

For all end user categories stock growth was assumed to be proportional to either population or GSP. Categories proportional to population were assumed to be:

- public buildings
- schools
- hospitals and other health facilities
- aged care facilities
- hotels and accommodation
- miscellaneous other ACT government buildings and facilities
- street and traffic lighting, pumping
- water heating and other central services in apartment buildings

Categories proportional to population were assumed to be:

- office light and power
- office central services
- data centres
- universities and laboratories
- retail, including cafes and restaurants
- non-retail, i.e. “upstream” cold chain refrigerators and freezers
- other (undefined) large uses of (mainly) gas.

Finally, further, quite modest consumption reductions, attributable to MEPS for electric motors, HVAC equipment, computers, and other electrical equipment, were applied to the relevant end use category.

### 3.2.4 Transport Modelling

While transport was not the focus of this study, a 'wedge' of steadily increasing electricity consumption was added to electricity consumption from buildings and other stationary energy uses, to represent electricity consumption by light rail and electric road vehicles.

The model to estimate transport electricity consumption considers both passenger and freight transport.

The passenger transport task begins with an estimate of annual passenger kilometres per capita. This task is split by vehicle categories including cars, buses and light rail. The electric vehicle share of the annual passenger task for each vehicle category is projected in five year periods. These shares, along with population, differ under the low, medium and high scenarios.

Electrical demand for passenger tasks is highest under the low emissions scenario. This is because the low scenario assumes a higher rate of take-up of electrical vehicles – which reduces the share of the passenger task performed by vehicles running on diesel and petrol. The overall emissions for the transport sector would therefore drop as the electric vehicles run on zero emissions electricity.

The estimate of electricity demand for freight vehicles begins with an estimate of vehicle kilometres travelled in the ACT each year to 2050. Total vehicle kilometres are split into three freight vehicle categories – light commercial vehicles (LCVs), rigid trucks and articulated trucks. Electric versions of those categories are then assigned a share of the category task to 2050 with shares adjusted in 5 year periods. It is assumed that electric vehicle options will exist for LCVs and rigid trucks, but that heavy articulated vehicles will be powered by a form of liquid fuel or gas.

Electrical demand for freight transport tasks is again highest under the low emissions scenario. The take-up of electric LCVs and rigid trucks is highest under this scenario. A larger quantity of liquid fossil fuels is displaced by zero emissions electricity under this scenario - therefore overall ACT emissions are reduced.

Further detail on the transport modelling is available in the appendix.

## 3.3 Medium Reference Case – Modelling results

### 3.3.1 Residential Sector Results Overview

#### *Space heating and cooling*

The effects of the dramatic improvement in RCAC technology are now being clearly seen in the ACT. We understand that it is now the default technology choice for new Class 1A and Class 1B dwellings, and it is almost certain that at least some new suburbs will be built without a reticulation of natural gas to individual blocks. Accordingly, the Reference case modelling assume that, whereas prior to 2009 64% of new dwellings in these Classes used gas heating, between 2013 and 2020 RCAC only 30% do so, with RCAC accounting for the remaining 70%. After 2020, all new dwellings use RCAC. It is further assumed that when old gas heating systems (and also old electric resistance heaters) reach the end of their working life, they are replaced by RCAC, which may be either a ducted system or one or more individual non-ducted systems. The outcome is that between 2040 and 2050 gas is no longer used for residential space heating in the ACT under all three

Scenarios. Many, particularly high rise, Class 2 dwellings use reticulated space heating from a large centralised system; the modelling assumes that such systems account for 50% of Class 2 space heating and cooling, and are included under commercial space heating and cooling. The remaining 50% with individual space heating and cooling are assumed to already be predominantly RCAC, with very little gas.

We are aware that these assumptions have welfare implications, because the capital cost of new RCAC is higher than the corresponding cost of new stand-alone gas or electric resistance heating. However, the change to RCAC as a replacement in older, less thermally efficient dwellings is justified on economic grounds alone, because of the much lower operating costs compared with either gas or electric resistance heating, not to mention the much higher level of thermal comfort it provides. The change does not need to be justified in terms of emissions reduction; we believe that it should be seen as a welfare measure, not a climate policy measure.

The result is that, in the Mid-case Scenario, electricity consumption in 2050 is 47% higher than in 2015-16. The increase is 40% in the Low Scenario and 96% in the High scenario.

### *Hot water*

Although water heating uses significantly less gas than space heating in ACT dwellings as a whole, consumption is still significant. Moreover, while use of gas for space heating is steadily declining, its use for water heating is growing. The main driver of increased gas use for water heating is the National Construction Code prohibition on the installation of large (typically off-peak) electric water heaters in new dwellings. The alternatives are gas, solar or heat pump water heaters. Instantaneous gas water heaters are the technology of choice in most new dwellings because of their capital cost is much lower than the cost of either solar or heat pump water heaters. The Code does not prohibit like for like replacement of off-peak electric resistance water heaters. They will therefore remain important, though over the longer run manufacturers may reduce or cease production. Small (continuous tariff) electric water heaters are likely to retain a place in some Class 1B and many Class 2 dwellings. Note that many (particularly high rise) Class 2 dwellings use distributed water heating, associated with distributed space heating, based on central gas fuelled boilers.

The Reference case modelling assumes that 60% of new Class 1A dwellings and 65% of new Class 1B dwellings use gas water heating, with solar and heat pump accounting for 40% and 25% respectively; small electric resistance accounts for the remaining 10% in Class 1B dwellings. In Class 2 dwellings the shares of new installations are 30% small electric resistance, 10% gas and 10% solar/heat pump; the remaining 50% of dwellings have centralised supply of hot water. For replacements of existing systems at the end of their assumed 18 year average life, like for like replacement occurs for 75% of electric systems in Class 1A dwellings and 90% in Class 1B dwellings. Of the remainder, which change technology, it is assumed that half shift to gas and half to solar/heat pump. The efficiency of new solar and heat pump water heater systems is assumed to increase at a rate of 1% per annum. However, the efficiency of both new electric resistance and new gas water heaters is assumed to remain unchanged, as both are mature technologies.

The overall outcome of these Reference case assumptions is strong growth in gas use throughout the period to 2050. Gas use more than doubles under the Mid and High scenarios, and almost doubles under the Low scenario. Electricity consumption decreases slightly in Class 1A dwellings, because of the greater efficiency of solar and heat pump water heaters, compared with electric resistance. The dominance of electric resistance in Class 1B and Class 2 dwellings results in gradual growth of electricity use for water heating, as

the stock of dwellings increases. Overall, these increases outweigh the small decrease in Class 1A dwellings, resulting in an overall slight increase in electricity consumption for residential water heating.

### *Cooking and pool heating*

The share of gas cooktops in ACT, driven by the improved performance and probable reduced cost of induction cooktops, together with growth in the share of all electric Class 2 dwellings, together with a steady shift to all electric new Class 1A and Class 2 dwellings. These trends are likely to be accelerated by looming gas price increases. Higher gas prices are also expected to influence a gradual shift to heat pump and/or solar options for pool and spa heating.

The result is a fall in gas used for cooking, estimated to be 30% by 2050, in the Mid case scenario, 39% in the Low scenario and 14% in the High scenario. Electricity consumption increases in all scenarios. In the case of pool and spa heating, gas consumption falls slightly in the Low scenario, but increases somewhat in the Mid and High case scenarios.

### *Lighting, refrigeration and other electrical loads*

The estimated MEPS savings are large for all three of these categories of electricity consumption, and continue to gradually increase throughout the projection period. The outcome in the Mid case scenario is that, while household numbers have increased by 63% in 2050, electricity consumption for lighting increases by only 24%, for refrigeration by 38% and for other plug loads by 33%. In the Low scenario household numbers increase by 40% to 2040 and the increases in electricity consumption are 7%, 19% and 15% for lighting, refrigeration and other loads respectively. In the High scenario, the increases are 98% increase in dwellings and increases of 51%, 68% and 62% respectively for the three categories of electricity consumption.

## 3.3.2 Commercial Sector Results Overview

### *Heating and cooling*

Canberra is unusual, if not unique among Australian cities in using such a high proportion of gas for space heating in commercial buildings. This reflects both Canberra's climate and the particular historic circumstances of the arrival of natural gas in Canberra in 1979. By comparison, in Hobart, with a comparably cool winter climate, the overwhelming majority of commercial buildings use chillers for both heating and cooling. The Reference case modelling for commercial HVAC adopts the relatively conservative assumption that 50% of replacements of old gas heating systems switch to chillers and that chillers also account for 50% of new installations. At the end of the 20 year replacement cycle, i.e. from 2036-37 on, 50% of the remaining gas heating is again replaced by chillers, while gas continues to account for 50% of heating in new buildings. These assumptions take account of the likely response to much higher gas prices.

The result is that by 2050 gas consumption for commercial heating has fallen to about 6% of its level in 2016-17 in the Mid case scenario. Electricity consumption increases by 35%. In office buildings, which are estimated to account for roughly a quarter of energy use for HVAC in non-residential buildings, the inclusion in the model of building turnover results in a more rapid switch from gas to electricity in the 2020s and 2030s. However, it does not significantly affect the 2050 levels of electricity and gas consumption.

Note that significant increases in the thermal efficiency of the commercial building stock also contribute to both the reduction in gas consumption and to keeping the increase in electricity consumption less than it

would otherwise be. In the Low scenario, gas consumption decreases by 96% and electricity increases by 28%. In the High scenario, with less efficient buildings, gas consumption decreases by 91%, whereas electricity consumption increases by 104%, i.e. more than doubles.

### *Hot water*

Hot water is a relatively much less important use of energy in the commercial sector than it is in the residential sector. While some commercial categories use multiple small water heaters, similar to residential water heaters, others use large boilers, typically fuelled by gas. These include hospitals, aged care homes and hotels, where laundry facilities are important consumers of hot water. The Reference case modelling assumes that larger commercial hot water users, in particular, will be more sensitive to high gas prices than residential consumers. They will therefore be more willing to switch from gas to heat pump and/or, where feasible, solar water heating for at least part of their requirements. It is therefore assumed that 50% of replacement and 50% of new installations will switch from gas to heat pump/solar across all categories of commercial users. At the end of the 18 year replacement cycle, i.e. from 2036-37, 50% of the remaining gas water heaters are again replaced by heat pump/solar systems, and the fraction of gas in systems installed in new buildings is also again halved.

The result is that by 2050 gas consumption for commercial hot water and cooking has fallen by 55% of its level in 2015-16 and electricity has increased by 63%. The corresponding changes in the Low scenario are gas decrease of 62% and electricity increase of 27%, and in the High scenario a gas decrease of 35% and an electricity increase of 167%.

### *Lighting*

The assumed steady increase in the efficiency of lighting systems, together with the relatively modest savings from commercial lighting MEPS, results in a slow increase in electricity consumption, increasing by 11% relative to 2015-16 in the Mid case scenario. In the Low scenario electricity used for lighting actually falls by 13%, while in the High scenario it increases by 57%

### *Machinery and equipment*

This is a large and heterogeneous category of non-residential energy consumption, about which there is very little concrete data. Undoubtedly most of the consumption is accounted for by electric motors, driving machinery such as lifts and pumps, including all the pumps used by Icon Water, and computing and other electronic equipment. The modelling assumes that the category also includes equipment used in research laboratories and for medical diagnostic and treatment activities, and also a variety of light manufacturing activities. This is likely to include relatively modest quantities of gas used for thermal processes, including some used in high temperature equipment such as kilns and metal treatment processes. No substitution of electricity for gas is assumed, but, as with other energy use categories, steady, modest increases in average energy efficiency are assumed.

In the Mid case scenario, electricity consumption, which is large, increases by 9% to 2050, while gas consumption, which is assumed to be small, increases by 23%. The corresponding changes in the Low scenario are a decrease of 13% in electricity and 2% in gas consumption, while in the High scenario electricity increases by 57% and gas by 74%.

### *Refrigeration equipment*

This category of electricity consumption covers refrigeration and freezers used in supermarkets and other food stores, cafes and restaurants, hospitals and nursing homes, laboratories, wholesale kitchens and other food manufacturing facilities, and wholesale distribution facilities. A relatively small quantity of electricity consumption is allocated to this end use. Consumption is projected to increase by 11% to 2050 in the Mid case scenario, decrease by 11% in the Low scenario and increase by 57% in the High scenario.

## 3.3.3 Charts

Figure 11 to Figure 13 below illustrate various aspects of the Medium Scenario Reference projections.

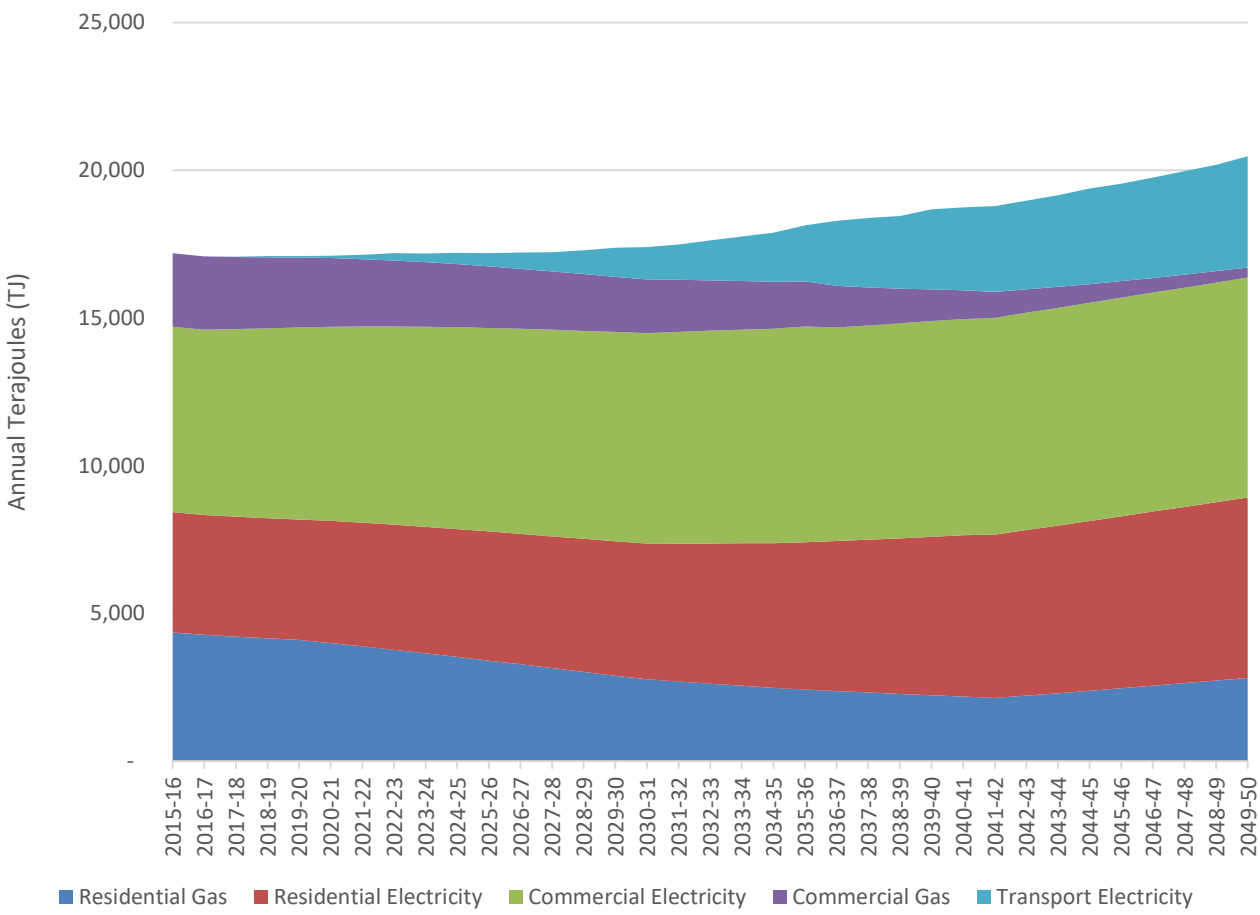



**Figure 11: Energy Consumption by Sector and Fuel - Reference Medium Scenario Stationary Energy Use**

Figure 11 shows a scenario where total demand increases. A decline in gas use is more than offset by growing consumption of electricity. Electricity demand growth is driven by switches from gas to electricity for space heating and other uses; an increasing population and economic activity; and a switch from liquid fuelled vehicles to EVs.

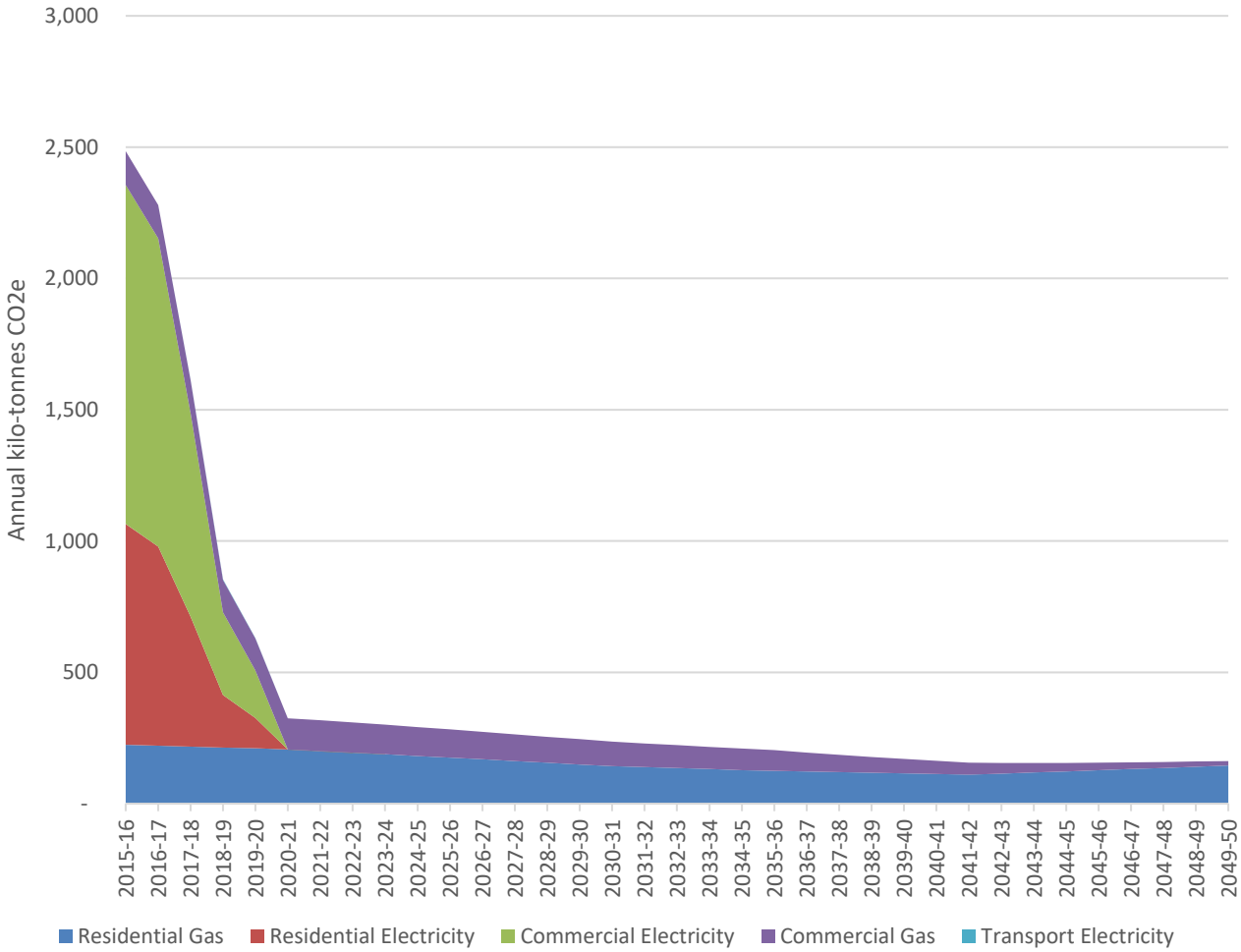



**Figure 12: Greenhouse Gas Emissions from Stationary Energy Use – Reference Medium Scenario**

Figure 12 shows a scenario where electricity emissions fall to zero by 2020 due to the current ACT policy of sourcing 100% of electricity from renewables. The policy objective of zero emissions from electricity use is continued to be acted upon under this scenario, with new renewable electricity supply contracts as required to match any growth in demand for electricity after 2020. Emissions from stationary energy use are accordingly confined to gas after 2020. Gas emissions modestly decline as residential and non-residential buildings switch the delivery of energy services (particularly space heating) from gas to electricity.

All new and additional renewable electricity supply post-2020 will reduce ACT emissions relative to the counter-factual, which would be purchases from the NSW pool. Although the emissions intensity of the NSW pool (net of supply from LRET accredited wind and solar generators) was fairly constant until early 2017, it has fallen since the closure of Hazelwood power station in Victoria ended large net imports of brown coal generated electricity from Victoria. Assuming that the LRET is fully "built out" by 2020, all new generation in NSW from then on will contribute to the NSW pool. The large Liddell power station is scheduled to close in 2022 and it is very likely that its output will be largely replaced by new wind and solar generation, thus significantly reducing the emissions intensity of NSW pool electricity. However, the rate of growth and the total quantity of renewables in NSW will depend in part on future policy choices. At present the design of such a mechanism is the focus of debate at the political level (such as the Finkel Review's Clean Energy

Target), and is highly uncertain. Consequently, the future emissions intensity of the NSW pool can only be estimated in an approximate manner. For illustrative purposes only, we might envisage a scenario where emissions intensity dropped by 4% per year in NSW. This would bring emissions intensity in the NSW grid from around 0.9 tonnes $CO_2e$ per MWh down to around 0.2 tonnes $CO_2e$ per MWh by 2050. Compared to this particular scenario, the ACT's 100% Renewable Electricity policy avoids around 50,000 kilotonnes of $CO_2e$ to 2050.

