Victorian residential case study

A note for Gas Energy Australia – 15 November 2022

Pathway to reduced emissions

There are numerous technological pathways for LPG to achieve net zero emissions.

Currently, the emissions from the use of LPG compare favourably with most other forms of energy, including electricity. Whether this continues to be the case depends on the rate of emissions reductions that can be achieved for LPG and for other forms of energy. For electricity, it is expected that emissions intensity will fall significantly over coming years. There are technologies available that can deliver similar reductions in emissions for LPG.

However, for LPG to deliver net zero, it is not only important that the emissions intensity of LPG falls over time, but also that LPG remains competitive as a source of energy to customers.

This note considers both emissions intensity and costs of LPG during the energy transition, focusing on a case study for a Victorian residential LPG customer.

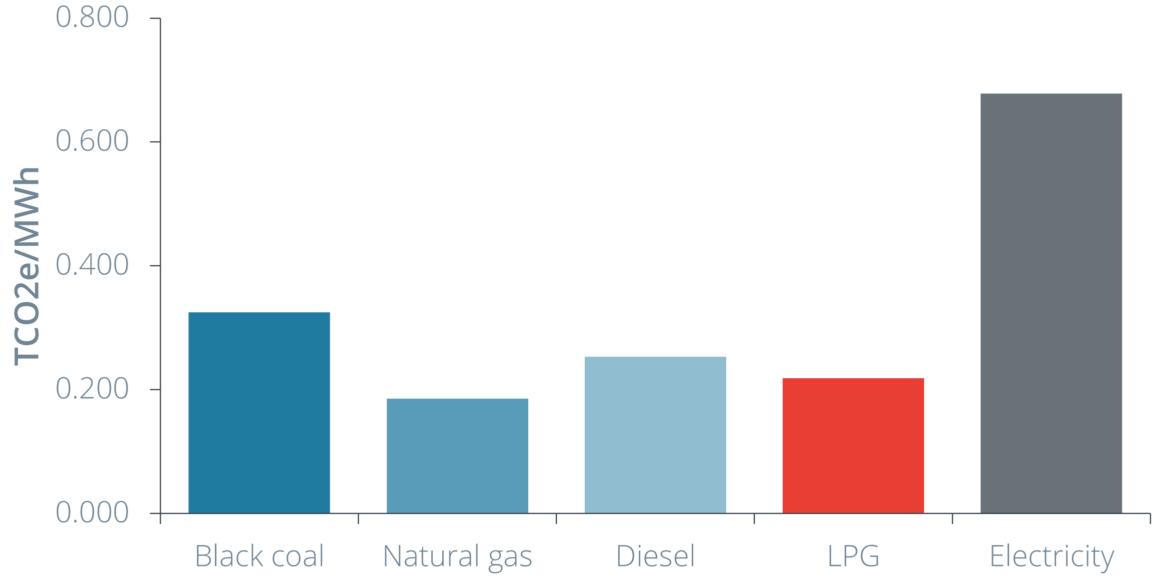
Emissions intensity

Users of LPG are likely to have available to them other forms of energy that they could use in place of LPG, if necessary. Depending on the customer, these alternatives might include electricity, diesel or coal. Natural gas is also a long-term potential option, but it is typically not available in areas where customers use LPG. The emissions intensity of these different forms of energy are shown in **Figure 1**.

It is clear from **Figure 1** that the emissions intensity of LPG is currently lower than the likely alternatives for existing users of LPG, so that the emissions resulting from the use of a MWh of LPG are lower than the emissions resulting from the use of a MWh of these other forms of energy. The emissions intensity of LPG is:

- 67% of the emissions intensity of black coal,
- 86% of the emissions intensity of diesel, and
- 32% of the emissions intensity of electricity.

Figure 1: Emissions intensity



Source: Australian Government, National Greenhouse Accounts Factors, August 2021; AEMO, Carbon Dioxide Equivalent Intensity Index.

However, emissions *intensity* is not the only determinant of the emissions associated with using energy. The amount of energy used also matters. This is determined by the energy efficiency of appliances.

It is likely that the energy efficiency of LPG, diesel, natural gas and coal appliances are sufficiently similar that the emissions intensities shown in **Figure 1** are also a good indicator of the total emissions for these forms of energy.

However, when comparing LPG emissions with electricity emissions, the energy efficiency of appliances matters because electrical appliances can be significantly more efficient than LPG appliances. This means that customers using electricity may use less energy in total than customers using LPG.

Given that the emissions intensity of LPG is currently less than a third of the emissions intensity of electricity, in order for the emissions from using electricity to be lower than the emissions from using LPG, it would need to be the case that, on average, electrical appliances are more than 3 times more efficient than LPG appliances.