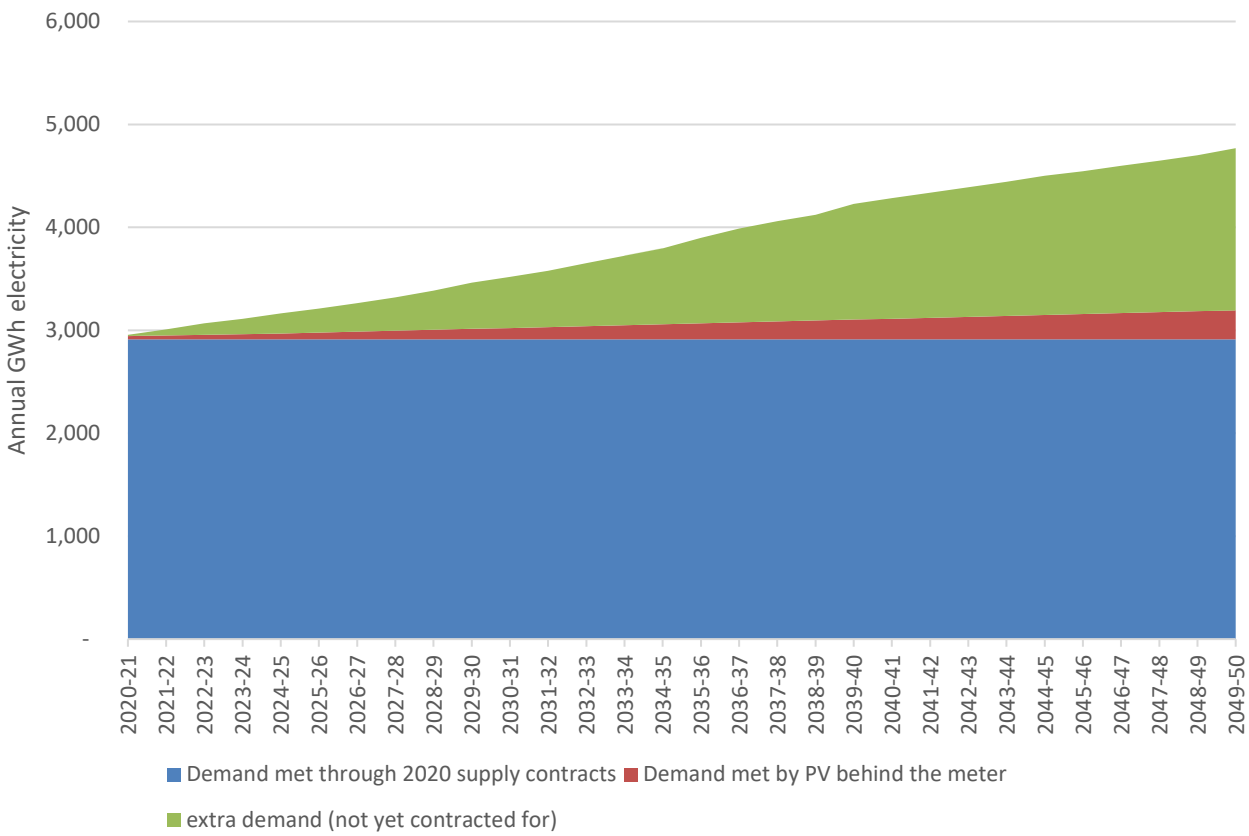



**Figure 13: Electricity Demand & Supply from 2020 - Reference Medium Scenario**

Figure 13 shows wedges of electricity demand. The small red wedge represents the portion of electricity demand that is met by behind-the-meter generation. This is the PV electricity produced and used in ACT buildings on-site. The blue wedge is the chunk of demand that will be covered by ACT contracts for large scale renewable electricity that will be in place from 2020. The green wedge shows demand growth for electricity that is projected to occur under this scenario. This projected demand growth is not yet met through any supply contracts or policies to drive extra embedded generation.

The extent of demand growth could be lowered by new energy efficiency programs (the reference scenario takes into account current policies impacting energy efficiency and embedded generation).

The financial benefits which energy use efficiency improvement provides to consumers have been enhanced by the large increase in retail electricity prices for 1 July 2017. These increases have been caused by very large rises in wholesale electricity prices across the NEM during 2016-17. While wholesale prices are expected to moderate from the extreme levels reached during the June 2017 quarter, there is no informed

expectation that they will revert to the levels prevailing prior to mid-2016. For example, the modelling undertaken for the Finkel review projects wholesale prices in the NSW pool, with current policy settings, will be in the range $75 to $80 per MWh (in 2017 dollars) between now and around 2028. Should the Review's preferred Clean Energy Target policy be implemented, the modelling projects somewhat lower prices, falling as low as $55 per MWh in 2030, which is still substantially higher than pre-2016 prices.

These expectations of continuing high wholesale electricity prices have two implications for the ACT. Firstly, the benefits of increased electricity use efficiency will remain high. Secondly, contracting for additional renewable electricity supply after 2020 is unlikely to cost more, and may well cost less, than purchasing through the NEM.

The technology pathways section of this study (Chapter 4) show:

- Technical options for lowering electricity and gas demand from reference scenario levels via energy efficiency
- Technical options for meeting energy demand with embedded energy renewable energy sources.

The policy pathways section of this study (Chapter 5) shows how those technical opportunities might be realised through the implementation of new policy measures.

## 3.4 Reference Case – Low and High Scenarios

### 3.4.1 Specification of Low and High Scenarios

The Low and High scenarios were defined by changing the assumed rates of growth of population and GSP. For the Low scenario, population was assumed to grow at 0.8 times the rate used for the Mid scenario. GSP was then assumed to grow at 1.25 times the rate of population growth, rather than 1.5 times as assumed for the Mid scenario. For the High scenario, population was assumed to grow 1.2 times faster than in the Mid scenario. GSP was in turn assumed to grow at 1.75, rather than 1.5 times, the rate of population growth.

These changed assumptions directly affect the projected stock of dwellings in the residential sector model, which in turn feeds through to all components of residential energy consumption. In the commercial sector model, the synthetic stock models for HVAC and hot water are similarly affected, feeding through to energy consumption projections. For all other energy use categories, in both the residential and commercial sectors, projections of energy use are directly affected by the changed rates of growth of population and GSP.

The only other differences between the three cases relate to the future regulated energy efficiency requirements of new buildings, in both the residential and non-residential sectors. For residential buildings, the assumptions are as follows:

**Table 3: Scenario Definitions**

| Sector | Scenario | Parameters |
|---|---|---|
| **Residential** | Mid emissions | 7 star in 2022-23, 7.5 star in 2028-29, 8 star in 2034-35 |
| | Low emissions | 7 star in 2019-20, 7.5 star in 2022-23, 8 star in 2025-26 |
| | High emissions | 6 star only throughout |
| **Commercial** | Mid emissions | 30% increase in the new building minimum efficiency in 2019-20, followed by further increases of 15% in 2025-26 and again in 2031-32 |
| | Low emissions | 40% increase in the new building minimum efficiency in 2019-20, followed by further increases of 20% in 2025-26 and again in 2031-32 |
| | High emissions | 20% increase in the new building minimum efficiency in 2019-20, followed by further increases of 10% in 2025-26 and again in 2031-32 |

All other assumptions and independent parameter values are unchanged from the Mid scenario.

### 3.4.2 Reference Case High Scenario Results Charts

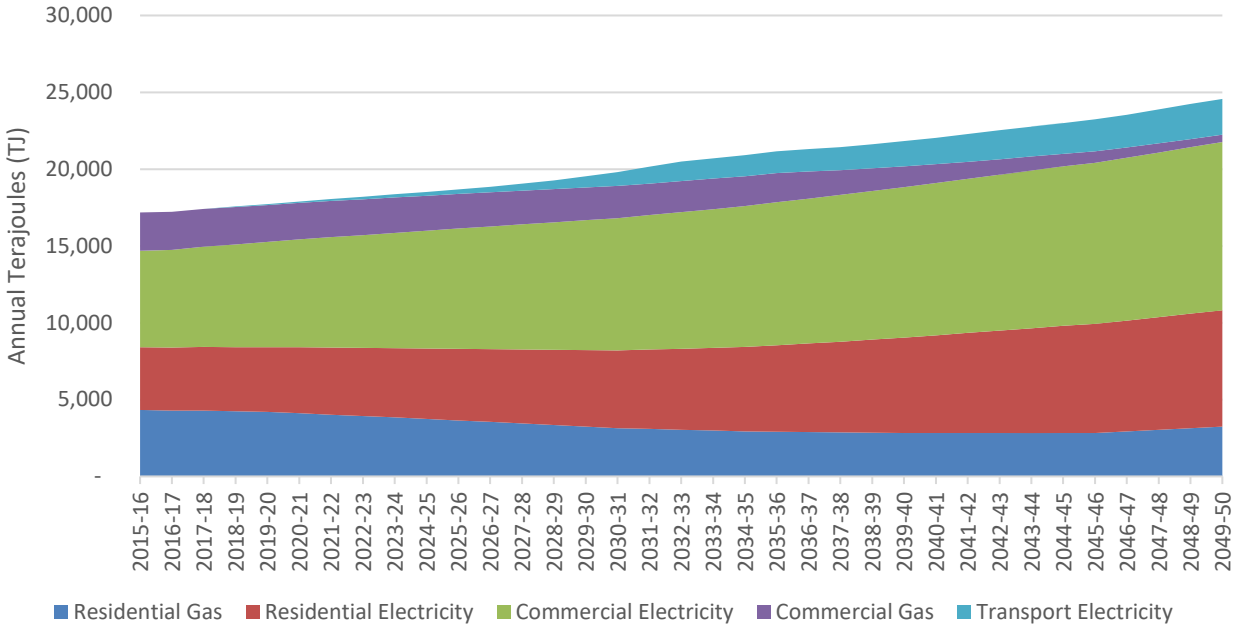



**Figure 14: Energy Use Projections by Sector – Reference High Scenario**

Figure 14 shows a scenario where total demand for stationary energy increases to a point higher than under the medium scenario. The additional demand is driven by higher population and economic activity. A decline in gas use still occurs with switching from gas to electricity. Transport electricity use is smaller under this scenario with a lower rate of switching from liquid fuelled to electric vehicles.

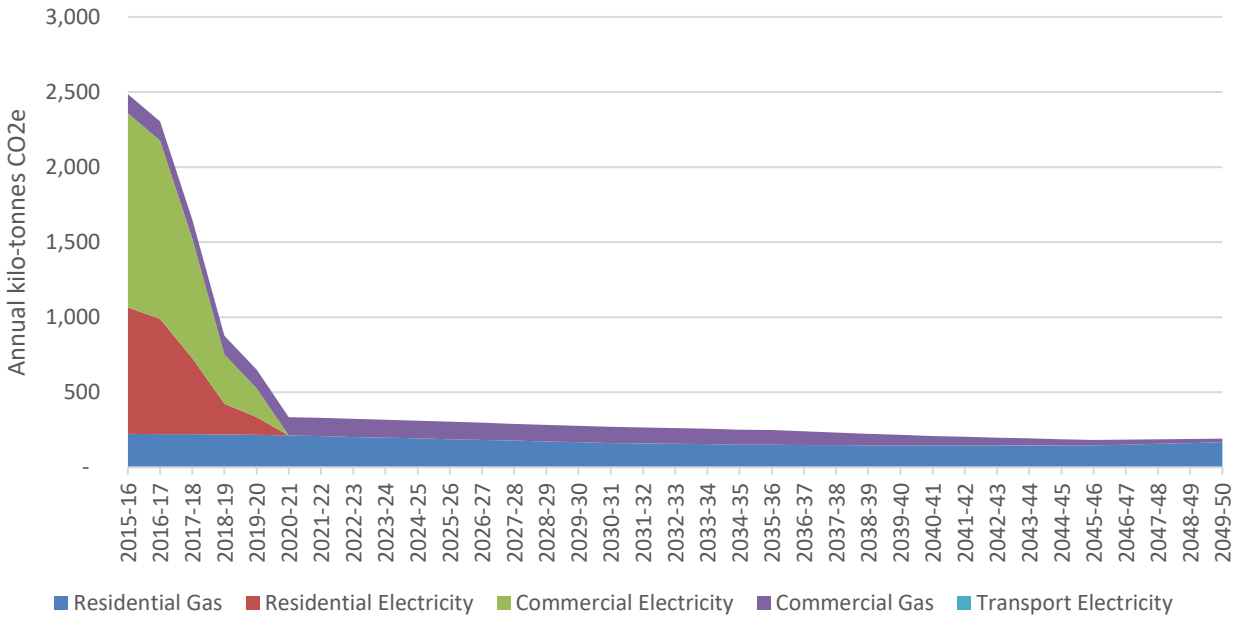



**Figure 15: Stationary Energy Greenhouse Gas Emissions - Reference High Scenario**

Emissions under the high scenario are greater than the medium scenario due to more gas consumption.

### 3.4.3 Reference Low Scenario Result Charts

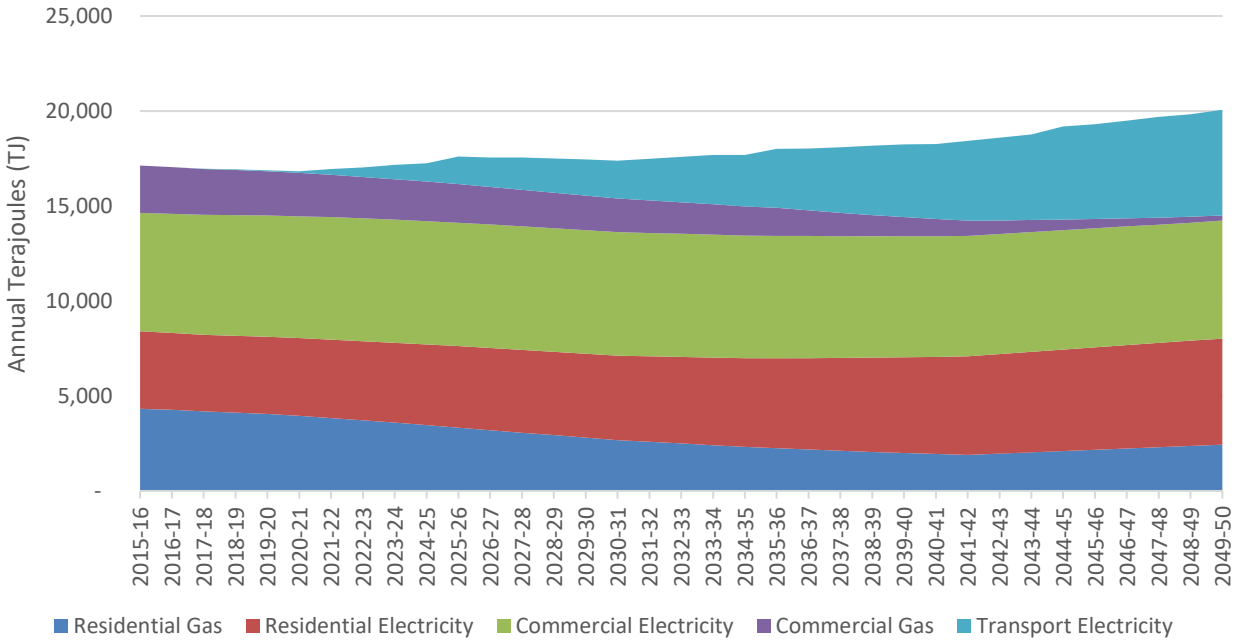



**Figure 16: Stationary Energy Consumption - Low Reference Scenario**

Under the low scenario non-transport energy use falls over the period to 2050. Energy efficiency improvements modestly outweigh population and economic growth. Total energy use rises though with a higher rate of electric vehicle use for transport. Note that this higher rate of electricity use would see overall ACT emissions fall as electric vehicles are more energy efficient on a Joule per km basis than their liquid fuelled counterparts.

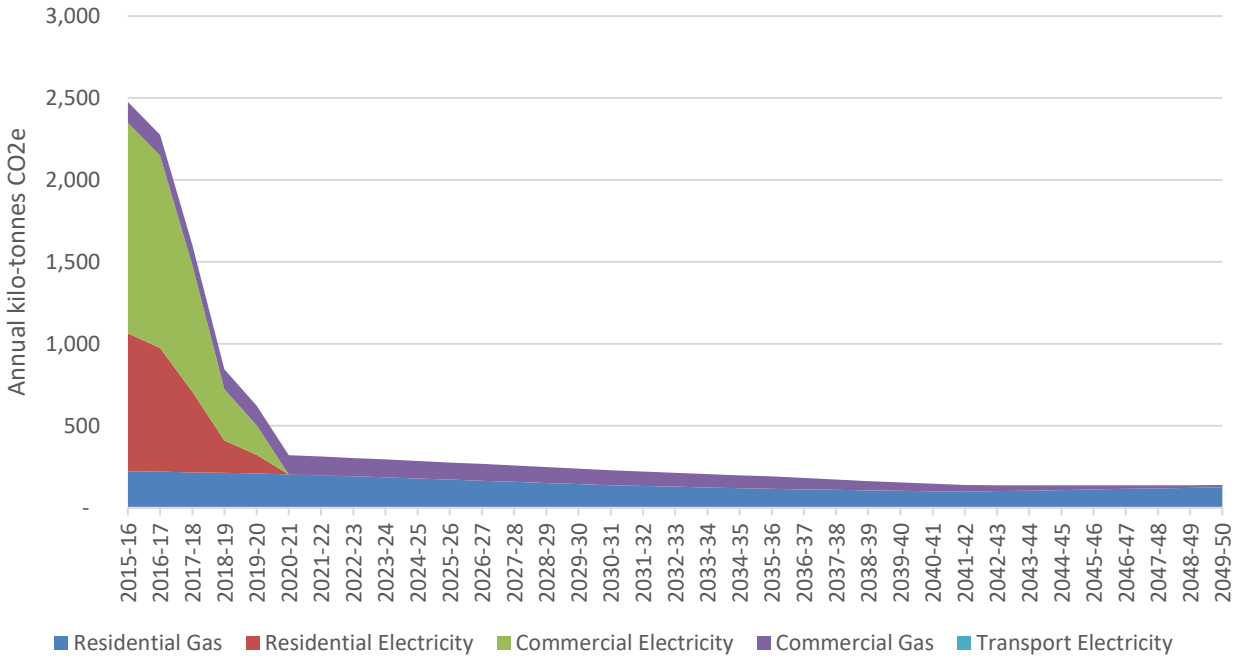



**Figure 17: Stationary Energy Greenhouse Emissions - Reference Low Scenario**

Figure 17 shows the lowest level of emissions of the reference scenarios. Gas emissions remain under this reference scenario.

# 4. Abatement Potentials

For the purposes of this analysis, technical abatement potential means the maximum beneficial effect of feasible technological measures over time. In the short term, this assumes full uptake of best-available technology by 2020, ie, without practical constraints imposed by cost, policy or of uptake timing. The purpose is to provide an envelope of potential – the hypothetical best-case scenario.

## 4.1 General

The rate of adoption of high-performing (ie, very efficient) products and methods is highly sensitive to energy tariffs and policy settings. However, for the purposes of this analysis, best-available technology is assumed to be adopted immediately and completely, as this scenario examines technology potentials, and not expected outcomes.

The technology approach is substantially drawn from that described in the Beyond Zero Emissions (BZE) Zero Carbon Australia Buildings Plan (the 'Buildings Plan') (BZE, 2013).

## 4.2 Summary

The analysis in this document is summarised by the charts shown below (from the accompanying spreadsheet). These show that the greatest scope for improvement lies with on-site generation and HVAC.

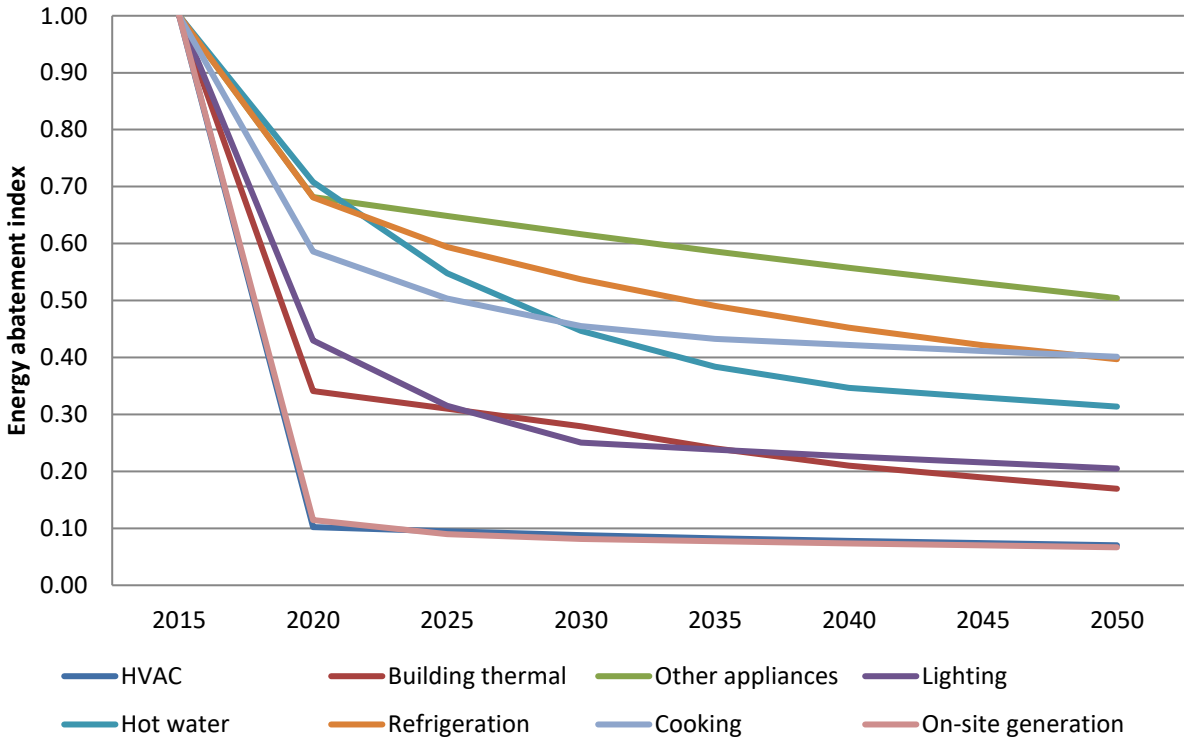



**Figure 18: Abatement Potentials – Residential Sector**

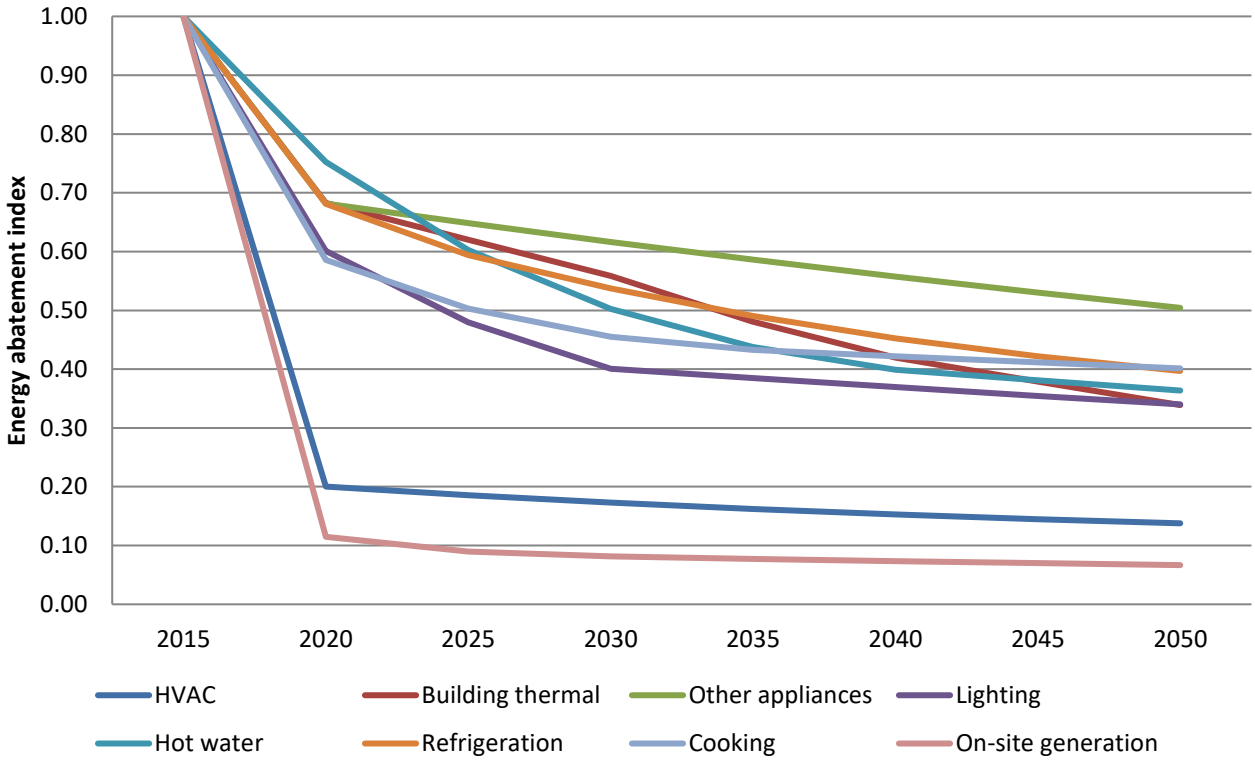



**Figure 19: Abatement Potentials – Non-Residential**

## 4.3 Space Heating & Cooling

### 4.3.1 ACT Baseline situation

*Residential.* As at 2015 each home in the ACT uses, on average, 32.4 GJ/annum on heating and cooling. This corresponds to 219 MJ/m$^2$/annum.

**Table 4: Residential Energy Baseline for 2015**

| Heating energy split | Energy [PJ/annum] | Proportion [%] |
|---|---|---|
| **Electric** | 0.62 | 12.0% |
| **Mains gas** | 4.04 | 77.8% |
| **LPG** | 0.01 | 0.1% |
| **Wood** | 0.53 | 10.1% |
| **Total** | 5.20 | 100.0% |

*[Source: EES/BZE Stock Model as used in the BZE Buildings Plan (BZE 2013)]*

New dwellings are subject to 6-star thermal efficiency minimum standard, which in the ACT corresponds to nominal 165 MJ/m$^2$/annum.

### 4.3.2 Technology and contextual trends

Changes to space heating and cooling will be influenced by local climate changes. ACT climate projections included in NARCliM climate model (NSW and ACT Climate Model).[4] From ACT Climate Adaptation Strategy (2016):

> *By 2030 warming of 0.6–1.3°C above 1986–2005. By 2090, for a high emission scenario warming is 2.7–4.5°C; intermediate scenario warming is 1.3–2.4 °C above 1986–2005. Frost days, temperatures under 2°C, could halve by mid-century.*

#### *Residential retrofit performance*

BZE modelling (2013, Part 5, Section 2.1) for Canberra of the effects of comprehensive home retrofit indicated substantial improvement as shown below.

**Table 5: Residential Retrofit Performance**

| *Home* | *Stars* | *MJ/m2* | *Building Envelope Improvement* |
|---|---|---|---|
| **Assumed stock average** | 2.7 | 430 | 0 |
| **Improved by retrofit** | 6.3 | 152 | 65% |

#### *Residential new-build performance*

A reasonably feasible useful upper limit to thermal performance achievable in the Canberra climate today for construction en-masse is 9.0 stars (confirmed by Adams, 2017). In the mid-term future, this could be raised to 9.5 stars. Beyond this level of build performance there is a diminishing return, ie, the further operation benefits are outweighed by the increased costs to achieve progressively higher thermal performance.

[4] https://climatedata.environment.nsw.gov.au/, viewed 30/6/2017.

**Table 6: Residential New-build Performance**

| *New-build home rating* | *Stars* | *MJ/m2* | *Building Envelope Improvement (relative to 6.0 stars)* | *Building Envelope Improvement (relative to 2.7 stars)* |
|---|---|---|---|---|
| **Assumed stock average** | 2.7 | 430 | - | 0 |
| **Minimum current nominal** | 6.0 | 165 | 0 | 62% |
| **Assumed max feasible en-masse 2020** | 9.0 | 35 | 79% | 92% |
| **Assumed max feasible en-masse 2035** | 9.5 | 17 | 90% | 96% |

Current best-available technology exemplar (for domestic use) is the Daikin US7 reverse-cycle split system.[5] Key points:

- Seven-star performance;
- Coefficient of Performance/Energy Efficiency Ratio (COP/EER) of 5.81/5.95 for heating/cooling for the smallest of the three sizes available;
- COP/EER of 4.60/4.24 for heating/cooling for the largest of the three sizes available;
- Provides humidity control;
- Provides fresh air delivery.

Current best-available technology exemplar for commercial use is a system based using centrifugal water-cooled chiller, which is capable of COPs as high as 10 (Bannister 2017). Use of water-cooled chillers increases performance by a factor of about 2x (op cit) and might be expected on systems over about 600kW(thermal) capacity.

### *Near-term*

- Increased technical performance of heat-pump heating which is an alternative to gas;
- Efficiency of vapour-compression heat pumps continues to improve.
- Smart HVAC management becomes common eg CSIRO Building IQ (CSIRO, 2016)

### *Mid-term*

- High-efficiency non-vapour compression heat-pump technologies appear commercially (Bouza, 2015). Thermoelastic Cooling (TEC) technology looks promising.
- Heat pump performance (COP) in commercially available products reaches 12.

[5] http://www.daikin.com.au/us7, viewed 30/6/2017.

- Air-quality management becomes a recognised and important capability of residential heating and cooling systems. New standards governing indoor air-quality apply (Romm 2016, Allen 2016). Greatly reduced cost of sensors for air quality makes them ubiquitous, monitoring humidity, temperature, $CO_2$, VOCs and particulates.
- Ubiquitous network connections (IoT) integrate sensor data on a massive scale, facilitating improved management of heating and cooling.
- Reduced heating and cooling intensity (MJ/m$^2$/annum) requirements due to improved building form, materials and building practice. We can expect to see large-scale thermal improvement to existing stock through natural turnover and retrofits.
- Large-scale switch off gas for heating in existing stock, especially in residential as a result of near-term factors mentioned above applying to retrofits and stock turnover.
- Climate shift reduces heating energy and increases cooling energy requirements. Climate trends improve average efficiency of heat pumps for heating and lessen efficiency for cooling.
- Targeted heating and cooling systems integrated into furniture (like Japanese Kotatsu in-table heater).
- Ground-source heat pumps remain niche products because of very high capital costs.

***Long-term***

- Gas in residential substantially or completely eliminated because of global pressures for its elimination.
- Heat pump performance (COP) in commercially available products reaches 15.
- Targeted heating and cooling systems integrated into clothing (climate adaptation issue).

### 4.3.3 Impacts

***Building performance***

Comprehensive retrofit of existing stock undertaken by 2020 raising average performance of old stock to 6.3 stars. Code stringency is assumed to rise to 9.0 stars in 2020, and to 9.5 stars in 2035. The effect of these measures will be a steady rise in the building stock to 8.2 stars in 2050. Increase in performance of non-residential buildings is assumed to be half that of residential.

***HVAC***

Rapid adoption of best-available technology (ie using heat pumps, not gas) has the potential to increase the functional efficiency by a factor of ten in residential applications. The effective performance of HVAC equipment will continue steadily in the long term. Over the entire period heat pump performance will improve. Performance in cooling will dominate non-residential applications. As a result, replacement of gas will be more straightforward. Thermal envelope is slightly less critical because internal heat loads have a greater relative impact than in residential. Overall the potential for best-case improvement is estimated to be only half that available for residential based on a general observation of the current state of each domain.

*Ground-source heat pumps.* It is worth noting that our assessment excludes ground-source heat pumps (GSHPs) as a worthwhile candidate technology for mass-market high-efficiency HVAC. This is because, although very efficient, the very high capital cost and complexity are expected to remain. So, the GSHP's marginal benefit in efficiency (relative to best air-source devices) is more than offset by the mass-market simplicity and maintainability of high-efficiency air-source technology. Another factor working against GSHPs is the relative difficulty in retrofitting them because of the ground works required. So, air-source heat pumps are likely to remain the HVAC technology of choice.

## 4.4 Other Appliances

### 4.4.1 ACT Baseline Situation

***Residential***

As at 2015 the estimated energy used per household per annum by other appliances (ie excluding lighting, refrigeration, cooking) is 3536kWh (BZE 2013), which corresponds to an average continuous power of about 400W. This is 19.8% of home energy use. Main loads in this category are dishwashers, washing machines, clothes dryers, pool pumps and televisions.

### 4.4.2 Technology Trends

Increased number of appliances per household will be offset by continuing improvement in energy performance.

We can expect a significant increase in the number of small electronic devices such as home monitoring, and security systems (including cameras).

### 4.4.3 Impact

Rapid adoption of best-available technology will see a reduction in per-household energy use in this category by 32%. Premises will continue to see increased number of devices over time which will counteract improvements in per-device efficiency. Long-term trend is expected to be a continuing very slight reduction.

## 4.5 Lighting

### 4.5.1 ACT Baseline Situation

***Residential***

As at 2015 the energy used for lighting was about 800kWh/annum/home (BZE 2013). This is about 4.5% of overall energy or about 11% of electricity use.

Significant lighting energy in ACT is expended on streetlights.

### 4.5.2 Technology Trends

US DoE (Penning, 2016) forecast annual lighting energy demand to drop 75% (2015-2035), due mainly to wholesale adoption of solid-state (ie LED) lighting. Lighting efficiency (based on luminous efficacy for A-type light bulbs) is expected to increase from 79lm/W to 133lm/W in the same period.

Smart control (networked IoT) technology has potential to reduce energy used for street lighting beyond what is possibly by LEDs alone (eg Silver Spring, 2013, pp4) by better matching output with need.

### 4.5.3 Impact

Rapid adoption of best-available technology will see a reduction in per-household energy use in this category of 53%. Expect lighting energy intensity to reduce by 75% by 2035. Most of the reduction will occur by 2023. Minimal improvement post 2035.

## 4.6 Hot Water

### 4.6.1 ACT Baseline Situation

***Residential***

As at 2015 homes in the ACT use 17% of their overall energy on water heating. This is split about 5.2GJ/annum (1444kWh/annum) of electricity and 5.7GJ/annum of gas (BZE 2013).

### 4.6.2 Technology Trends

Heat pumps and solar hot water technologies give potential to reduce HWS energy by 75% using today's best-available technology. Heat pumps and solar thermal systems can be combined to create systems capable of 95% energy savings (Keech 2011), however these are unlikely to be economical due to diminishing returns from the higher up-front costs.

Heat pump units are already available that can heat efficiently even in cold weather (Eklund 2013).

Hot water systems will benefit from new the same improvements in heat-pump technologies mentioned above for space heating and cooling.

ACT has good wintertime insolation, so both solar hot water and heat pumps will continue to be good candidates for reduced energy. However, competition for available rooftop space is likely to crowd out solar hot water collectors in favour of PV.

Hot water energy performance is amenable to considerable further improvement through increased stringency and enforcement of standards.

Typical life of a unit is 10-15 years, so most existing homes to have units replaced by 2030 by natural turnover.

Exemplar of best-available technology today is the Sanden Eco (model GAU) heat pump from Japan which uses a $CO_2$ refrigerant (low-GWP). COP measured 4.1 at 20C (Eklund 2013).

Washing machines and dishwashers are increasingly not taking a hot-water input. This will continue to lessen total hot-water demand and possibly smaller HWS tanks.

Higher ambient temperatures will slightly reduce total hot-water energy requirements, by reducing standing losses and slightly increasing cold-water inlet temperatures.

### 4.6.3 Impact

Rapid adoption of solar and heat pumps will reduce per-home hot-water heating energy requirements by 29%. Continued incremental improvement in unit efficiency is likely to see per-home hot-water heating energy requirements reduce by 69% (relative to 2015 stock average) by 2035.

*Complementarity with PV.* It is worth noting that increased adoption of rooftop PV will increase the incentive for all-electric hot-water (for both new-build and retrofit) because of the capacity for hot water systems to serve as a flexible electric load which can improve solar self-consumption (Forcey 2015). It is reasonable to expect that +1kW of solar PV capacity will fully offset the hot-water energy requirements, even in the worst month of the year (BZE 2013). So, PV and electric hot water are highly complementary to one another. This will serve to soften the impact of any transition to all-electric hot water.

## 4.7 Refrigeration

### 4.7.1 ACT Baseline Situation

***Residential***

As at 2015 the energy used by refrigeration equates to 4.4% of total home energy, or about 11% of electricity.

### 4.7.2 Technology Trends

Historical trends to 2014 (EES 2016) indicate a reduction in refrigeration energy per litre by about 2.7% per annum. In 2014 the average new refrigerator in Australia consumed 453 kWh/year (op cit), whereas in the same year in the EU the average new refrigerator consumed only 242 kWh/year (46% less)[6].

There is no fundamental impediment to refrigeration efficiency continuing to improve at the historical rate for the foreseeable future.

Refrigeration will benefit from new the same heat-pump technologies mentioned above for space heating and cooling. For example, other advanced heat-pump technologies like thermoelastic cooling (TEC) will emerge on the market.

### 4.7.3 Impact

Rapid adoption of best-available technology in this category would lead to reduction of 32% per household. The 2.7%/annum average rate is expected to taper off as incentive for further improvement diminish.

## 4.8 Cooking

### 4.8.1 ACT Baseline Situation

***Residential***

As at 2015 the energy used by cooking equates to 3.4% of overall energy, split about 55:45 gas:electricity (BZE 2013).

[6] http://www.topten.eu/uploads/File/White-Goods-in-Europe-short.pdf

### 4.8.2 Technology Trends

Near-term:

- Market share of electric induction cooktops increases as a) awareness of benefits rises, and b) costs come down because of economies of scale and market maturity.
- Very low-energy cooking technologies (eg insulated crockpots and cookware) become available but uptake is limited.
- Well-insulated electric ovens (pyrolitic) increase in market share.
- Electric cooking requires relatively high electric power for short periods, often at peak time.
- Induction using about 50% less energy than gas, and about 10% less energy than conventional electric (BZE 2013 pp97).
- Use of microwave ovens as a substitute for conventional oven and cooktop cooking activities will lessen cooking energy.
- Switching to all-electric cooking using best-available technology expected to reduce cooking energy by 29%.

Mid- and long-term:

- Further incremental improvements arising from things like improved materials (better-insulated ovens and cookware).

### 4.8.3 Impact

Significant reductions in cooking energy in the near and mid-term are possible, arising from insulated ovens (pyrolitic), greater use of microwave ovens, and replacement of gas cooktops with induction electric. Rapid adoption of this best-available technology would lead to a 41% reduction in per-household cooking energy. Only modest but consistent annual improvements expected thereafter as a result of incremental improvements in induction electronics and high-performance insulation (for ovens).

## 4.9 Onsite energy generation

### 4.9.1 ACT Baseline Situation

***Residential***

As at March 2017 13.7% of dwellings had solar PV installed (APVI 2017). For small installations (<10kW) this represented 49MW of installed capacity. Well-configured PV in the ACT can achieve a capacity factor of 17.9%. Total installed current PV capacity in the ACT is 107MW. The biggest PV facility in the ACT is the 24MW Royalla (Acciona 2017) commissioned in 2014. In ACT 7.69MW of new PV capacity was installed in 2016 (average 663kW/month). Rate of installation seems fairly constant for the last three years.

Installed PV in ACT cost in April 2016 about $1.37/W for 5kW systems, installed, incl. tax, net of STC rebate (Martin, 2016). Australia-wide the cost of a 5kW system fell from $2.20/W to $1.40/W between October 2012 and October 2015. This corresponds to an annual rate of reduction of 14%.

### 4.9.2 Technology Trends and Potential

*Fuel Cells*

In the past fuel cells were seen as a way to add on-site generation. This option has faded because it depends upon gas. However, biogas and hydrogen are options for fuel cells in the future. Uptake will depend on the fuel availability and the relative economics with PV and batteries.

BZE (2013, pp194) estimated that viable rooftop solar potential for the ACT was 513MW (469MW residential) based on 2011 roof area.

**Table 7: Rooftop Solar Potential**

| Rooftop potential increase | Dwellings | Increase | Domestic [MW] | | Commercial [MW] | | Total [MW] |
|---|---|---|---|---|---|---|---|
| **2011** | 129146 | - | 469 | | 44 | | 513 |
| **2015** | 146095 | 13.1% | 531 | | 50 | | 580 |
| **2020** | 160102 | 24.0% | 581 | | 55 | | 636 |

Reduction in installed PV system price will taper as installation and balance-of-system costs start to dominate. Notwithstanding, an installed price of $1/W is feasible in the medium term (Munsell 2016).

*Roof-integrated PV*

Considerable potential and interest arises from PV integrated into roof structures, for example those announced by Tesla in 2016. However, it remains to be seen if this would amount to a significant increase the net solar potential by very much (relative to conventional roof-mounted panels).

*Non-roof options*

Beyond conventional on-roof deployment, there are considerable opportunities in the near-term for façade-mounted and building-integrated PV. Winter-time yield of north-facing vertical PV is surprisingly good.

*PV shade structures*

The use of PV modules for shade is emerging for both dedicated shading structures such as over car parks, and also for fixed awnings on buildings. For climate-adapted cities this shade will be important. Thus, PV modules can serve a dual purpose.

In 2016 AEMO commissioned Jacobs to forecast PV growth out to 2037 (Galianis, 2016). This forecasts (their Figure 17) growth (on the entire NEM) of connected rooftop generation to reach about 15GW in 2037 (residential) and about 6GW (commercial). Growth can reasonably be expected to greatly exceed this because:

- rooftop resource is considerably more than this (nationally about 33GW based on 2011 areas),

- inverters will routinely incorporate export limiting capabilities so that local network saturation will not be an issue going forward,
- onsite generation won't be limited to rooftops as discussed above,
- trends towards all-electric homes gives additional incentive to add PV, hence consumer sentiment is likely to favour high installed capacity to reduce energy costs

According to Carbon Tracker (Sussams 2017)

> *Solar PV (with associated energy storage costs included) could supply 23% of global power generation in 2040 and 29% by 2050, entirely phasing out coal and leaving natural gas with just a 1% market share. ExxonMobil sees all renewables supplying just 11% of global power generation by 2040.*

Beyond 2020 further potential could be realised by the use of ubiquitous building-integrated PV which harnesses facades, windows and other non-roof surfaces.

### 4.9.3 Impact

PV will remain the overwhelmingly dominant technology for on-site generation for the foreseeable future. A small amount of fuel-cell deployment is likely if biogas and hydrogen become commonplace but that seems unlikely. Hypothetical full and rapid adoption of the rooftop solar resource in ACT would see 636MW of rooftop capacity by 2020, split 581MW residential and 55MW commercial. This would amount to the average home hosting 3.6kW of PV. In this scenario, subsequent growth of per-home capacity would be modest. The impact on PV of a trend towards higher-density living will be offset by the use of facades and non-roof structures to host PV. The amount of PV per dwelling is likely to plateau by 2030. Small growth subsequently will arise from incremental improvement in the underlying material performance.

## 4.10 Onsite Energy Storage

### 4.10.1 ACT Baseline Situation

#### *Residential*

As at 2015 there is very little on-site energy storage in the ACT. Improvements in grid connection economics improve the payback time though systems like Reposit Power and Geli.

ACT currently rolling out subsidised storage to about 200 homes and businesses through the first round of the Next Generation Renewables Energy Storage Pilot program (ACT, 2016). This roll out expands to about 600 homes in round two (Parkinson, 2016).

### 4.10.2 Technology Trends

Stationary battery systems have traditionally used variations of lead-acid technology. This is being eclipsed by others cell technologies that are emerging and maturing. Most prominent of these is Lithium Ion.

Stationary energy storage will benefit from rapid advances and economies of scale in EV cells. Cell price for EVs has reduced ~80% in 6 years, a 23.5% annualised rate of reduction (McKinsey, 2017). Price dropped from $1000/kWh in 2010 to $277/kWh in 2016 (op cit). South Australia was quoted $250/kWh for 100MWh systems (Sonali 2017).

In-home energy storage is rapidly growing in popularity and awareness from a very low base. Concern about grid energy price and reliability is heightened and will remain high for the foreseeable future. This sentiment will help fuel interest in storage, even before it becomes economical.

High-power vehicle-to-grid energy storage will be limited in the near- and medium-term future because of:

- Poor interoperability between different vehicle and grid systems, and
- Concern for vehicle battery warranty due to cycle life limitations.

Behind-the-meter storage installations will always give the best payback. Notwithstanding, on-grid storage at scale is already starting to happen. Deployed examples include Mira Loma – 80MWh (Cardwell, 2017) and Kauai island 52kWh (Chediak, 2017). The proposed price for 100MW of storage in SA was at $250/kWh (Parkinson, 2017).

Broad adoption and integration is highly dependent upon complementary energy-market rules. In 2016 AEMO commissioned Jacobs to forecast PV and battery-storage growth out to 2037 (Galianis, 2016). This forecasts NEM-installed battery storage rising steadily to 6900MWh in 2037 (Figure 18). This is likely to be a significant underestimate because:

- Energy-security considerations have already significantly changed the landscape since the report was written,
- Battery price drop is likely to be much more aggressive than their forecast (their Figure 9).

In the Asia-Pacific region, battery production rose by 150% in 2016 (GMI 2017).

### 4.10.3 Impact

In the medium-term future, availability of highly affordable on-premises energy storage is assured. Consequently, very high penetrations of the technology can be reasonably expected, except in rented properties. Uptake is hard to predict but we forecast that the average dwelling will have 2kWh of energy storage by 2030 and 8kWh by 2050.

#### *Microgrids*

As onsite generation and storage of energy becomes ubiquitous, another significant emerging trend will be the use of microgrid arrangements to help optimise the distribution of electricity at the end of the distribution network. A microgrid is essentially an arrangement allowing a local group of electricity customers to share both:

- a single grid connection and
- local power generation and storage (usually PV and batteries respectively).

*Embedded network.* A microgrid can be thought of as a special case of an embedded power network. An embedded network is where multiple customers share one grid connection. This is commonly seen in multi-unit residential situations and brings the benefits of economies of scale, such that multiple small-market electricity customers (<160MWh/annum) combine to become a single large-market customer. Embedded networks are normally facilitated by a third-party provider company who acts in the middle, serving both as the customer of the network service provider, and the power retailer for the end users.

*Shared renewables and storage.* By adding PV and batteries, an embedded network becomes a microgrid. This brings with it important benefits:

- *Physical sharing*. In multi-unit residential, configuring per-premises PV and storage can be problematic because of rooftop constraints and property boundary issues. A cooperative approach is usually more effective;
- *Economies of scale*. A single large installation is often more efficient than multiple smaller one, thus brining economies of scale at the levels of installation, operation and maintenance.
- *Demand charges*. The use of renewable and storage can reduce a site's peak demand. Since demand charges make up a significant part of the cost for large-market customers, there is increased potential to save money beyond simple avoided energy charges.
- *Avoided grid upgrades*. The use of microgrids in brownfield/in-fill developments can potentially avoid infrastructure spend that would be otherwise needed to support increased grid demand.
- *Grid rules.* Benefits from microgrids potentially accrue to both customers and network providers. However, there are complexities in setting up microgrids that relate especially to dealing with network connections. Updating the service connection regulations to make microgrids easier would help the uptake of these beneficial but less conventional approaches. For example, it may be necessary to relax the threshold requirements that currently qualify customers as large-market customers.