For some customers this may be the case. For instance, estimates suggest that electrical heat pumps used for residential space heating can be 3 times more efficient than LPG heaters and that electrical heat pumps used for residential water heating, and electrical induction cooking, are around 2 times more efficient than LPG appliances. However, lower-cost electrical resistance appliances offer a much smaller efficiency advantage over LPG appliances. This also applies for commercial and industrial LPG customers; heat pumps may not be reasonable alternatives to LPG appliances for all commercial and industrial LPG customers, which would mean that any efficiency gain these customers achieve by switching from LPG to electricity would be more limited.

If we assume, on average for the mix of residential, commercial and industrial LPG customers, that electrical appliances that replace LPG appliances are 2 times more efficient, this suggests that, currently, the total emissions from using LPG are 64% of the total emissions from using electricity.

At the same time as the emissions intensity of electricity is expected to decline as part of the transition to net zero in 2050, there are many opportunities for the emissions intensity of LPG to also decline as part of the transition to net zero. The opportunities for emissions reduction for LPG include:

- BioLPG produced as a by-product of renewable diesel or sustainable aviation fuel (SAF) through the hydrotreated vegetable oil (HVO) process.
- BioLPG produced as by-product of renewable diesel or SAF through gasification with the Fischer-Tropsch process.[1]
- DME produced from biomass, blended with conventional LPG or bioLPG.
- Renewable DME, blended with conventional LPG or bioLPG.
- LPG produced from renewable energy through a Power-to-X process.[2]

We have developed a transition path for LPG to zero emissions that involves:

- BioLPG produced as a by-product through the HVO process, commencing in 2025. There are a number of HVO plants currently planned for Australia, including:
  - Sherdar Australia has announced plans for a biorefinery in Australia
  - Oceania Biofuels has selected Gladstone as the site for a planned biorefinery.
  - BP has proposed a biorefinery at its former refinery site in Kwinana.
- BioLPG produced as a by-product through gasification and the Fischer-Tropsch process, commencing in 2030.
- Renewable DME blending, commencing in 2035.
- Zero emissions LPG through Power-to-X, commencing in 2040.

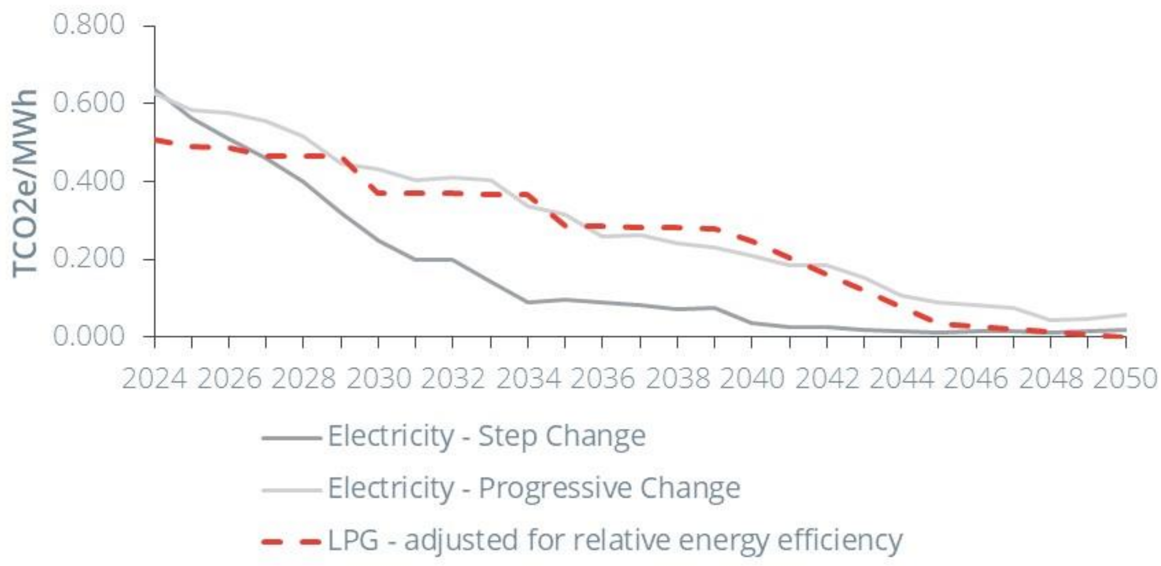
The resulting emissions intensity for LPG is shown in **Figure 2**, and compared with forecasts of emissions intensity for electricity, adjusted for relative energy efficiency (assuming electrical appliances are 2 times more efficient than LPG appliances, on average). The emissions intensity of electricity is shown for two scenarios from AEMO's ISP, with the Step Change scenario being identified by stakeholders as the most likely scenario and the Progressive Change scenario being identified by stakeholders as the next most likely scenario.