## 4.11 Options for Renewable Fuels

The general trend in zero-emission energy use is toward electrification. However, there are potential advantages for liquid and/or gaseous fuels – such as biofuels, hydrogen, non-fossil methane and methanol – for example with respect to ease of storage.

The supply of renewable fuel may be necessary, at least in the medium term, to address those remaining energy uses which are not immediately amenable to electrification. In the longer term, there is some hope that electrification might be feasible for almost all end-uses. In the meantime, renewable fuels will play a part.

Since ACT chooses to be at the vanguard of decarbonisation, it follows that ACT may decide to show leadership in the deployment of suitable renewable fuels.

Also, given the widespread dependence upon methane and the extensive infrastructure and appliances built around it, it might be attractive to directly substitute fossil methane with synthetic- or bio-methane to the extent that they are available. This avoids great cost by utilising existing infrastructure, compared with creating a new energy infrastructure.

### 4.11.1 Biofuels

*Background*

Bioenergy production in Australia was 3.6TWh in 2016, amounting to 1.4% share of generation.[7] This was up 11.4% from 2015, but about steady over the preceding decade. Biomass, biogas and biofuels make up 63% of all renewable consumption, and renewables are 5.8% of total energy consumption.

**Table 8: Biofuels in 2016**

| Source | Proportion of total renewable energy consumption (%) |
|---|---|
| Biomass | 54.4 |
| - wood, wood waste | 23.8 |
| - bagasse | 30.0 |
| - other | 0.6 |
| Biogas | 5.6 |
| Biofuels | 3.3 |
| Bioethanol | 2.0 |
| Biodiesel | 1.4 |

Electricity generation from biofuels is at about 0.9% of total generation. The largest single contributor to bioelectric generation is from bagasse (sugar cane waste) – mostly in QLD. CEC Bioenergy roadmap8 forecasts 72TWh/annum bioelectric generation in 2050, the great majority of which uses agricultural waste as a feedstock.

On top of existing bio power, there is some scope for an expanded role for bio-based stationary energy to serve as backup power. Bio-energy backup power could serve along with pumped hydro to give complementary grid energy for those times when neither wind nor solar are sufficiently available. Bio-energy backup generators were envisaged in exactly this role in BZE's Stationary Energy Plan.

Framing this as 'backup' capacity would mitigate concerns about forests being burned for energy. The idea would be to emphasise the potential to exploit readily available agricultural residuals without diverting productive agricultural resources from food etc.

[7] Office of the Chief Economist (OCE), 2016, 'Australian Energy Statistics 2016', Australian Government, https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/aes/2016-australian-energy-statistics.pdf

[8] CEC, 2008, 'Australian bioenergy roadmap : setting the direction for biomass in stationary energy to 2020 and beyond', Clean Energy Council, http://trove.nla.gov.au/version/45678414

Via the torrefaction process there's potential for turning waste biomass into a coal-equivalent material. This may give rise to the opportunity to re-purpose some existing coal-fired generation assets (including perhaps some of the jobs) for backup power[9].

### *Hydrogen*

The promise of hydrogen. Hydrogen gas (H2) has been widely proposed as a renewable fuel and industrial feedstock produced by using water and renewable electricity. Talk of the 'hydrogen economy' has been around for years based on the idea that H2 offers better prospects than the combination of renewable electricity and (chemical) batteries or other energy storage.

**Hydrogen properties.** Hydrogen gas has an energy density (by weight) about three times that of gasoline. Hydrogen molecules are very small so proper containment is more difficult than for other fuels.

**Table 9: Hydrogen Heating Capacity in Context**

| Fuel | Energy density [higher heating value MJ/kg] |
|---|---|
| Hydrogen | 142 |
| Methane | 55 |
| Propane | 50 |
| Gasoline | 47 |

**Hydrogen from electrolysis.** The process of electrolysis of water using electricity yields hydrogen and oxygen plus heat. Where electricity is abundant then hydrogen can be used as an energy storage and transfer medium. The most common electrolyser technology is alkaline electrolysis. Proton Exchange Membrane (PEM) electrolysis is more efficient. Other technologies are in the pipeline. There does not appear to be any in-production large-scale use of electrolysis for hydrogen as a fuel. Most (>90%) industrial hydrogen production is currently from steam reforming of methane (SRM) and is used as an industrial feedstock not as a fuel.

**Electrolysis water and energy.** The basic chemistry of electrolysis involves 9.0kg of water to produce 1.0kg of hydrogen. An example commercial high-end alkaline electrolyser (Nel A-Type, see Figure 20) uses 10L of water and 42.3 – 48.9kWh of electricity per kg of 200bar hydrogen produced, making it 41% - 47% efficient.

[9] Livingston, W.(ed), 2016, 'The status of large scale biomass firing: The milling and combustion of biomass materials in large pulverised coal boilers', IEA, ISBN 978-1-910154-26-7, http://www.ieabcc.nl/publications/IEA_Bioenergy_T32_cofiring_2016.pdf

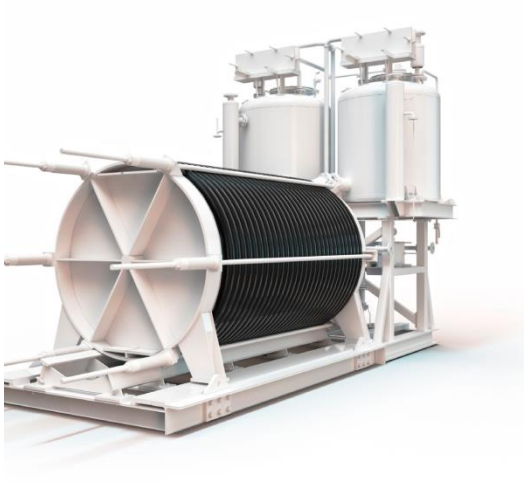


**Figure 20: A Nel A-Type commercial alkaline electrolyzer (Nel)**

### *Potential uses for hydrogen*

**Electrical generation.** Hydrogen can serve as a means of direct electrical generation through the use of fuel cells. Fuel cells take hydrogen and air and generate electricity and water. Their efficiency varies, but a good average estimate is 47%[10]. Fuel-cell technology is still maturing. The most widely used fuel cells are based on a technology that depends on non-trivial amounts of platinum as a catalyst. As a result, they are currently very expensive. Creating low-cost fuel-cell technology is the subject of much active research.

**Supplementing natural gas.** A possible role for hydrogen is to blend with methane ('natural gas'). This might be done to reduce the emission intensity of the gas and/or to create a flexible load for renewable energy generators. This appears to be viable[11] at concentrations up to 15% without modifying the existing gas infrastructure or appliances. It has also been proposed that hydrogen distribution could take place through the gas network by blending, and then separating at the point of use. Leakage could be an issue because hydrogen permeation rates are 4 to 5 times that of methane in typical polymer pipes.

**Electrical energy storage.** It is possible to use H2 for effective storage of (perhaps surplus) electrical energy. An electrolyser creates the H2, and a fuel cell turns it back into electricity. However, the round-trip energy efficiency of this process is about 30%, compared to about 83% for lithium batteries10.

**Fuel-cell vehicles.** There has been an enormous investment in the development of Hydrogen Fuel Cell (HFC) vehicle technology based around H2 as a fuel. The promise of HFCs is that they offer long driving range, rapid refuelling with a (potentially) emission-free fuel for fuel-cell vehicles (FCVs). Currently Honda, Toyota and Hyundai have FCVs (Clarity, Mirai and ix35 respectively) in very limited production. They are not available in Australia though Hyundai have announced the ix35 in Australia. In an FCV, H2 is stored in high-pressure tanks, typically made using filament-wound carbon fibre for strength. The Hyundai ix35, for example, stores 5.6kg of H2 at 700bar[12]. If the automotive market reaches the expected EV tipping point17 in the near future, then

[10] Pellow, M., et al., 2015, 'Hydrogen or batteries for grid storage? A net energy analysis", DOI: 10.1039/C4EE04041D (Analysis) Energy Environ. Sci., 2015, 8, 1938-1952, http://pubs.rsc.org/en/content/articlehtml/2015/ee/c4ee04041d

[11] Melaina, M., et al, 2013, 'Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues', NREL, http://www.nrel.gov/docs/fy13osti/51995.pdf

[12] For comparison, LPG-fuelled vehicles store that fuel in tanks at about 6bar to 15bar depending on the temperature according to Elgas.

it's unlikely that FCVs, even if they become mature and affordable, will be able to prevent EVs from achieving market dominance. So, it might not be sufficient for FCVs to be as good as EVs if they 'miss the boat'.

**Figure 21: Filament-wound tank from a Hyundai ix35 FCV**

**Hydrogen conversion.** Creation of H2 from renewable energy can be an intermediate step in the creation of other, more familiar fuels or intermediates such as methane, methanol and ammonia. This is discussed further in section 4.11.2 below.

### *Challenges and Issues with Hydrogen*

**Physical properties.** Some basic physical properties of hydrogen are relevant. Hydrogen combusts in air across a very wide range of concentrations (4% to 75%). For comparison, gasoline is explosive only between 1.4% and 7.6% concentrations13, although its very low density means that leaking gas will rise quickly and dissipate if a pathway exists. Hydrogen burns in air with only a very faint blue flame which is almost invisible in daylight. Unlike most hydrocarbons, hydrogen flames emit in the UV band, and very little in the near-IR band making it hard to see. The minimum energy required for hydrogen ignition (0.02mJ) is about one tenth that required for gasoline. Hydrogen isn't corrosive but it can make some metals brittle.

**Embodied water.** Each kg of hydrogen derived from electrolysis requires 9L-10L of high-purity water as a feedstock. It follows that an economy producing large amounts of Hydrogen requires a reliable source of water that might otherwise be required for environmental flows and/or agricultural production. Looked at another way, consumption of large amounts of hydrogen involves large amounts of embodied water.

**Transportation of Hydrogen.** The low volumetric density of hydrogen increases fuel transportation costs. It has been estimated[16] that at 40-tonne delivery truck, capable of carrying 25t of gasoline, would only carry 300kg – 500kg of H2. Even allowing for H2's high energy capacity (by weight), this represents a significant efficiency penalty. This might not be so much of an issue if H2 can be generated onsite.

**Compression.** The volumetric density of H2 is 0.090g/L at standard temperature and pressure (STP). Therefore, volumetric energy density at STP is only 12.7J/L. The very low volumetric density of H2 at

[13] H2Tools, 'Hydrogen compared to other fuels', https://h2tools.org/bestpractices/h2properties

atmospheric pressure dictates that very high-ratio compression is necessary for practical storage and transportation. The commonly seen pressures used for hydrogen refuelling stations (HRSs) are 350bar and 700bar[14]. Adiabatic[15] compression to 700bar requires energy equivalent to about 16% of the energy in the hydrogen[16].

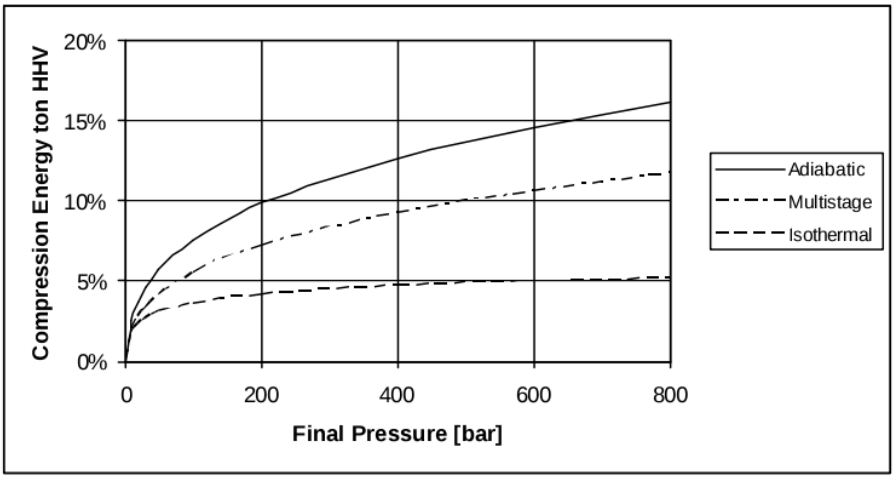



**Figure 22: Energy loss from hydrogen compression (from Bossel and Eliason)**

**Fuel Efficiency.** The use of hydrogen as a fuel presents some practical problems. For stationary energy-storage applications the very low round-trip efficiency (about 25% - 30%) is a grave limitation. In this application, hydrogen would need to compete against pumped hydro and batteries – both of which offer round-trip efficiencies greater than 80%. The same efficiency issues apply when hydrogen is used in FCVs for transport. So EVs are about three times more energy efficient (grid to wheels) than FCVs[17].

[14] SAE J2061

[15] Adiabatic compression loses energy due to heat loss arising from the compression.

[16] Bossel, U. and Eliason, B., 2003, 'Energy and the Hydrogen Economy', http://www.afdc.energy.gov/pdfs/hyd_economy_bossel_eliasson.pdf

[17] Seba, A., 2015 'Toyota vs. Tesla – Can Hydrogen Fuel-Cell Vehicles Compete with Electric Vehicles?', http://tonyseba.com/toyota-vs-tesla-can-hydrogen-fuel-cell-vehicles-compete-with-electric-vehicles/

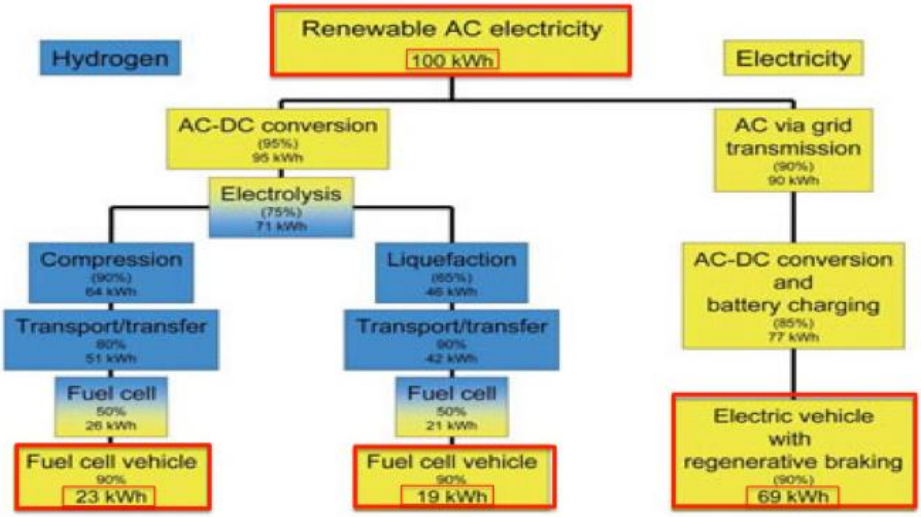



**Figure 23: Comparative efficiency of FCVs and EVs**[17]

**Infrastructure.** Hydrogen as a transport fuel suffers from the 'chicken and egg' problem. Without a widespread network of affordable fuelling stations, there will be no demand for FCVs. And without the FCVs there's no commercial incentive to build the refuelling infrastructure. Whereas EVs can charge at home with zero or very small infrastructure investment, there is no reasonable prospect of FCVs filling at home. Creation of hydrogen refuelling infrastructure, comparable to today's gasoline distribution would be extremely expensive.

**Competition from other technologies.** The core case for hydrogen as a transport fuel centres on it having long range and quick refuel compared with EVs. Rapid advances in EV range and refuelling appear to diminish the business opportunity for FCVs. For example, the Tesla Model 3, due in Australia in 2018, is expected to have a range of about 350km, and charging at a rate of about 500km of range per hour of charge (using a Supercharger). The capability of overnight, at-home EV charging also tends to negate the quick refuel benefit of an FCV.

**Cost.** It's not clear what the long-term at-the-pump cost of H2 will be, nor what the cost of FCVs will be. However there seem to be unlikely that FCVs will have a life-cycle cost advantage over EVs based on the underlying efficiencies and fuel-cell costs. A 2016 report described a cost of hydrogen USD16.63/kg at the pump[18], although this doesn't appear to be a realistic market price.

**Safety.** The physical properties of hydrogen gas present many challenges to make systems safe. Foremost seems to be the relative difficulty in avoiding leaks, combined with its highly flammable nature. With appropriate engineered measures, the use of hydrogen can, no doubt, be sufficiently safe. However, these safety systems will be costly. In automotive applications, hydrogen may, in one way, be safer than gasoline because H2 will very quickly dissipate if a tank is ruptured.

[18] Wong, 'Fill 'er Up: Refueling the 2016 Toyota Mirai', https://www.cars.com/articles/fill-er-up-refueling-the-2016-toyota-mirai-1420690448036/

### 4.11.2 Non-fossil Methane and Methanol

**Pathways.** An alternative to direct use of hydrogen and biofuels is the direct use of renewable energy in the synthesis of fuels such as methane and methanol. A number of possible pathways exist which could offer a direct pathway to renewable fuels. One such pathway is synthesis of methane from renewably sourced hydrogen. Another possible pathway involves methanol synthesis from hydrogen. Yet another is synthesis of ammonia for export using hydrogen as a feedstock.

**ACT context.** In the context of the ACT, sources of both methane and methanol could have utility. However, the ACT's lack of an existing petrochemical industry possibly makes synthesis in the ACT more of a challenge. Hydrogen-derived ammonia is of interest for energy export purposes but may not be viable at a small scale, given the amount of processing required.

#### *Methane synthesis*

**Sabatier reaction.** There is a chemically well-understood reaction, the Sabatier reaction, which takes H2 and CO2 and gives methane and water and heat. Given a source of renewable H2 (discussed in the previous section) it seems an attractive proposition[19] to produce renewable methane and water, and in the process, consume CO2.

**Synthetic methane.** As discussed in the previous section, there is some merit to mixing hydrogen with methane to lower the effective emissions of methane. However, this has only marginal utility compared with complete substitution of existing fossil methane with renewable methane. The carbon emitted when burning synthetic methane is fully offset by the carbon used in the creation of the methane in the first place, so the synthetic methane becomes carbon-emission neutral if fully combusted.

[19] Sterner, M., 2009, "Bioenergy and renewable power methane in integrated100% renewable energy systems: Limiting global warming by transforming energy systems", University of Kassel, Faculty of Engineering and Computer Science, http://www.uni-kassel.de/upress/online/frei/978-3-89958-798-2.volltext.frei.pdf

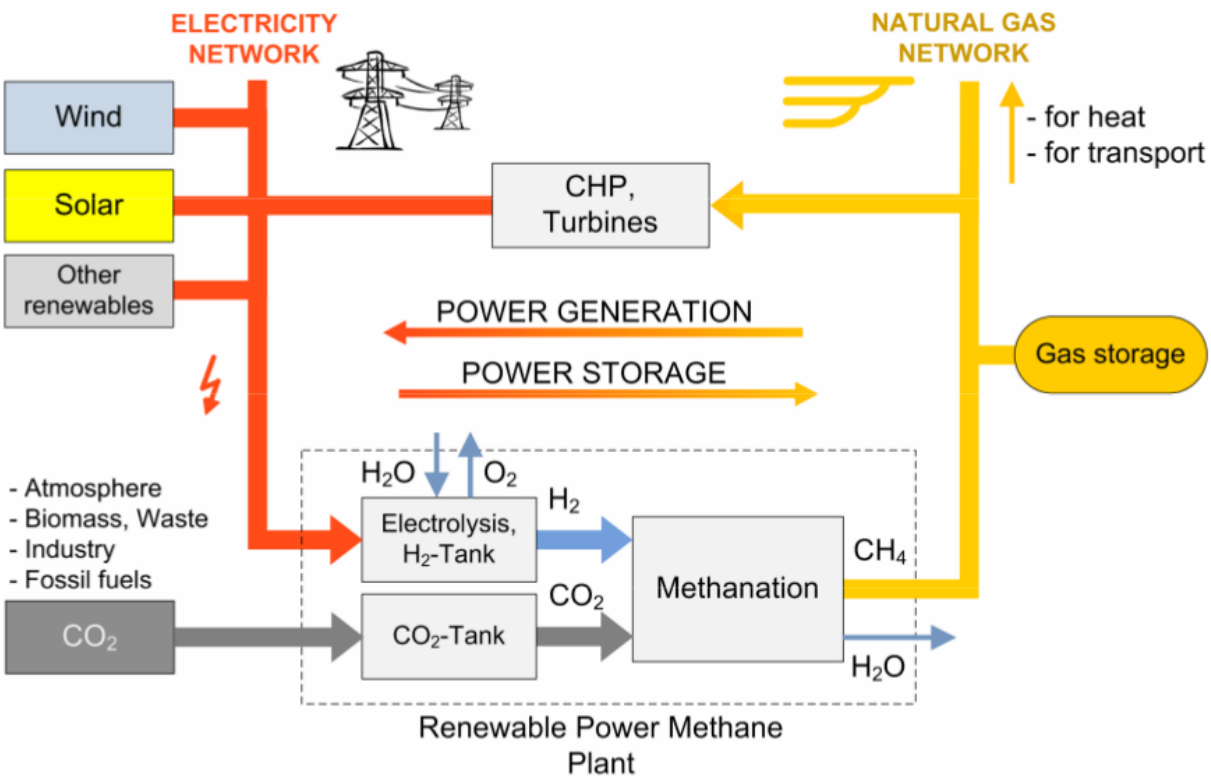



**Figure 24: Renewable Production of Methane[19]**

### *Methanol synthesis*

A similar approach to methane synthesis can be applied to produce methanol. Methanol is particularly useful as a transport fuel – either directly as a fuel blend, or as a feedstock for production of biodiesel.

**ACT context**. Renewably sourced methanol, and/or its derivatives, could play an important part in decarbonising. Perhaps most of the transport requirements will be electrified, but some residual transport fuel requirements are likely in the medium to long term.

**Precedent**: Vulcanol. The firm CRI in Iceland produces renewable methanol known as Vulcanol. Their Georg Olah plant has been producing methanol since 2012. It has a current capacity of 5ML/annum, making it the largest plant of its type. The power used in the production is all from hydro and geothermal plants[20]. There is a small net carbon emission in the process because the geothermal resource emits CO2. However, the net emissions from methanol production are 90% less than if the input energy was fossil-derived.

[20] CRI, 2017, http://carbonrecycling.is/

**Figure 25: The Georg Olah methanol ('Vulcanol') plant in Iceland**

### *Ammonia synthesis*

Another role for hydrogen is in the use of ammonia as an energy storage medium which can be shipped in bulk. Synthesis of ammonia from hydrogen serves to make the energy potential of hydrogen available in a form that is more energy dense and which is a better prospect for shipping than hydrogen gas21. This use of hydrogen is of little direct relevance to the ACT but is relevant to understand the broader context of the interest in hydrogen.

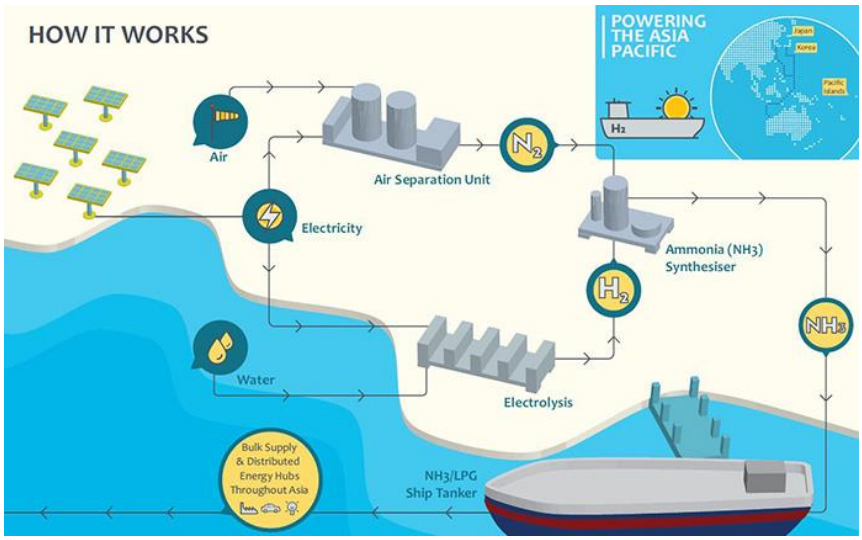



**Figure 26: Ammonia export model (source: Renewable Hydrogen)**

[21] http://www.abc.net.au/news/2017-05-11/hydrogen-breakthrough-could-fuel-renewable-energy-export-boom/8518916

# 5. ACT Policy Scenarios

## 5.1 Background

The policy options highlighted in this Chapter were determined via a process of synthesis and review of a wide range of available options. Importantly, it is not our intent in this Chapter to review all possible policy models and parameter choices – as this task would be very large indeed. Also, many policy options effectively target the same abatement opportunity, and represent alternative pathways to the same outcome. We recommend that the final selection of policy models by the ACT, and the micro-design of their key parameters, and the timing of their roll-out, should be informed by subsequent benefit cost analysis. This Chapter highlights what we consider to be a core set of policy models that would be expected to do the 'heavy lifting' in moving to net zero emissions.

### *Policy Design*

We recommend that the following approach is taken to the overall task of policy design:

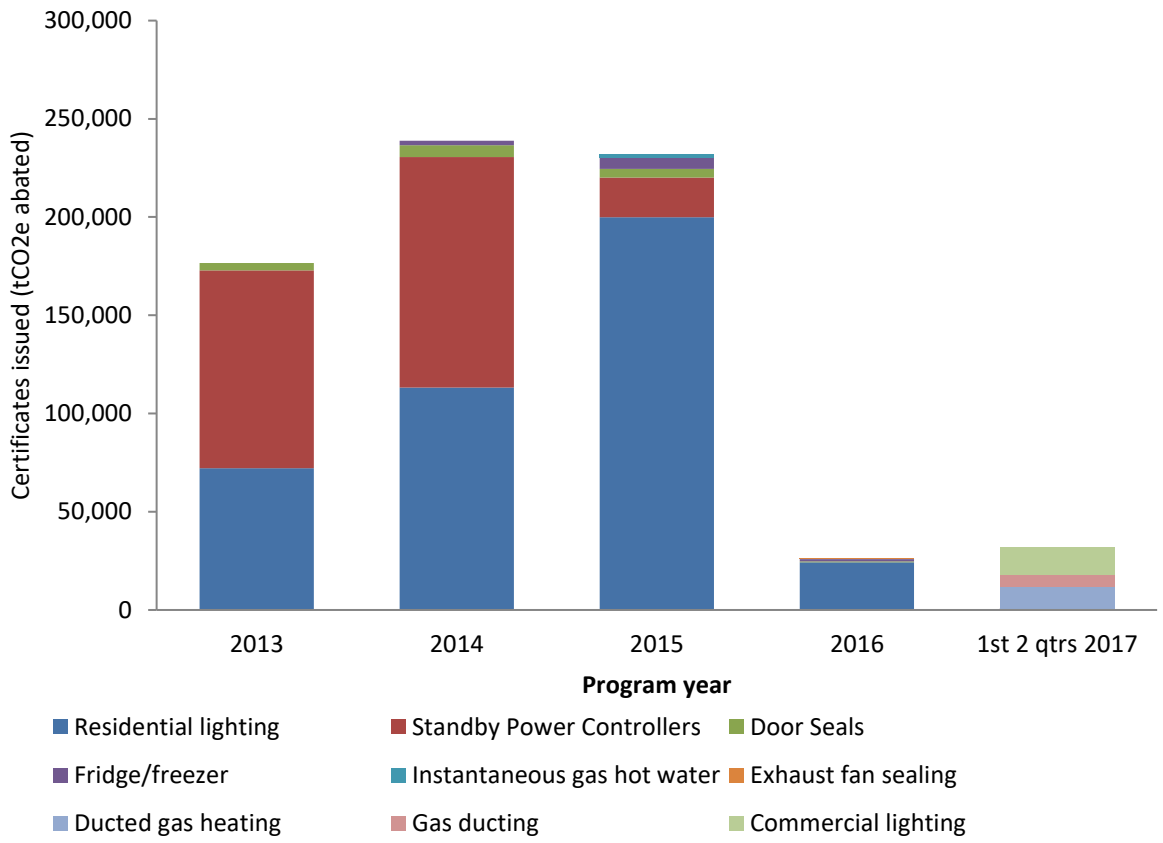
- Clear signalling of strategic directions (eg, phase out use of fossil fuels in favour of renewable electricity and fuels)
- Clear targets – to give substance and timelines to strategic directions
- Enable market solutions as far as possible, including strong energy services companies, quality and choice for consumers – but don't assume market will solve all problems, or ignore equity issues
- For abatement options that are privately cost effective, support can be provided primarily via information, advice, facilitation – financial assistance may be considered a) to help access finance for larger investments, b) on social equity grounds
- For abatement options that are socially cost effective, but marginally cost effective on a private basis, or that are less attractive to consumers (eg, gas phase out), regulations may be used, in addition to information and (means tested) financial support
- For options where there are opportunities for commercial cost recovery – eg, rental standards, standards for commercial buildings – support may be provided via information/facilitation or assistance with accessing finance, where needed
- For options that are strategically important, but not cost effective privately in the short term, financial support may be provided (in addition to information/facilitation), and market transformation initiatives designed to help bring down costs or overcome other, non-price barriers.

### *Existing Policies and Measures*

As set out in Appendix B, our projections of energy use and emissions for the ACT take into account at least the historical impact of existing policies and measures. In the case of at least the Energy Efficiency Improvement Scheme (EEIS), we note that the mix of activities supported by that scheme has changed over time, and is expected to change further in coming years (see Figure 27). In common with similar schemes in other states, there has been a noticeable increase in commercial lighting refits to LED lamps, and a reduction in uptake of residential compact fluorescent lamps. Program managers have indicated

that a future focus of the scheme is expected to be the replacement of inefficient residential heating (electric resistance or gas) with high efficiency heat-pump technology.

**Figure 27: Energy Efficiency Improvement Scheme: Total Abatement Credits Issues by Year and Activity**




*Source: ACT Government. Note that the lower abatement in more recent years reflects the falling ghg intensity of electricity supply in the ACT over time, as explained below.*

Going forward, existing policies and measures – not only EEIS, but also measures such as building regulations and planning provisions – should be reviewed regularly to ensure that they are contributing in an optimal manner to the ACT's strategic objectives in this area. With respect to EEIS, we note that its use of a carbon saving metric will mean that the measured abatement of, and therefore degree of support for, electrical energy savings supported under the program will continue to fall over time, and should reach zero by 2020. However, as we noted earlier, enhancing electrical end use efficiency will continue to contribute to abatement efforts by reducing the call on (and cost of) procuring renewable electricity, and moreover will continue to offer other benefits including reducing energy costs for businesses and households, reducing peak demand (depending on the measure), and improving thermal comfort, adaptation and resilience in the face of climate change. This suggests that the basis upon which incentives are calculated may need to change.

In this context, the ACT Government should consider also opportunities for EEIS to contribute to the phase out of fossil gas consumption. Improving the energy efficiency of gas use may contribute to reducing emissions in the short term, and may also be cost effective. However, the strategic

consideration is whether it is useful to encourage consumers to continue to invest in gas-using equipment, which will contribute to greenhouse gas emissions for many years, when zero emissions alternatives (including those based on renewable electricity) are available and (generally) cost effective. While we note that some fuel switching away from gas is likely to occur in any case, particularly in the residential sector, EEIS could actively support this, for example for low income households or for businesses where fuel switching is not privately cost effective. For businesses, to a much greater extent than for households (where gas end-uses are more generic), it is likely that the business case for switching individual end-uses away from gas will vary considerably: some will be cost effective without government assistance, but some will not. This suggests that a tailored policy approach is likely to be most effective and cost effective.

At present, EEIS is structured to address opportunities where the business case (for energy efficiency or fuel switching) is more predictable and consistent. This suggests that either EEIS would need to modify its approach, to effectively target gas substitution, or an alternative mechanism may be required. While the use of an energy rather than carbon metric would help in this context, it would not distinguish between electrical and gas savings, and therefore not assist in the strategic objective of phasing out fossil gas use. Also, as noted, we believe there are other policy drivers and considerations that should be considered, such as equity and affordability, and also cost effectiveness. This suggests that a 'balanced scorecard' approach might offer the best results – but further exploration of these issues should take place in the context of a dedicated EEIS review, which we understand is already anticipated.

### *Potential New Policies and Measures*

Table 10 below summaries a range of possible policies and measures that the ACT could consider to address the objectives identified. This includes a summary of policy objectives and rationales, including those that are secondary or complementary to greenhouse gas abatement; examples of specific measures; and linkages to other new or existing measures that should be considered to ensure maximum joint impact.

**Table 10: Policy Programs, Objectives and Measures**

| Program | Policy Objectives/ Rationale | Measures: | Policy Linkages |
|---|---|---|---|
| 1. Optimise performance of new and refurbished buildings | • Reduce lifetime operating costs<br>• Comfort, safety and climate resilience<br>• Other system benefits – avoided network costs | • Building Code settings reoptimized every three years<br>• Enforcement activity, including for retrofits<br>• Build on and enhance EEIS | • Code can also be used to promote fuel switching away from gas – eg, require high performance electric HW heaters<br>• Link to planning scheme provisions – style and location of new developments, transit oriented |

| Program | Policy Objectives/ Rationale | Measures: | Policy Linkages |
|---|---|---|---|
| | | | development, solar passive design, urban heat island effects, etc<br>• Enforcement and ensuring new building standards apply to all retrofits would accelerate the rate of improvement in the total stock |
| 2. Deep retrofit program – to bring existing buildings and their equipment up to acceptable minimum energy performance standards over time | • Climate resilience<br>• Reduce lifetime operating costs<br>• Other system benefits – avoided network costs<br>• Social equity – ensure that lower income families have access to climate-safe and affordable housing<br>• Support is means tested | • May be targeted via an enhanced EEIS<br>• Mandatory performance standards for rental properties (residential)<br>• Universal mandatory disclosure scheme<br>• Targets set for retrofit activity – eg, x% of the stock each year – target high consumption house, low income families, low rated houses first<br>  ○ Target outcome, eg, minimum of 4 star (+ solar + no gas) for retrofitted houses?<br>  ○ For commercial buildings, could use NABERS stars but limited tool scope; could use 'equivalent' benchmarks for those not covered by NABERS<br>• Estimate:<br>  ○ volume of savings per year from target<br>  ○ percentage able to be privately financed<br>  ○ implied demand for innovative financing | • Support commercial building retrofits via government leasing of high performance space<br>• Universal MD will assist with identifying high-consumption buildings; targeting by ESCOs; also name and shame effect<br>• Mandatory disclosure link to EUAs/demand for innovative financing<br>• Retrofits are an opportunity to advance fuel switching away from gas – leverage via information and ROS<br>• Implement in parallel with low income solar to ensure low income houses retrofitted and fitted with solar PV |

| Program | Policy Objectives/ Rationale | Measures: | Policy Linkages |
|---|---|---|---|
| | | ○ implied demand for incentives offered via Retailer Obligation Scheme (RIS) for retrofit/appliance upgrade purposes<br>○ share achieved through rental property standards (residential) – from 2018 phased in over 3 years | |
| 3. Embedded renewables | • Most take-up will be cost-effective and market driven<br>• Ensure that low-income households do not miss out on solar benefits | • Extend the low income solar scheme to direct investment in PV for social housing, and innovative financing for low-income households<br>• Continue feed-in tariff (FIT) and EEIS | • Implementation linked to deep retrofit program |
| 4. Fuel switching from fossil fuels | • Zero carbon economy over time<br>• May be able to cover minor residual gas usage via bio-gases in future (including renewable hydrogen) | • Estimate impact from Code (measure 1), and deep retrofit program (measure 2)<br>• Targeted switching via ROS<br>• Estimate switching at larger scale due to innovative financing<br>• Levy on gas sales – hypothecated to biogas/fuel switching | • Possible linkage to Waste/LULUCF programs – eg, waste to biogas |
| 5. Innovative financing | • Facilitate the transition<br>• Ensure low-income persons able to participate in benefits<br>• Shift financing costs away from government to the extent possible | • Generic loan guarantee scheme – could be delivered at no cost by CEFC, carbon bonds<br>• EUA for commercial upgrades | • Deep retrofit program<br>• Low income solar program<br>• Also assist with incremental capital costs for new/refurbished buildings |
| 6. Government leadership | • Lead by example<br>• Direct investment in | • 6 star or carbon neutral office leasing | |

| Program | Policy Objectives/ Rationale | Measures: | Policy Linkages |
|---|---|---|---|
| | own facilities and infrastructure<br>• Facilitate outcomes via planning scheme | • Accelerated roll-out of LED street and traffic lights<br>• Reduced urban heat island effect on energy loads<br>• Additional (to Code) benefits from orientation, shading, solar passive. | |

## 5.2 Policy modelling

Our choice of which measures to model has been guided by two general considerations.

First, we have concentrated on categories of energy use over which an ACT government can, potentially, exert significant influence. While the ACT cannot influence the levels of energy efficiency of equipment, such as household refrigerators and commercial refrigeration plants, lamps, computers and so on, it can – and indeed already does, through the EEIS – encourage the uptake of higher efficiency equipment from within the mix available on the market. Chapter 4 provides an overview of technical efficiency improvements potentially available and is intended to be used as background material to support consideration of any possible policies to encourage uptake of more efficient equipment.

Second, given the ACT's commitment to 100% renewable electricity, achieving zero emissions from stationary energy use in 2050 will critically depend upon phasing out (or potentially offsetting) the use of natural gas and other types of gas derived from fossil fuels (such as LPG). The modelling has therefore focussed on measures which could be used to achieve this objective. The results described below are not intended to represent the outcomes of any specific policy settings. Rather, they aim to demonstrate the potential of various options, concentrating on measures which affect decisions made around end of life replacement of energy using equipment and the choice new equipment which is adding to the total stock of equipment. Policies framed in this way will be less costly, and are likely to be more palatable to consumers, than policies which force the premature retirement of equipment with some years of remaining serviceable life – unless the 'business case' for switching is attractive, for example due to changes in the relative cost of technology or energy, or because of policy incentives.

The effectiveness of policies focussing on end of life replacement will of course be heavily dependent on average equipment life. It will be more difficult to achieve zero emissions by 2050 for long lived than for short lived equipment. This suggests stock turnover perspective highlights that an early decision on the future of natural gas use in the ACT would help to create certainty for consumers and limit purchases of gas using equipment that may delay and increase the cost of later abatement efforts. The modelling is intended to show how the various categories of energy use differ with respect to this, and other characteristics, and to thus illuminate the nature and extent of the policy challenges of achieving zero emissions by 2050.

## 5.3 Mid Case Scenario – Modelling Results

### 5.3.1 Residential Sector

#### *Space heating and cooling: accelerated retrofit program*

The number of retrofit upgrades of pre-4-star Class 1A dwellings was increased in the policy case – as with other measures, key parameters for such a program should be based on feasibility and benefit cost analysis. Retrofits are assumed to include a switch from gas heating to RCAC. Since gas is the predominant heating fuel in the refurbished dwellings, this change reduces gas consumption to near zero about five years earlier than in the Reference case. (A small amount of gas heating remains in Class 1B dwellings until the early 2040s.) There is also a small reduction in 2050 electricity consumption.

#### *Hot water*

The policy applied is a very stringent one of prohibiting the use of gas water heaters in a specified year. For new builds, the prohibition is assumed to take effect in 2020-21, meaning that all new dwellings from then on will have to use either heat pump or solar water heating. Prohibition of like for like replacement of gas water heaters reaching the end of their life is applied from 2025-26 and the prohibition of like for like replacement of electric resistance water heaters from 2031-32. This later date has been adopted because, with 100% renewable electricity, electric resistance water heating will not contribute to greenhouse gas emissions.

Implementation of policies such as these could be challenging. Following the effective NCC ban on new off-peak electric water heaters, instantaneous gas is competitive with heat pump and solar options in terms of operating cost, assuming no significant increase in gas prices, and is by a wide margin the lowest capital cost option. Probable large increases in gas prices later in 2017 will somewhat change this relationship but, as with so many building options, higher up-front costs will remain as a barrier for a great many builders and owners. Availability, or, to be precise, non- availability of suitable space, will also be a challenge in many cases, particularly for solar. The overall effect of these measures is to eliminate gas use for water heating by the late 2040s. We note that EEIS already supports the take-up of heat-pump hot water systems, and that this could accelerate the replacement of gas based hot water systems.

As noted above, with zero emission electricity there is no climate policy advantage in the ban on electric resistance water heaters, and the ACT could choose to remove the requirement for ACT dwellings to comply with this part of the Code, or even replace it with a policy that explicitly targets high-efficiency electrical technologies.[22] However, returning to this form of water heating would not restore the operating cost advantage which off-peak electric water heating currently enjoys, because it is most unlikely that the current off-peak tariff would be restored to new owners of the water heaters. Without this tariff, electric resistance is the most expensive, not the cheapest form of residential water heating. The logic of off-peak tariffs derives from the inflexible operating characteristics of coal fired electricity generation. As the Australian electricity supply mix moves away from coal and towards wind and solar, there is no system operating cost benefit to be obtained from encouraging more consumption in the middle of the night. South Australia has already

[22] We note that requirements would not have to be prescriptive, but could specify energy performance levels that currently can only be attained by heat-pump systems – this would not preclude other technologies/fuels that might in future be able to attain similar performance levels.

passed that point and the spike in demand which occurs every day just before midnight in the South Australia NEM region has become an anachronistic impost on all electricity consumers in that state.

In the grid of the future, it may make sense to offer off-peak water heating for a period around the middle of the day, though a variety of other factors would affect any decision to move in this direction. It is more certain that electric resistance water heaters with large storage capacity, i.e. water heaters of the kind now accessing off-peak tariffs, could be financially attractive to households with rooftop PV systems. For some such households, a storage electric resistance water heater might be the alternative to installing a battery. Of course, heat pump and solar water heaters also rely on storage of hot water, so these systems will always have an operating cost advantage over electric resistance, assuming all three options have access to the same electricity tariff. However, heat pump and, particularly, solar, also have higher purchase and installation costs than electric resistance, which may therefore be preferred by some on that basis. A possible option for the ACT would be to lift the ban on large electric water heaters after 2020, perhaps accompanied by advance notice of a future ban on gas water heaters, and allow consumers to choose between the three different electric water heating options.

#### *Cooking and pool heating*

For cooking, a policy which encourages the shift from gas to electric induction is applied. It is assumed that each year 5% of households switch across from gas to electric induction cooktops and, in addition, the proportion of new households adopting gas cooktops declines gradually to zero by about 2030. These changes eliminate gas use for cooking by a few years before 2050.

For pool and spa heating, it is assumed that 5% of households switch from gas to heat pump/solar heating each year, with the results that gas use is eliminated by the early 2030s.

EEIS supports upgrades in both cooking and pool heating, and this could potentially be enhanced to offer additional support in future. As with most of the other categories of gas consumption, moving away from gas will also be stimulated by higher gas prices.

#### *Lighting, refrigeration and other electrical loads*

For each of these categories of residential electricity consumption the policy assumption is that electricity consumption per household decreases by 1% per annum, compared with no decrease in the Reference case. When combined with the different reduction from the various MRPS measures, the overall effect is that electricity consumption declines in absolute terms for all three categories of electricity consumption. Again, EEIS could assist in delivering these outcomes.

### 5.3.2 Commercial Sector

#### *Space heating and cooling: more stringent minimum energy performance standards for new buildings*

Two separate policy measures were applied to this energy use category. Firstly, the required increase in the minimum energy efficiency of new buildings in 2020 is increased to 50%, compared with 30% in the Reference case Mid scenario and 40% in the Reference case Low scenario. In addition, two further stringency increases of 20%, as in the Reference Low scenario, are introduced. This change reduces consumption of both electricity and gas across most of the projection period. Secondly, from 2036 on, the use of gas heating

systems in both new and replacement installations is prohibited. As would be expected, this has the effect of greatly accelerating the removal of gas from HVAC systems so, in fact, it reaches zero a couple of years before 2050.

### *Hot water*

After 2036, which is assumed to be the average end of life of commercial hot water systems being installed today, use of gas heating in both new and replacement systems is prohibited. This would be challenging for large water heating systems, such as those used in commercial scale laundries, as large heat pump water heaters are currently not widely used and it is likely to be difficult to find the space need for solar systems in urban areas. Development in heat pump technology over the next 20 years may make this a much more suitable option by the 2040s. Alternatively, some large volume hot water applications may be an appropriate use of zero emission gas.

### *Machinery/equipment, lighting and refrigeration*

No new ACT policy measures have been assumed to apply to these energy use categories, which consume predominantly electricity. This is firstly because national policies are assumed to continue to push efficiency improvements in these areas, in addition to those that arise from purely market forces or the effect of other country's efficiency policies. From a climate policy perspective, reducing electricity consumption is a less urgent priority than reducing gas consumption, because lower electricity consumption does not mean lower emissions when electricity supply is 100% renewable. It is near certain than continued technical innovation will enable further improvement in electricity use efficiency, but these will almost certainly be less dramatic than, for example, the successive switch from incandescent to CFL to LED lighting. These are also changes over which an ACT government can have less influence. However, as noted, EEIS can and does offer incentives for businesses to adopt more energy efficient solutions from the range available on the market.

Our conclusion, therefore, is that the adoption of any new requirements for increased energy use efficiency in the commercial sector should be based on comparing the costs of the new requirement with the monetary benefits of reducing electricity consumption at prevailing and likely future retail electricity prices. It is possible that it would be cost effective to promote the uptake of best-in-class equipment and products, for example via a retailer obligation scheme, but this should be confirmed in benefit cost analysis. The additional abatement is likely to be small, and the ACT Government should as a rule ensure that it is not offering financial incentives for activities which are already privately cost effective for those businesses to adopt.[23]

As previously discussed, we assume that relatively small quantities of gas are currently used in various types of light manufacturing and laboratory equipment, especially equipment used for high temperature processes. Since there are fewer alternatives to gas, on the basis of both cost and performance, for many of these applications, they should be considered as a priority use for new, zero emission substitutes for conventional gas.