1 The Fischer-Tropsch process is a collection of chemical reactions that converts a mixture of hydrogen and carbon monoxide into liquid hydrocarbons. The process has a long history being used to convert syngas from coal gasification into liquid hydrocarbons. It can also be used with biomass gasification to produce liquid hydrocarbons.

2 Power-to-X is a term to describe processes that convert renewable energy into fuels and chemicals. It can be used to convert renewable energy to synthetic hydrocarbons.

While there is, of course, a great deal of uncertainty about both the transition for the electricity sector and the transition for the LPG sector, and the relative efficiency of appliances, what this LPG transition path demonstrates is that there are options for reducing LPG emissions that would result in the emissions from LPG following a similar reduction path as the emissions from electricity.

Figure 2: Forecast emissions intensity for electricity and LPG (adjusted for appliance energy efficiency)



Source: Frontier Economics calculations; AEMO 2022 ISP

Case study for Victorian residential customer

For LPG to play a role in the transition to net zero, it is not only important that the emissions intensity of LPG falls over time, but also that LPG remains competitive as a source of energy to customers.

In this note we investigate the financial impacts of LPG use during the energy transition for a typical Victorian LPG customer.

We assume that this typical residential customer is a household in a regional area, without access to natural gas. We assume the customer is located in Swan Hill, so we use estimates of LPG prices and electricity prices in for Swan Hill. We assume that the typical residential customer uses LPG for cooking, water heating and space heating, and that the amount of LPG used by the customer for these purposes is equal to the average residential consumption of LPG in Victoria.

Methodology

We consider the financial impacts of LPG use during the energy transition for a typical Victorian LPG customer that uses LPG for space heating, water heating and cooking, relative to the alternative of using electricity. The financial impacts if LPG use relative to electricity depend on:

- **Changes in household energy bills**. Electrification will bring about changes in the costs to households of purchasing energy. Electrification of household use of LPG will mean that households will no longer purchase LPG, but will face higher electricity bills, reflecting higher electricity consumption. The total energy bills that households face are one part of the financial impact to households of electrification.
- **Changes in household appliance costs**. Electrification will also bring about changes in the costs of appliances that households use. Electrification of household use of LPG will mean that households will need to purchase and install electrical appliances for cooking and heating, rather than LPG appliances.

We estimate the financial impacts for households from both of these changes – changes in energy bills and appliance costs.

The type of electrical appliances that a customer chooses to replace their LPG appliances will have a significant impact on the financial impact. Customers can choose higher-cost but more efficient appliances, such as heat pumps for space heating, heat pumps for water heating and induction cooktops, or can choose lower-cost and less efficient appliances, such as electric panel heaters, traditional electric storage water heaters and electric coil cooktops. A customer that chooses the more efficient appliances will face higher upfront appliance costs but lower electricity bills over time, relative to a customer that chooses the less efficient appliances. Because of this difference, we consider outcomes for both appliance mixes.

We calculate energy bills based on estimated consumption and estimated prices for our representative household:

- For LPG, we use the Residential Baseline Study[3] for estimates of average consumption of LPG for cooking, space heating and water heating (indicating 26,000 MJ/annum of LPG use for an average customer). Estimates of LPG prices are from a price comparator website[4] (indicating average prices of 4.47 c/MJ and 10.54 c/day), and we assume that wholesale bioLPG, rDME and renewable LPG will have a cost premium of 50% relative to conventional LPG. Estimates suggest that the cost premium could be between 25% and 100%, so we also discuss scenarios with these higher and lower cost premiums.
- For electricity, we calculate average consumption based on the assumption that the household requires the same output (heat) as when using LPG. This means that the amount of additional consumption of electricity due to electrification of gas use is determined by the relative efficiency of electrical appliances and LPG appliances. As we discuss, this depends on the efficiency of the electrical appliances that a customer chooses:
    - **Higher efficiency electricity appliances**. For induction cooking we assume an efficiency of 75%, for an electrical heat pump used for space heating we assume a coefficient of performance (CoP) of 2.5, and for an electrical heat pump used for water heating we assume a coefficient of performance of 2.0. These compare to assumed efficiencies of 40%, 85% and 85% for LPG cooking, LPG space heating and LPG water heating respectively.

3 2021 Residential Baseline Study for Australia and New Zealand for 2000 – 2040. https://www.energyrating.gov.au/document/report-2021-residential-baseline-study-australia-and-new-zealand-2000-2040

4 https://home-lpg-prices.com.au/about/

This implies, for instance, that using electricity for space heating means the household would require 34% of the energy that the household would require if using LPG for space heating.

- **Lower efficiency electricity appliances**. For electric coil cooktops we assume an efficiency of 75%, for electric panel heaters we assume an efficiency of 100%, and for electrical storage water heating we assume an efficiency of 95%. These compare to assumed efficiencies of 40%, 85% and 85% for LPG cooking, LPG space heating and LPG water heating respectively. This implies, for instance, that using electricity for space heating means the household would require will be only 85% of the energy that the household would require if using LPG for space heating.