[23] In a situation where such activities were shown to be cost effective, but where nevertheless not being taken up, then voluntary/information-based strategies, or regulation, may prove effective and cost effective.

**Table 11: Gantt Chart – Indicative Timeline of Policy Actions to Achieve Zero Emissions in Advance of 2050 (Medium Scenario)**

| POLICY ACTION AREA & IMPACT | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| **100% Renewable Electricity** | Maintain 100% RE electricity under an extension to legislated target. | | | | | |
| **Energy efficiency improvement** | Growth in electricity consumption is curtailed with the introduction of new settings into the EEIS or similar mechanism. The scheme is adjusted every 3-5 years to boost incentives for energy efficiency of equipment as well as the installation of embedded generation and storage as required. | | | | | |
| **Fuel Switching from fossil fuels to electricity and renewable gases** | Planning requirements prevent distribution of fossil fuel gas in new suburbs.<br>The EEIS is designed to incentivise zero emissions forms of energy, and not only more efficient use of fossil fuels | Announce planning intention that fossil fuel gas distribution will cease by 2045. In the interim 20 years, policies that encourage switching to electricity and zero emissions gas will ensure that use of fossil fuel gas is close to zero by 2045 | EEIS continues with increased incentives | EEIS continues with switching incentives.<br>In non-residential buildings, fossil fuel gas for heating is prohibited under a variation to the NCC (in addition to the other NCC measures cited below) | Residential fossil fuel gas consumption is zero by this point due to the deep retrofit program (see relevant row below) and other trends and measures. | Regulations prevent the distribution and use of fossil fuel gas. Specific exemptions are considered and granted if necessary. Offsets are used to cover any exemptions. |
| **Building Code** | 7 star in 2020 / 20% stringency hike for non-residential | 8 star in 2022, 9 star in 2025 / 10% stringency hike for non-residential in 2025 | 10 star by 2028 / In 2031 a 5% stringency hike – non-residential | In 2036, a 5% stringency hike – non-residential | In 2042, a 5% stringency hike – non-residential | In 2048, a 5% stringency hike – non-residential |

| POLICY ACTION AREA & IMPACT | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| **Sustainable planning scheme** | Implement a new planning scheme from 2020. The new scheme will give greater force to achieving twin goals of community wellbeing and low environmental impact via: a transition to zero emissions: materials efficiency (energy, water, waste) and climate change adaptation. The scheme will explicitly protect solar access, introduce albedo requirements to minimise urban heat island effects, protect biodiversity and natural shade, and encourage active transport and local outdoors recreation opportunities. | | | | | |
| **Deep Retrofit program – 600 homes retrofitted per year** | Commence program – 4 star minimum + zero emissions energy using equipment (equipment must run on electricity, solar or another zero emissions fuel) with 600 homes per year | Continue | Continue | Lift requirement to 5 star. Solar and zero emissions requirements continue | Continue | 6 star minimum + solar and zero emissions energy |
| **Innovative Financing** | Commence the "One for Zero" program with CEFC 1% interest rate loans for incremental cost on zero emissions buildings for the non-residential sector | By 2025 contract a series of MEETS - metered energy efficiency transaction structure (a power purchase agreement for energy efficiency) * | Continue to administer "One for Zero" loans and MEETS that extend to 2050 | | | |
| **Embedded Renewables & storage** | Expand low income solar + storage program to retrofit solar - and eventually battery - systems to residential buildings. ACT owned buildings are retrofitted in stage 1. | | In stage 2 low cost rental homes are targeted to overcome the split incentive. Storage introduced only when fully cost effective. | | In stage 3 medium cost rental homes become eligible | |

| POLICY ACTION AREA & IMPACT | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Government Leadership** | 100% LED Streetlights by 2024 | Govt lease of 6 star buildings only | ACT Government led development of new zero ENERGY suburb (the suburb has zero net consumption of imported energy) | | Development of zero net energy suburbs continues according to population growth | |
| **Abatement Impact of Measures** | | | | | | |

**MEETS will likely require NEM rule changes. It should be championed with AEMO first then the rule making bodies. For an example of MEETS in action, see https://www.greentechmedia.com/articles/read/This-May-Be-the-Most-Innovative-Energy-Efficiency-Financing-Tool-Yetkj*

## 5.4 Policy Impacts – Charts

### 5.4.1 Medium Emissions Scenario Charts

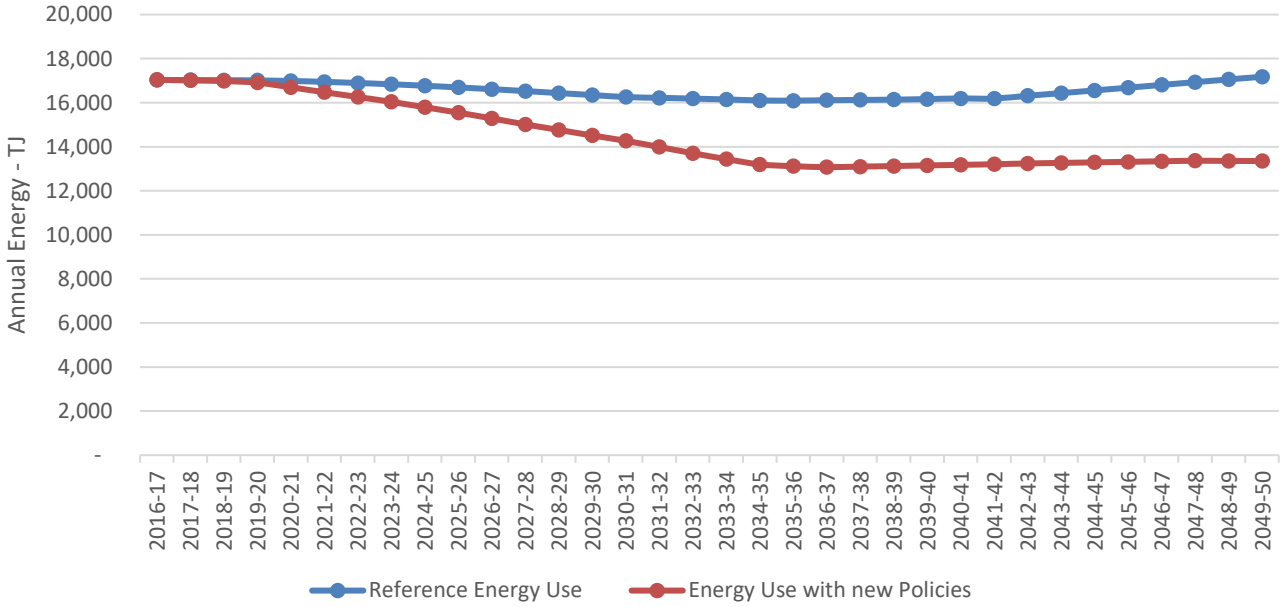



**Figure 28: Total Energy Use - Reference vs With New Policies – Medium Scenario**

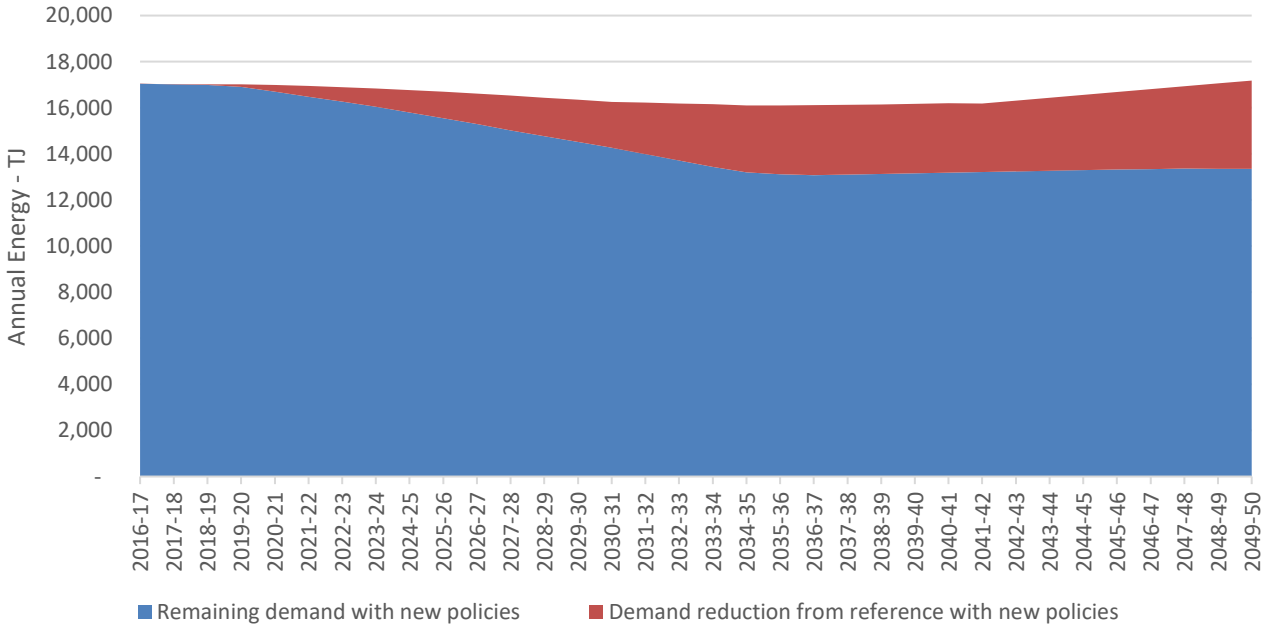



**Figure 29: Projected Impact of New Policies on Stationary Energy Demand - Medium Scenario**

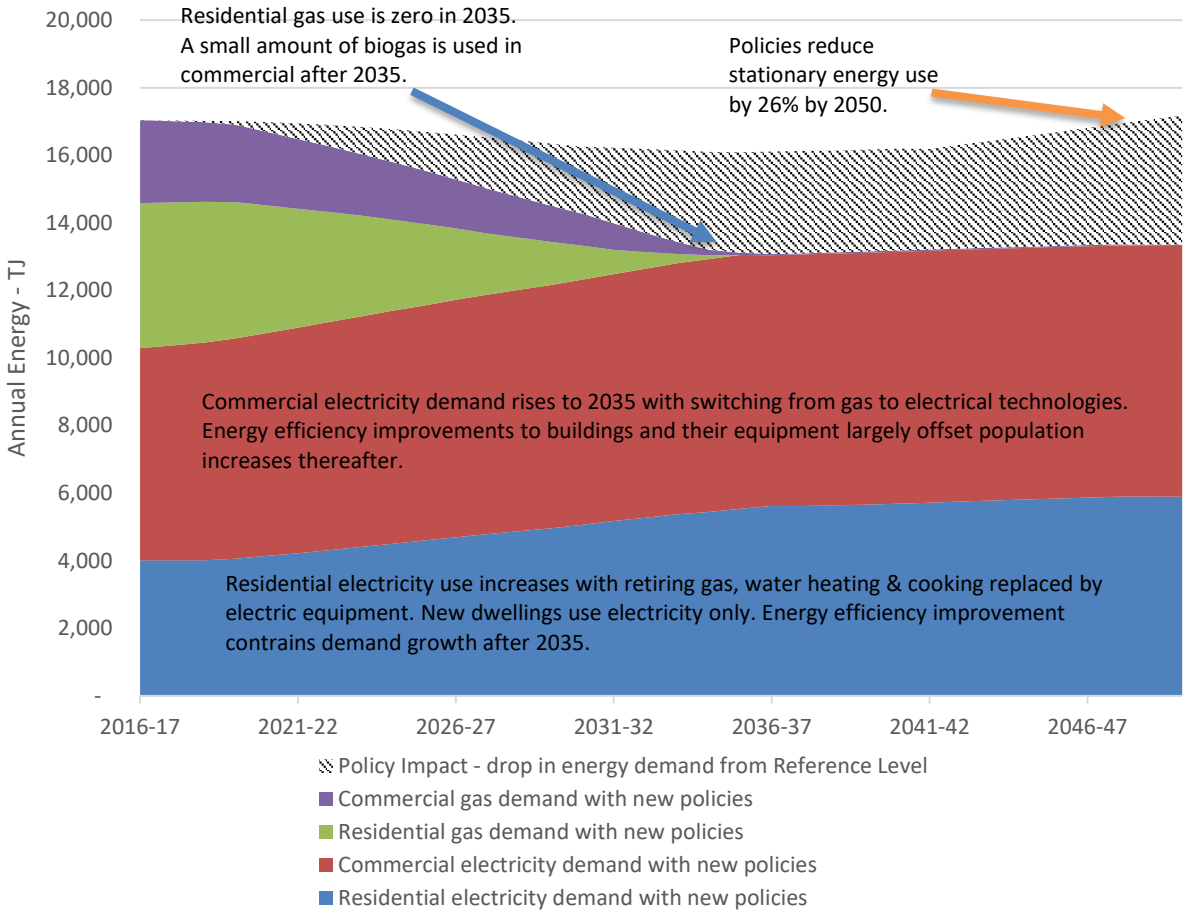



**Figure 30: Total Policy Impact and Remaining Energy Demand Wedges**

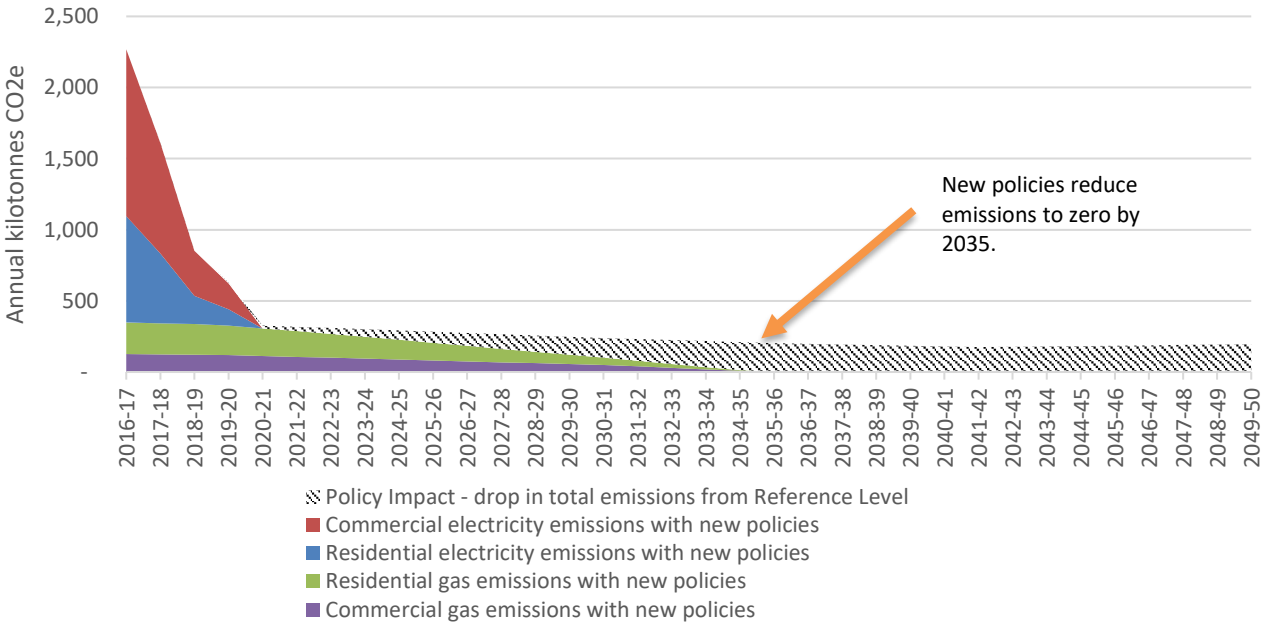



**Figure 31: Policy Impacts on Emissions by Source**

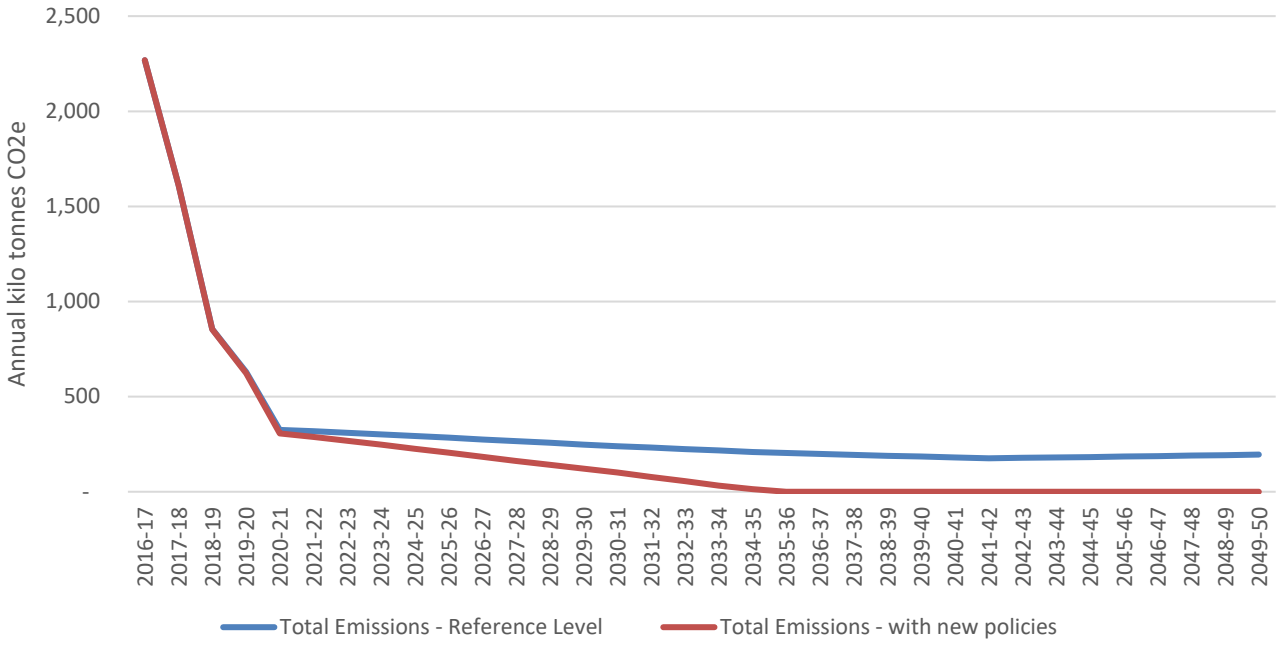



**Figure 32: Total Stationary Energy Emissions: Reference vs With New Policies**

### 5.4.2 Low Emissions Scenario charts

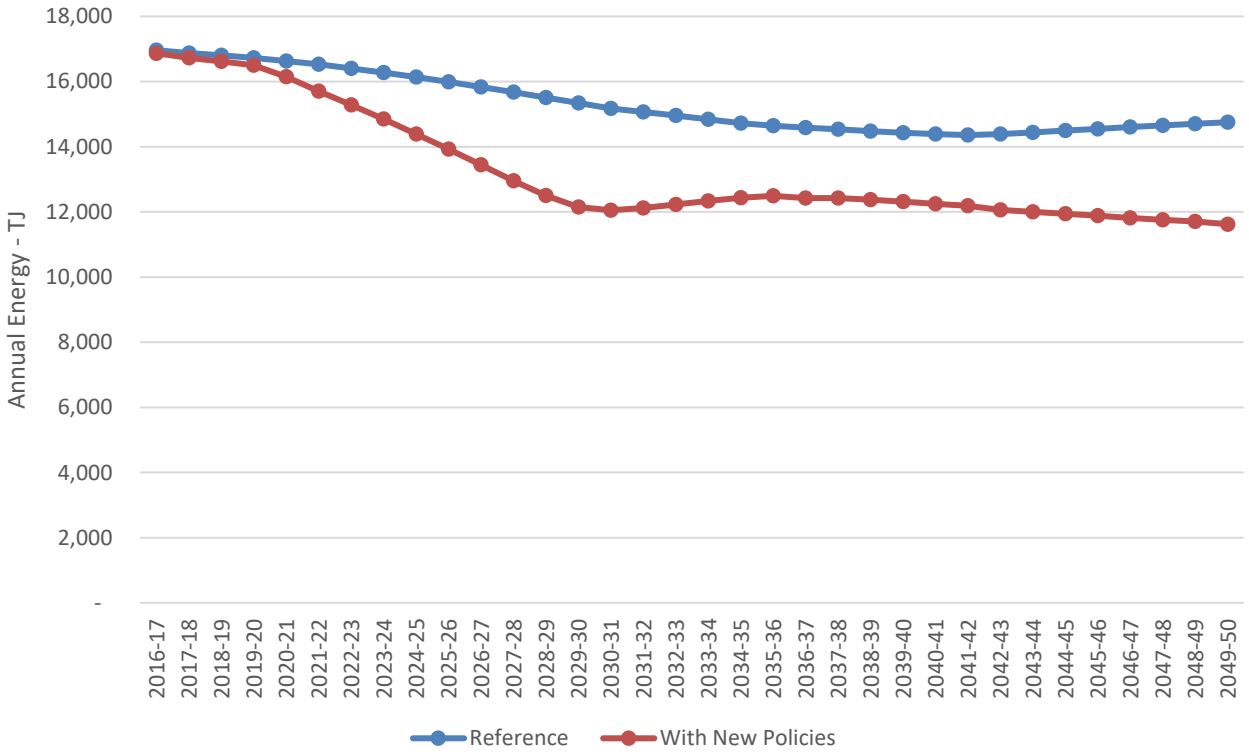



**Figure 33: Low Emissions Scenario Energy Use – Reference vs With New Policies**

Figure 33 shows a fairly steep fall in energy use under new policy settings to 2030. Then a slight and temporary increase in energy use occurs, before a gentle fall in consumption resumes. The steep fall is driven by aggressive switching from gas to electricity. Electrical equipment is generally more efficient than gas, particularly in the case of electrical heat pumps used to replace gas space heating. This sharp improvement in efficiency from fuel switching can't be replicated once gas has been replaced. The more incremental efficiency gains thereafter (from building envelope and electrical equipment efficiency improvement) are temporarily overwhelmed by drivers of increased energy use – economic and population growth.

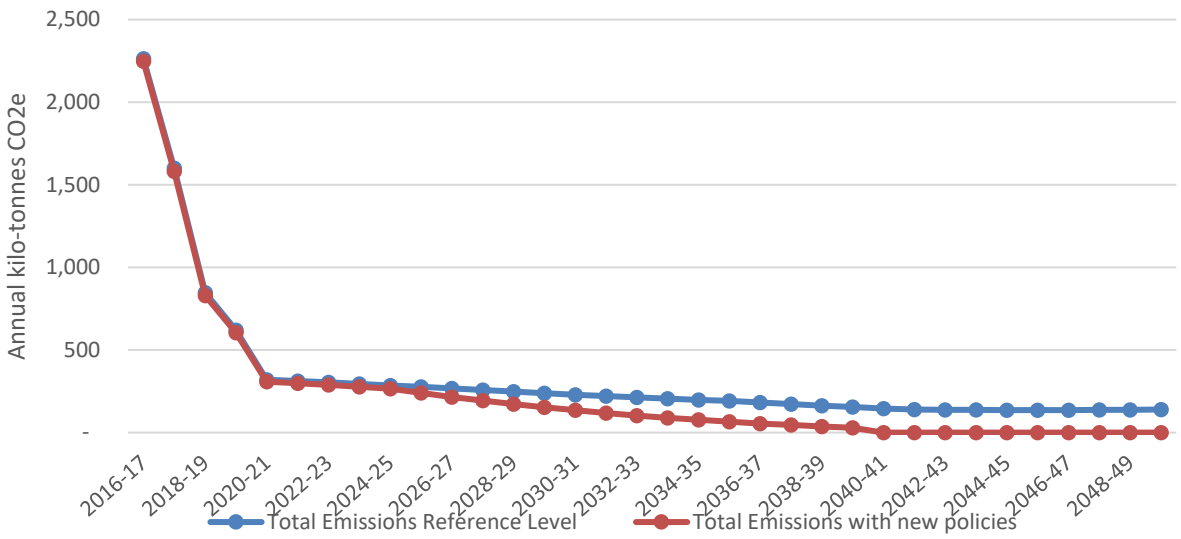



**Figure 34: Low Emissions Scenario – Greenhouse Gas Emissions Reference vs With New Policies**

### 5.4.3 High Emissions Scenario Charts

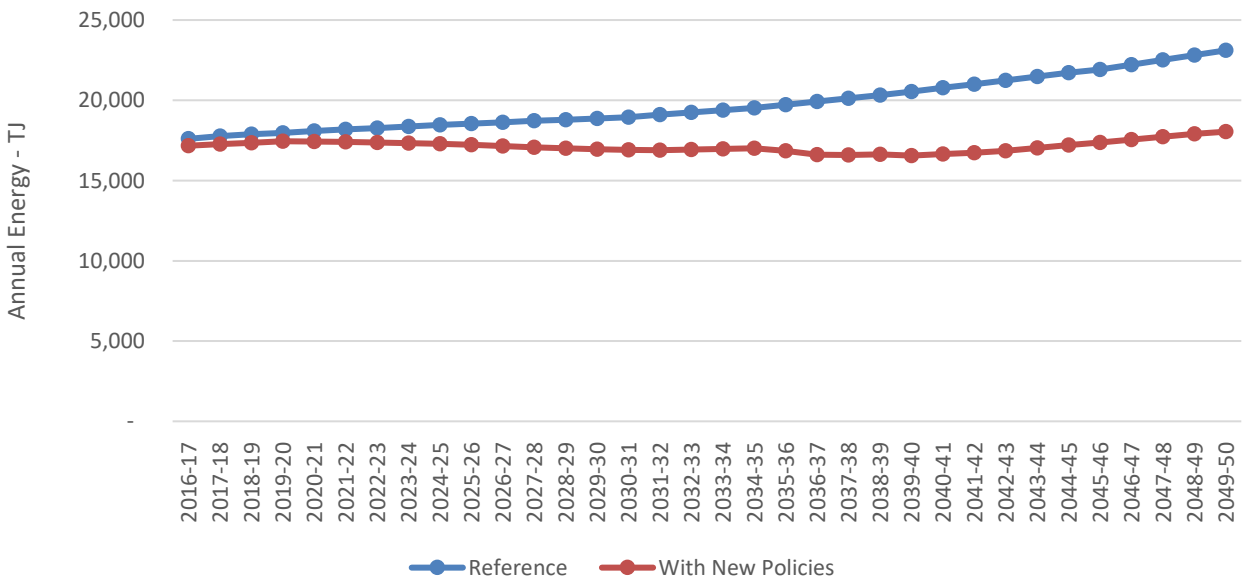



**Figure 35: High Emissions Scenario Energy Use – Reference vs With New Policies**

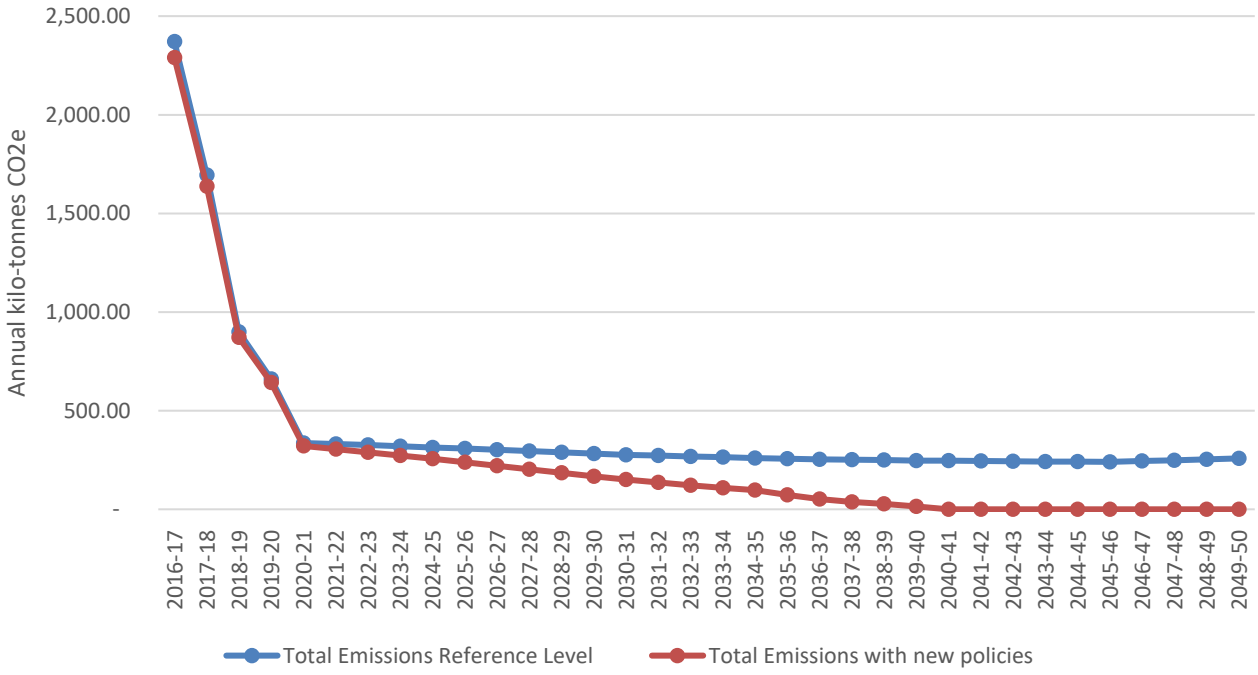



**Figure 36: High Emissions Scenario Greenhouse Gas Emissions – Reference vs With New Policies**

# 6. Conclusions and Recommendations

This report analyses stationary energy demand and related emissions between now and 2050. It shows how energy demand and emissions are likely to evolve without changes in policy, and also what could be achieved through new policies and the adoption of new technology. This analysis allows us to draw a number of interesting conclusions, as outlined below.

## 6.1 Conclusions

- ***Zero emissions target date***

The ACT can attain zero emissions in the stationary energy sector by 2035, and it may also be possible to reach that milestone by 2030 or potentially earlier.

The critical ingredients are:

- reaching and maintaining 100% renewable electricity
- promoting energy efficiency
- encouraging rapid switching away from the use of fossil gases.

Further research will be required to establish the feasible substitution possibilities for fossil gases, at the level of individual (larger) users, and the practicality and cost effectiveness of a range of renewable gas supply and distribution options. This process will require consultation with gas producers, distributors and customers.

- ***Detailed policy design***

This report outlines the policy measures that will enable the transition to zero emissions. Before the measures are finalised, we recommend that detailed benefit cost analysis is undertaken, to ensure that the least-cost choices are selected.

- ***Maximise ancillary benefits***

Policies such as 100% renewable electricity and zero emissions identify the ACT as a leader in this area. This is already bringing significant benefits beyond emissions reduction, such as investment, jobs and an enhancement of ACT's reputation as a centre of innovation and research capability. More broadly, education, construction, tourism, light manufacturing and transport sectors, are all more likely to thrive in conditions where sustainable innovation is incentivised. These benefits can be maximised through careful 'micro-design' of policies and effective communication of the ACT's strategic intent to major players such as technology providers.

- ***Maximise access to the benefits of a zero-carbon economy***

More energy efficient homes and buildings, solar energy, battery storage, electric transportation and other features of the zero-carbon economy offer significant financial benefits for households and businesses. They also offer benefits such as improved comfort, greater resilience to extreme climate events, and reduced morbidity and mortality. At the same time, the transition process requires investments that pay back over time. Those unable to access these benefits will be increasingly disadvantaged over time. It will therefore be

important for ACT to design strategies and programs that enable everyone, including low income groups and tenants, to participate in and benefit from this transition.

- ***Integrate climate adaptation***

Climate projections indicate future increases in the extremity and frequency of heatwaves. Measures such as improving the thermal envelope of buildings, installing more efficient cooling systems, encouraging on-site generation and lower energy bills, paying attention to albedo effects, and reducing the 'urban heat island' will all contribute to healthier, cooler living conditions. Opportunities such as the installation of PV panels to shade car parks and other public areas will help the ACT prepare for hotter weather, while delivering renewable energy benefits. Air conditioning of homes is already prevalent and should be expected to increase in future – underscoring the need to ensure that high-efficiency heat pumps are preferred. The impact of heat pump use on peak demand should be considered, and we note that rooftop PV, local energy storage and demand management technologies will all assist in this area.

- ***Reform planning policy***

Planning regulations play a critical and often under-estimated role in shaping urban form over time, including its carbon- and energy-intensity. Planning can be a vehicle that encourages and supports the development of compact urban form; transit-oriented development around light rail and other public transit corridors; diverse, people-friendly and flexible working/living patterns, including multi-use buildings and attractive, liveable precincts. Planning can facilitate the shift to electric vehicles and the use of renewable sources of heat for industry and manufacturing.

- ***Remaining open to future innovation***

While choices and investments have to be made in the short term based on the options that are available today – and delaying the transition to zero carbon imposes opportunity costs on the community – the ACT should remain open to emerging and innovative technologies, for example by encouraging local investment by technology and solution-providers, and supporting trials.

## 6.2 Recommendations

We recommend:

- In the next iteration of the ACT's climate change strategy:
    - Adopt a policy to maintain 100% renewable electricity from 2020 onwards
    - Set a target date for the elimination of fossil gases, such as 2035
    - Set targets for the adoption of electric and zero-emission vehicles in ACT.
- To the extent possible, set performance- and outcome-based targets, rather than prescriptive pathways.
- Conduct detailed studies of (larger) gas user needs and substitution possibilities, and also of options for replacing fossil gases with alternatives including electricity, renewable gases or other strategies.
- Consider innovation hubs for renewable industrial heat and mobile energy.

- Establish specific programs and regulations – with the detailed micro-design subject to benefit cost analysis – to target:
    - The highest cost-effective level of energy performance of new and refurbished buildings
    - Deep retrofits for existing buildings
    - Fuel switching to zero-emissions sources.
- Carry out benefit-cost analysis to support the micro-design of policies and programs.
- Ensure that there is universal access to the benefits of a zero-carbon economy.
- Balance least-cost approach with a portfolio approach which leaves options open for emerging technologies.

Monitor progress and carry out thorough policy reviews every 3 to 5 years.

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# Appendix A: Project Brief

## Objectives

### *Energy*

Create a portfolio of emissions analysis for the energy sector which covers: a business as usual (BAU) baseline, the energy sector emissions profile (percentage difference between gas and electricity across the timeframe), demand trends, known potential for reductions and projections to 2030, 2040 and 2050.

Utilise international examples for existing trends and examples of emissions reductions in areas of energy efficiency, and demand load changes from energy transitions such as electrified transport and transition off gas to electricity.

Work with the Energy Policy team to calculate interdependencies between renewable energy, energy efficiency and projected demand. Utilise projections for grid intensity for abatement potentials related to electricity consumption.

### *Buildings and Built Environment (energy efficiency)*

Advise on areas where additional emissions savings can be made beyond BAU for energy efficiency measures.

Reference the Building Code of Australia (BCA) standards and known changes.

Utilise international examples for existing trends and examples of emissions reductions in areas such as building efficiency.

To consider efficiency options in the built environment outside of buildings such as sustainable planning and low energy demand street lighting.

Demonstrate interlinkages between climate mitigation measures and climate adaptation i.e climate wise and zero emission buildings.

### *Interlinked*

Quantify the potential emissions abatement from proposed policies, and advise emissions targets for each aspect of the emissions profile to achieve targets.

Advise on potential interim targets for 2030 and 2040 based on pathways options and emissions projections.

Set policy measures along an implementation timeframe demonstrating the abatement and timing of when the abatement will be achieved.

Provide a report and an Excel tool of the modelling that can be used and amended by the Directorate as current and future policy develops (wedge graph analysis of electricity and gas reductions with overlays of energy efficiency). Ownership of all material created for the purpose of providing the service, including reports, information, assumptions, data and any intellectual property rights, vests on its creation with the Australian Capital Territory Government.

An example of the work the Directorate would like is at the indicative graph in Attachment A.

## Key modelling and analysis

The consultancy is to include analysis in two parts:

***Part 1***

1. Baseline modelling/ BAU analysis based on all current policy (as aligned with IPCCC Global Protocol for GHG accounting standards) to 2030, 2040 and 2050.

- Analysis to include a sensitivity range for low, medium and high emission reduction scenarios with an averaged line out to 2050.
- This will include assumptions provided by the ACT Climate Change Council and EPSDD covering economic, policy and technology trends.
- Energy (gas and electricity) demand modelling including a section on peak
- demand considering impacts of electrified transport uptake.
- Energy (gas and electricity) supply modelling including any known impacts on emissions intensity of supply, or supply flows/quantum.

2. Identify the emissions abatement across the energy sector required to achieve net zero emissions by 2050 under the low, medium and high scenarios

***Part 2***

**A) Energy Sector**

This section covers the modelling requirements for gas, renewables and energy efficiency in supply and distribution:

1. Identification of abatement policies in the energy sector that can be implemented within the timeframe to 2030, 2040 and 2050.

2. Quantification of emissions reductions from identified new policy options in energy efficiency and its impact on electricity and gas demand.

3. Identification of gas and electricity emissions trajectories/pathways (with interim targets to 2030, 2040, 2050) creating scenarios of low, medium and high emission abatement.

4. Supply and demand for electricity and gas to be modelled separately. Policies which may influence supply include:

- Potential limitations of gas connection to new suburbs
- Assumed take-up rates for high efficiency electrical appliances for space heating, cooking and hot water
- Sensitivities as advised by the Directorate and identified experts on the renewable energy mix in the National Energy Market

5. Specific analysis on the impact on the 100% renewable electricity target, including:

- Electricity demand projections for the ACT, including electric transport uptake (vehicles and light rail), current battery storage programs and transition from gas to electricity.
- Renewable energy mix in the National Energy Market (including Federal RET and household solar)

6. Options will need to consider demand forces such as population growth, and substituting natural gas and transport fuels for electricity as well as price elasticity.

**B) Buildings/ Built Environment**

This section covers the modelling required for energy efficiency of buildings as a subset to energy sector emissions from grid supply.

1. Identification of abatement policies in the buildings sector that can be implemented within the timeframe to 2030, 2040 and 2050.

2. Quantification of emissions reductions from identified new policy options in building efficiency

(including impact on electricity and gas demand).

3. Identification of energy and building sector trajectories/pathways (with interim targets to 2030, 2040, 2050) creating scenarios of low, medium and high emission abatement.

4. Specific modelling on energy efficiency improvement potential in residential, commercial and industrial buildings and impact on demand.

- End use model based on BCA building types including:

  i. new and existing residential buildings (i.e retrofit vs new build)

  ii. new and existing commercial buildings including schools, hospitals, ACT Government and commonwealth operations where possible (i.e retrofit vs new build)

  iii. Industrial zone use
- Scenario modelling based from a high consumer activity model, using low/medium/high potentials of energy efficiency, including higher standards used in new suburban builds.
- Phased instalment of “zero carbon buildings” and potential for net energy neutral or energy positive buildings.

5. Specific consideration of ancillary benefits of emission reductions to the transport sector (i.e. EV charging inclusions in buildings), and through sustainable planning.

6. Options will need to consider demand forces such as population growth, and substituting natural gas and transport fuels for electricity as well as price elasticity.

# Appendix B: Methodology and Key Assumptions

## Reference Scenario

The projections of demand for electricity are taken from work being undertaken under a separate concurrent project for the Directorate, by a team led by *Strategy. Policy. Research*. This project is developing projections of greenhouse gas emissions from stationary energy consumption in the ACT out to 2050. The project involves the construction of new models of ACT consumption of both electricity and gas. Of course, only the electricity projections are used for the current project.

All projections are prepared on the basis of demand for electricity services, meaning all electrical energy used by each consumer, irrespective of whether that electricity is supplied through the meter from the local distribution network or behind the meter from rooftop PV.

Separate models were developed for residential and non-residential (henceforward termed commercial) consumption. Both models use a bottom up approach, in which consumption is disaggregated by type of electricity service/equipment and/or category of consumer. In both cases, the modelled consumption for both the most recent complete years (2014-15 and 2015-16) was reconciled with actual electricity consumption for those years. Consumption was measured as the sum of electricity supplied by ActewAGL Distribution, as specified in the annual AER RIN template reports, and estimated behind the meter consumption of electricity from rooftop PV. The latter estimates were made by comparing estimated output of rooftop PV installed in the ACT, using installation data from the APVI Live Solar Map website, with reported electricity supplied to ActewAGL Distribution by embedded generation at the premises of residential and non-residential consumers, as specified in the annual AER RIN template reports.

## Residential model

Modelling was done in three components: space heating and cooling, water heating, and all other energy consumption.

### *Stock model*

Both the space heating and cooling and the water heating components are based on a detailed stock model of ACT dwellings. All dwelling numbers modelled are occupied dwellings, as defined in the Census. Numbers of occupied dwellings are less than total dwelling numbers, and considerably less than the number of individual residential consumers of electricity. The stock of dwellings is allocated into the three main categories specified in the Australian Construction Code (ACC): Class 1A (separate/detached houses), Class 1B (town houses) and Class 2 (apartments, including both low rise and high rise). Using Census data, other ABS data, and data provided by the Directorate, a model of stock and stock turnover in recent years was constructed. The model had to go back some years in order to estimate numbers of dwellings falling into each of the four successive energy star rating classes now in the ACT housing stock: pre-4 star (assumed to be 2-star on average), 4 star, 5 star, and 6 star. For each of the three dwelling Classes the model includes, on a cumulative year by year basis: demolition and rebuild of a new dwelling of the same Class, demolition and rebuild of a new dwelling of a denser Class, greenfields new build, and rating upgrade through major refurbishment.

For the future, the model is driven by population, overall average dwelling occupancy (persons per occupied dwelling), and the expected future share of the three dwelling classes, as advised by the Directorate. For each of the three dwelling Classes it provides projections of total dwelling numbers in each year of each of the four energy efficiency ratings: 2-, 4- , 5- ,and 6-star.

### *Space heating and cooling*

For the space heating and cooling sub-model, annual heating and cooling thermal loads are calculated for an average individual dwelling in each dwelling Class and energy star rating, using NatHERS modelling results. Thermal loads are determined by the combination of thermal energy per m2 of floor space and conditioned floor area; the latter is largest for Class 1 dwellings and smallest for Class 2. Note that these results show that cooling thermal load is only one tenth of the heating load in an average dwelling in Canberra. A mix of heating and cooling equipment types is then estimated for each of the three dwelling Classes, drawing on successive ABS triennial energy use survey data. Finally, a table of energy efficiency of each equipment type is constructed. Four vintages are assumed for both equipment shares in each dwelling Class and successively increasing efficiency of equipment. For each new dwelling in each Class falling into each of the four vintages, equipment type weighted average consumption of electricity and gas for heating is then calculated, together with an equipment type weighted average consumption of electricity for cooling. These detailed input data allow for differing mixes of equipment in the different dwelling Classes (more electricity, less gas in Classes 1B and 2, compared with Class 1A), and a shift over time (past and future) away from both gas and electric resistance heating and towards RCAC heating.

Finally, the model includes replacement of heating equipment in older Class 1A dwellings at the end of an assumed life of 25 years. For heating, the share of gas in the replacement equipment is much lower than in the equipment being retired. It is assumed that after 2020 the gas share falls to zero, as all new equipment is RCAC.

Overall, future electricity use for heating and cooling will be increased by: population growth, a shift to active heating and cooling in all dwellings, and a shift from gas heating to RCAC. Electricity use will be decreased by: increased thermal efficiency of the dwelling stock, and increased energy efficiency of heating and cooling equipment. The modelling shows that the latter factors outweigh the former, so that total electricity consumption for residential heating and cooling gradually declines. Incidentally, gas consumption declines much faster. There is no shift over time in conditioned area, the assumption being that the historic shift over several past decades, from single room heating to most of dwelling heating, has been effectively completed.

### *Water heating*

For the water heating sub-model, annual requirements of electricity and gas for each type of water heater and each hot water load are taken from simulation modelling results. ABS survey data are used to estimate the water heating equipment type shares in the existing stock in each of the three dwelling Classes. These shares are applied to the simulation modelling results for the applicable annual hot water load to calculate equipment type weighted average per dwelling consumption of electricity and gas for water heating in the existing stock of dwellings in each Class.

Since 2013 the installation of large electric resistance storage water heaters in new dwellings has been prohibited under the ACC. This has led to much greater use of instantaneous gas and solar/heat pump water heaters in new Class 1A and 1B dwellings. The effect has been less in Class 2 dwellings, because they use

small electric water heaters, which are not prohibited. Most high rise apartment buildings in the ACT use reticulated hot water, supplied from a central gas boiler. This consumption is included with commercial energy demand. It follows that the weighted average per dwelling consumption of electricity and gas in new Class 1A and 1B dwellings changed decisively away from electricity and towards gas in 2013.

The model also allows for the turnover of water heating equipment after an assumed average life of 18 years. Since the ACC does not currently prohibit like for like replacement of old electric resistance water heaters, the replacement stock is assumed to have a lower, but non-zero share of this type, compared with what is being replaced.

The overall result is that consumption of electricity for residential water heating stays almost unchanged, while consumption of gas accounts for all of the population related increase in water heating energy consumption. Note that limited available data suggest that, over the past two or three decades, adoption of more water efficient technologies, such as low flow showerheads and front loading clothes washers, has greatly reduced residential hot water consumption. This modelling, however, assumes not further reductions in average per household hot water consumption.

### *Other residential electric loads*

Other loads were separately identified as lighting, refrigeration, cooking, and all other plug loads for electricity, and cooking and pool and spa heating for gas. Base year per dwelling values (MWh per dwelling per year) for each service were initially set equal to those prepared several years ago by Energy Efficient Strategies for use in a major study by BZE. These input values are single values for each end use load type for the whole of Australia. Insertion of these values resulted in modelled total residential consumption in 2014-15 and 2015-16 a few per cent higher than the actual values for each year. Reconciliation was achieved by adjusting the initial per dwelling values down slightly. This adjustment is consistent with the observed steady decrease in per household electricity and gas consumption over the past several years.

Projections for each load type were driven by household numbers, taken from the stock model, and by the following annual rates of change in per household consumption for the various load types: lighting -1%, refrigeration -1%, all other plug loads -1%, electric cooking 0%, gas cooking -2%, and pool and spa heating gas -1%. These values imply a gradual shift from gas to electricity for cooking. Projected near term demand was further reduced by two additional amounts:

- incremental electricity savings from national MEPS applying to purchases of new lighting, refrigerators, televisions, clothes washers, dishwashers and a few smaller equipment categories;
- savings from EEIP.

The MEPS savings were sourced from a major study undertaken last year for AEMO. The EEIP savings were calculated from data provided by the Directorate.

## Non-residential (commercial) model

Much less data is available about the details of electricity and gas use by non-residential consumers. A variety of sources, including comprehensive data on energy gas use by all ACT government agencies and functions, were combined with expert judgment to compile an allocation of electricity and gas consumption segregated into the following end user categories:

- office building central services
- office building tenant light and power
- public buildings
- data centres
- schools
- universities and research laboratories
- hospitals and health facilities, including central laundry facilities
- aged care facilities
- hotels and accommodation facilities
- retail premises, including restaurants and cafes
- stand-alone cold store facilities
- central services in apartment buildings
- road and traffic lighting
- potable water and sewage pumping
- various ACT government community and other facilities
- manufacturing activities undefined.

For each category, energy consumption was allocated between up to five end use types for electricity and three end use types for gas.

The end use types for electricity are:

- HVAC
- hot water/cooking
- lighting
- machinery and equipment, including motors and electronic equipment
- refrigeration equipment.

The end use types for gas are:

- HVAC
- hot water/cooking
- machinery and equipment.

Two trend factors were applied to each end use category. Firstly, demand for energy services was assumed to increase either in proportion to growth in population or to growth in GSP, depending on the category. Secondly, the combined effects of increasing energy efficiency of new equipment and the turnover of stock

were modelled by applying annual reductions in energy consumed per unit of energy service delivered of either 1% or 2% per annum, depending on end user category.

Finally, specific adjustments were made to energy consumption for HVAC, representing a shift from gas space heating to large RCAC heating. The shift was applied to HVAC gas consumption in the following end user categories:

- office building central services
- public buildings
- schools
- universities and research laboratories
- aged care facilities
- hotels and accommodation facilities
- retail premises, including restaurants and cafes.

The shift was defined as an annual reduction in HVAC use of a constant small percentage of base year gas use. The annual percentage used was 2% in public buildings, schools, and aged care facilities, and 3% in the other end user categories. Reduction in gas consumption was offset by an increase in electricity consumption equal, in energy terms, to one quarter (25%) of the decrease in gas consumption. The difference reflects the different efficiencies at delivering thermal energy of the two technologies being used, i.e. gas combustion and electric motor driven heat pump. Note that larger commercial heat pump HVAC systems have somewhat lower coefficients of performance than small residential RCAC systems.

## Electric vehicles

### *Methodology*

The transport model looks at two transport tasks for motorised vehicles. The first task is moving passengers, the second is moving freight.

For the **passenger task**, the main steps are:

- Estimate overall annual passenger task in passenger km (one person moving one kilometre).
- Apply assumptions of shares of the motorised task, which is performed by mix of cars, light commercial vehicles, motor and electric bikes, buses, light rail. The shares are shown below for the medium scenario
- convert passenger km to vehicle km
- assign a electricity use per vehicle km factor to each electric vehicle class
- calculate annual electricity use.

**Table 12: Medium Scenario - Shares of Passenger Task by Vehicle Type**

| Projected Shares of Annual Motorised Task | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Share of Motorised Task - Petrol + Diesel Cars** | 83% | 71% | 51% | 41% | 24% | 18% | 13% |
| **Share of Motorised Task - EV (BEV + PHEV)** | 1% | 8% | 20% | 30% | 45% | 49% | 54% |
| **Share of Motorised Task - LCVs petrol + diesel** | 9.0% | 9.5% | 9.0% | 8.0% | 6.0% | 5.0% | 3.5% |
| **Share of Motorised Task - LCVs electric** | 0.3% | 0.6% | 1% | 2% | 4% | 5% | 6% |
| **Share of Motorised Task - Motorbikes** | 0.9% | 0.9% | 0.9% | 0.8% | 0.7% | 0.6% | 0.4% |
| **Share of Motorised Task - Bus non-electric** | 4.0% | 4.0% | 4.0% | 3.0% | 3.0% | 3.0% | 3.0% |
| **Share of Motorised Task - Bus electric** | 0.0% | 1.0% | 4.0% | 5.0% | 5.0% | 6.0% | 7.0% |
| **Share of Motorised Task - Light rail** | 2.0% | 4.0% | 8.0% | 8.5% | 9.0% | 9.0% | 9.0% |
| **Share of Motorised Task - Electric Bike** | 0.2% | 1.0% | 2.0% | 2.0% | 3.0% | 4.0% | 4.0% |

The low and high scenarios differ in two ways. The first is population - which change the passenger km figures. The second is the share of Motorised task - EV Cars - which alters the share of petrol & diesel cars.

The shares of EV cars for low & high take-up are:

**Table 13: Electric Vehicle Take-Up Assumptions**

| Projected Shares of MotorisedTask | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| EV Cars Share (low take-up) | 1% | 5% | 16% | 28% | 30% | 34% | 39% |
| EV Cars (high take up) | 1% | 20% | 35% | 45% | 55% | 65% | 67% |

The model does not calculate vehicle or fleet numbers. Rather we are looking at vehicle use; it is the split of the task that impacts energy use. Therefore, we don't make specific estimates of sales or what the stock of vehicles looks like.

There will be correlation between the share of the passenger task and the make-up of the fleet. However the correlation will not be perfect. While we haven't modelled vehicle stock turnover, we would expect the share of EV cars in the total car fleet to lag behind the EV car share of passenger km. For example, in 2023 a family might have two cars, an EV that they purchased in 2022 and a petrol car that they purchased in 2019. In this situation it is likely that more of that family's passenger task will be performed by the EV - because it is cheaper to run per km. The petrol car will fulfil the role of a second car, used less on a day to day basis and might be used to drive to Tathra, on the NSW south coast for the holidays due to range issues (so a higher share of the petrol vehicle kms will occur outside the ACT).

For the f**reight task**, the main steps are:

- Estimate total freight vehicle km (vkm) travelled; split by Light Commercial Vehicles (LCVs), Rigid Trucks (RTs) and Articulated trucks (ATs)
- Assume shares of freight vkm performed by electric versions of the three broad freight vehicle types
- Apply electricity consumption factors to electric freight vehicles
- calculate annual electricity consumption.

The transport task shares by vehicle type are shown overleaf:

### Table 14: Freight Task Shares by Vehicle Type

| Shares of freight vkm performed by Evs – MEDIUM Take Up | *2020* | *2025* | *2030* | *2035* | *2040* | *2045* | *2050* |
|---|---|---|---|---|---|---|---|
| Share of LVC vkm performed by ELCVs | 0% | 5% | 10% | 25% | 50% | 60% | 65% |
| Share of Rigid truck vkm performed by ERTs | 0% | 0% | 2% | 20% | 30% | 40% | 50% |
| Share of Artic trucks performed by EATs | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Shares of freight vkm performed by Evs – LOW Take Up | *2020* | *2025* | *2030* | *2035* | *2040* | *2045* | *2050* |
| Share of LVC vkm performed by ELCVs | 0% | 2% | 5% | 20% | 30% | 40% | 45% |
| Share of Rigid truck vkm performed by ERTs | 0% | 0% | 2% | 5% | 10% | 15% | 20% |
| Share of Artic trucks performed by EATs | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Shares of freight vkm performed by Evs – HIGH Take Up | *2020* | *2025* | *2030* | *2035* | *2040* | *2045* | *2050* |
| Share of LVC vkm performed by ELCVs | 0% | 20% | 30% | 50% | 80% | 100% | 100% |
| Share of Rigid truck vkm performed by ERTs | 0% | 0% | 20% | 30% | 60% | 70% | 80% |
| Share of Artic trucks performed by EATs | 0% | 0% | 0% | 5% | 20% | 50% | 50% |

0%

Fleet numbers and vehicle sales are not estimated for the freight sector.

Other key inputs and assumptions are tabled below:

## Table 15: Passenger Transport Inputs and Assumptions

| Description | Units | Value | Source |
|---|---|---|---|
| 2014 ACT Motorised passenger km Task per Capita 2014 | pkm per year | 13,560 | Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2014, Long-term trends in urban public transport, Information Sheet 60, BITRE, Canberra. |
| Average Annual fall in total Motorised Task per capita in the last decade | % | 0.9% | BITRE, 2014 |
| Projected Annual fall in motorised task per capita 2020-50 | % | 1.4% to 2.8% | SPR estimate. In recent years use of active transport, increased population densities surrounding business districts and the use of travel avoiding technologies like teleconferencing and webinars has lowered the passenger transport task. We expect this trend to continue and slightly strengthen. |
| Population – low growth | People | 415,000 in 2020 520,000 in 2050 | ACT Treasury |
| Population – medium growth | People | 424,000 in 2020 609,000 in 2050 | ACT Treasury |
| Population – high growth | People | 440,000 in 2020 730,000 in 2050 | ACT Treasury |
| **Electricity Consumption by example of vehicle class** | | | |
| 2014 Share of Motorised Task - Cars | % | 86.9% | BITRE, 2014 |
| 2014 Share of Motorised Task - LCVs | % | 8.1% | BITRE, 2014 |
| 2014 Share of Motorised Task - Motorbikes | % | 0.9% | BITRE, 2014 |
| 2014 Share of Motorised Task - Bus | % | 4.1% | BITRE, 2014 |
| Electricity consumption Nissan Leaf (for passenger cars) | kWh/vkm | 0.173 | https://www.greenvehicleguide.gov.au/Vehicle/QuickCompareVehicles |
| Renault Kangoo ZE (for electric LCVs) | kWh/vkm | 0.155 | Green Vehicle Guide |
| Light Rail | kWh/vkm | 3 | AECOM, ACT Light Rail Electrical Demand and Infrastructure assessment |
| Proterra Electric Bus | kWh/vmile | 2.15 | https://cleantechnica.com/2016/02/22/electric-buses-efficient-as-he-nrel-finds/ |
| Proterra Electric Bus | kWh/vkm | 1.33 | converted: 0.62 miles in 1 km |
| Electric Bike | kWh/vkm | 0.06 | http://www.nycewheels.com/energy-efficient-electric-bike.html reports that an average EB uses 1.8kWh per charge for a 20 mile (32km) trip |
| **Average Passenger numbers per vkm by example of vehicle class** | | | |
| Nissan Leaf (for passenger cars) | | 1.10 | |
| Renault Kangoo ZE (for electric LCVs) | | 1.00 | |
| Light Rail | | 110.00 | https://www.transport.act.gov.au/light-rail-project/faq reports that capacity is 207 passengers. SPR assumption of average utilisation is a little over half full capacity |
| Proterra Electric Bus | | 25.00 | https://cleantechnica.com/2016/02/22/electric-buses-efficient-as-he-nrel-finds/ |

### Table 16: Estimated Electric Vehicle Shares of Motorised Task from 2020 to 2050

| Growth scenario EV share | Source of estimate | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| **HIGH** | SPR | 1% | 20% | 35% | 45% | 55% | 65% | 67% |
| **MED** | SPR | 1% | 8% | 20% | 30% | 45% | 49% | 54% |
| **LOW** | AECOM, 2016, Table 3 for 2035 and beyond. SPR reduced AECOM figure by 5% for 2025 and 10% for 2030 for the low case. | 1% | 5% | 16% | 28% | 30% | 34% | 39% |

### Table 17: Freight Transport Inputs and Assumptions

| Description | Unit | Value | Source |
|---|---|---|---|
| ACT annual vehicle km travelled (to 31 Oct 2014) | million vkm | | ABS, Table 17, Survey of Motor Vehicle Use, Australia, ended 31 Oct 2014 |
| LCVs | M vkm | 738 | |
| Rigid trucks | M vkm | 77 | |
| Articulated trucks | M vkm | 12 | |
| Rate of annual decrease in tonne km (tkm) freight task in ACT in the decade to 2013-14 | % | -3.2% | NTC, Who moves what where, Aug 2016, p 181 |
| Year of Lowest freight tkm since 2000-01 | year | 2011-12 | NTC |
| Annual growth in freight nkm from 2011-2 to 2013-14 | % | 3.50% | NTC |
| Assumed Freight vehicle km change to 2050 | MED | LOW | HIGH |
| LCVs | 1% | 0.50% | 2% |
| Rigid Trucks | 1% | 0.50% | 2% |
| Articulated Trucks | -1% | -2% | 1% |
| *Note: While freight vehicle task in tonne km has declined over the last decade, in more recent years growth has resumed. SPR have assumed modest freight vehicle km growth for LCVs and Rigid Trucks. Articulated vehicles are very efficient on long haul runs, but less efficient in urban environments, therefore a small drop in articulated vehicle km is forecast under the low and medium scenarios)* | | | |
| Share of small electric LCVs | % | 70% | SPR |
| Share of medium & large electric LCVs | % | 30% | SPR |
| Electricity use Renault Kangoo (approx 500kg payload) | kWh/vkm | 0.155 | Green Vehicle Guide |
| Electricity Use Iveco Daily Electric (approx 2.5t payload) | kWh/vkm | 0.5 | SPR estimate - energy consumption between the Kangoo and Rigid ET |
| Electricity use Rigid Truck (10 t payload) | MJ/vkm | 2.86 | http://www.rms.nsw.gov.au/documents/about/environment/air/case-study-electric-distribution-truck.pdf |
| Electricity use Rigid Truck (10 t payload) | kWh/vkm | 0.80 | (converted, 0.28 kWh per MJ) |
| Electricity use Articulated Truck | kWh/vkm | 1.6 | SPR assumption – diesel articulated vehicles use approximately double the fuel as medium rigid trucks |

**Table 18: Assumed Electric Shares of Freight Vehicles**

| Growth scenario EV share | freight vehicle category | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| **HIGH** | LCVs | 0% | 20% | 30% | 50% | 80% | 100% | 100% |
| | Rigids | 0% | 0% | 20% | 30% | 60% | 70% | 80% |
| | Articulated | 0% | 0% | 0% | 5% | 20% | 50% | 50% |
| **MEDIUM** | LCVs | 0% | 5% | 10% | 25% | 50% | 60% | 65% |
| | Rigids | 0% | 0% | 2% | 20% | 30% | 40% | 50% |
| | Articulated | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **LOW** | LCVs | 0% | 2% | 5% | 20% | 30% | 40% | 45% |
| | Rigids | 0% | 0% | 2% | 5% | 10% | 15% | 20% |
| | Articulated | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

*Notes:*

- *SPR assume that EVs such as Renault's Kangoo electric small van, IVECO's Daily electric large van, and a 10-tonne rigid truck as tested for the GreenTrucks partnership will drop in purchase price over time and play an increasing role in the freight fleet*

For the medium and low EV growth scenarios, we have adopted IRENA's assumption that all articulated trucks will be driven by liquid biofuels rather than electricity. However, for the high growth scenario electric versions of articulated vehicles are given a share (Tesla is reportedly developing an electric semi-trailer truck).

## Policy Scenarios

The main emphasis of the modelling is on displacing gas and all results are set up to achieve zero gas use by 2050. This means that emphasis is on HVAC, water heating and cooking. At this stage, no assumptions, additional to the Ref case, have been about higher efficiency of refrigeration, lighting, electric motors and motor driven equipment, and electronic equipment.

Modelling for both HVAC and water heating is based on underlying models of the stock of buildings. The models represent the mix of stock of different vintages in each future year. This allows the modelling to represent changes in the efficiency of both equipment and, in the case of HVAC, the buildings themselves. They also allow policy changes in the form of changing requirements for new stock, replacement stock and upgraded stock to be explicitly represented and for replacement changes to be based on specified equipment lives, i.e. specified turnover rates, which are different for HVAC and water heating (and can also be varied if desired).

For the residential sector, the model is based on actual data on existing stock, demolitions, new builds and upgrades, together with projections of occupancy and the mix of the three dwelling types (NCA Classes 1A, 1B and 2). For the commercial sector, total consumption is first separated into different building categories (as well a few other activities such as street lighting). The building categories include offices, public buildings, schools, retail etc. For each category, a 'synthetic' stock model has been constructed, designed to be scaled against actual energy consumption in the base year (2015-16). The model allows for the fact that base year energy consumption is derived from a mix of existing equipment of different vintages with different efficiencies, and that this will continue into the future, but evolve as old equipment is replaced.

The main differences between the Mid, High and Low cases arise from different assumptions about future rates of population and GSP growth. There are a few other differences, specific to particular energy use categories. These are noted below, where they apply. The remainder of this note itemises the particular assumptions used for each end use category

## Residential Sector

### *Residential HVAC*

**Reference**

- For all three dwelling Classes, thermal performance requirement for new builds is lifted to 7 stars in 2022, 7.5 stars in 2028 and 8 stars in 2034.
- For pre-4 star Class 1A dwellings, accounting for 53% of total stock in 2016, demolitions/rebuilds are 0.4% of stock each year and major retrofit upgrades (to 4 stars) are about 0.1% each year.
- Equipment life/turnover interval for HVAC equipment is 25 years.
- All HVAC equipment in new dwellings is RCAC after 2017.
- All gas heating on retirement is replaced by RCAC after 2022.
- New RCAC equipment efficiency is assumed to increase at a rate of 1% p.a.

**With New ACT Policies**

Measures additional to Reference are:

- Thermal performance of new dwellings is lifted to 9 stars in 2036 and 10 stars in 2040; we assume that this will be realised by adding rooftop PV, but the effect will be to reduce demand for electricity from other sources.
- Major retrofits of pre-4 star Class 1 dwellings are increased to approximately 1% of stock p.a.
- Efficiency of new RCAC equipment increases by 1.5% p.a. during 2017 to 2024, 1.4% p.a. during 2024 to 2029, 1.3 p.a. during 2030 to 2034, 1.2% p.a. during 2035 to 2039, 1.1% p.a. during 2036 to 2040, 1.1% p.a. during a 2040 to 2044, and 1% p.a. thereafter.
- Comment: We have used fairly aggressive assumptions about RCAC replacing gas in the Reference case, reaching zero gas by 2035. The effect of the higher thermal performance requirement for new dwellings is to bring this forward by three years.

### *Residential hot water*

**Reference**

This category is a particular challenge because of the effect of the Code requirements in driving consumers to gas. Reversing this will need strong ACT-specific policies. Assumptions are as follows.

- System life/turnover interval is 18 years.

- When large electric resistance water heaters are retired about one third are replaced by either gas (the majority) of solar/heat pump, with the proportions varying between dwelling Class; the remainder are like for like. The proportions stay constant across the whole projection period.
- Water heaters in new dwellings are 60% gas, 40% solar/heat pump for Class 1A, slightly higher gas for Class 1B. Half the water heating in Class 2 is assumed to be centralised supply from large gas systems, included in the Commercial sector. The other 50% is mostly small electric resistance, with some gas and some solar/heat pump.
- No changes in efficiency.

**With New ACT Policies**

- No gas water heaters in new dwellings after 2020, i.e. in Class 1A effectively only heat pump or solar. Use of small electric resistance, consistent with the Code, would be allowed in Class 1B and 2.
- No like for like replacements of gas water heaters after 2025.

These assumptions drive a rapid transition away from gas water heaters.

### *Residential cooking*

**Reference**

Modelling is not based on as stock model, but on simple aggregate energy consumption.

- Each year 2% of households switch from gas to electric induction.
- There is no efficiency improvement for electric cooktops, which are assumed to be induction, over the period.
- Total numbers grow at the same rate as population.

**With New ACT Policies**

- From 2018, 5% of existing households switch from gas to electric cooktops (assumed to be induction) each year.
- From 2018 only 30% of new households use gas cooktops, and this declines to 20% in 2023, 10% in 2028 and zero in 2032. All these are replaced by electric at the end of their life, assumed to be 20 years.

### *Residential pool heating*

**Reference**

- Gas use declines by 1% p.a.
- Underlying demand for services increases at the same rate as population.

**With New ACT Policies**

- Gas use declines by 5% p.a. and is (implicitly) replaced by solar,
- Any additional electricity consumption, e.g. for heat pumps, is ignored, as being very small.

### *Refrigeration*

**Reference**

- Per household consumption decreases by 1% p.a. and, in addition, substantial savings arising from the national MEPS continue to reduce consumption for some years.

**With New ACT Policies**

- No change from Reference.

### *Lighting*

**Reference**

- Per household consumption decreases by 1% p.a. and, in addition, substantial savings arising from the national MEPS continue to reduce consumption for some years.

**With New ACT Policies**

- No change from Reference.

### *All other plug loads*

**Reference**

- Per household consumption decreases by 1% p.a. and, in addition, substantial savings arising from the national MEPS continue to reduce consumption for some years.

**With New ACT Policies**

- No change from Reference.

## Commercial Sector

### *Commercial HVAC*

**Reference**

- Depending on sector, the underlying driver for HVAC services is either population or GSP.
- System life/turnover interval is 20 years.
- Mandatory minimum energy efficiency of new buildings increases by 30% in 2020 (40% in the Low case, 20% in the High), and by 15% on a declining basis every six years thereafter.
- The technical efficiency of new electric equipment increases by 0.5% p.a. both in the past and in the future. The corresponding figure for gas heating systems is 0.2% p.a.
- As old gas systems are replaced 50% are replaced by electric systems with an efficiency (energy input to heat output) initially 4 times, and increasing at 0.5% p.a. These ratios are repeated on the next 20 year replacement cycle, on the declining balance, meaning that there would be still appreciably gas consumption in 2050 in the reference scenario.
- New systems are 50% gas heating and 50% electric.

- Behavioural changes by building occupants reduce thermal energy requirements by 0.4% per year.

**With New ACT Policies**

- From 2018, all new buildings use electricity, not gas.
- From 2018, 50% of all gas heating systems replaced are switched to electricity.
- The remaining 50% of gas is completely replaced with electricity on the next iteration, starting in 2038; this means that not all of the remaining gas heating has been replaced by 2050, as the second 20 year cycle has not ended.
- In addition, behavioural changes by building occupants, assumed to be supported by policy incentives, reduce thermal energy requirements by 0.8% per year.

### *Commercial water heating*

**Reference**

- Equipment life/turnover interval is 20 years in some sectors and 10 years in others.
- From 2018, 50% (40% for Public buildings) only of new buildings use electricity, not gas.
- From 2018, 50% (40% for Public buildings) of all gas heating systems replaced are switched to electricity.
- Another 50% (40%) of gas is replaced with electricity on the next iteration, starting in 2038; this means that not all of the remaining gas heating has been replaced by 2050.
- Technical efficiency and behavioural changes annual parameters applied are the same as for commercial HVAC.

**With New ACT Policies**

- From 2018 all new systems are 100% electric.
- On the second iteration of replacement, all remaining gas systems are replaced by electric, meaning that most, but not all gas is displaced by 2050.
- Behavioural changes by building occupants reduce energy requirements by 0.4% per year.

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