Estimates of electricity prices are from Victorian Energy Compare[5](indicating average prices of 20.75 c/kWh and 116.69 c/day), and we assume that retail electricity prices will change over time according to AEMO's forecasts of future electricity prices for Victoria.

The costs of appliances that households face extend beyond just the cost of purchasing new appliances. Households will also face a number of other costs associated with appliance replacement and installation. The potential appliance costs that we consider in this study are:

- The cost of removing existing appliances, including any rectification work that might be required. This includes activities such as covering up existing ducts, plastering, and painting.
- The cost of purchasing new appliances.
- The cost of installing new appliances, including labour and materials.

Estimates of LPG and electrical appliances costs for a representative household are based on Frontier Economics' recent study for the Gas Appliance Manufacturers Association of Australia (GAMAA)[6] and, for lower-efficiency appliances, prices from retail stores.

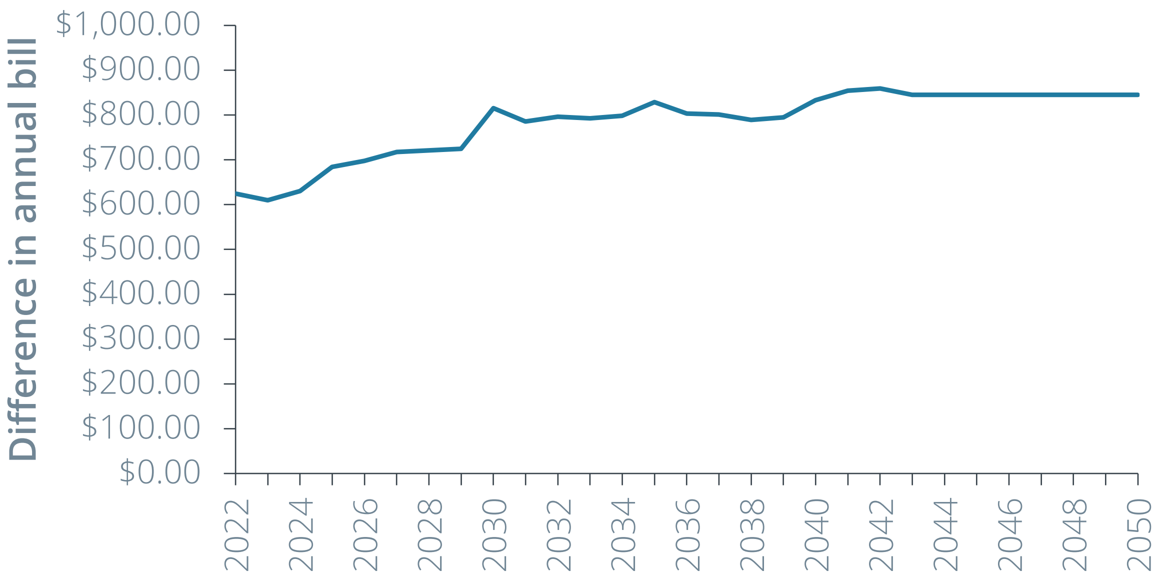
Outcomes for customers that choose **higher-efficiency** electrical appliances

Based on our assumptions, we find that our representative household in Victoria that chooses higher-efficiency electricity appliances would face lower energy bills by switching from LPG appliances to electrical appliances. While LPG is cheaper than electricity (per unit of energy) this benefit of LPG use is outweighed by the lower energy consumption that is enabled by more efficient electrical appliances, particularly heat pumps for space heating and water heating. The savings in energy bills are shown in **Figure 3** which include the assumption that wholesale bioLPG, rDME and renewable LPG will have a cost premium of 50% relative to conventional LPG. Based on this, the energy cost savings initially amount to around $600/annum, increasing to around $850/annum by the 2040s.

5 https://compare.energy.vic.gov.au/offers

6 Frontier Economics, *Cost of switching from gas to electric appliances in the home*, A report for the Gas Appliance Manufacturer's Association of Australia, 24 June 2022. Available here: https://gamaa.asn.au/

Figure 3: Savings in energy bills from switching from LPG to higher-efficiency electrical appliances



Source: Frontier Economics analysis

For a scenario in which wholesale bioLPG, rDME and renewable LPG will have a cost premium of 25% relative to conventional LPG, the energy cost savings will initially be around the same level of $600/annum, but those savings will only reach around $700/annum in the long-term. For a scenario with a cost premium of 100%, those savings will initially be around the same level of $600/annum but will reach around $1,150/annum in the long-term.

While these energy bill savings are substantial, the additional appliance costs from switching from LPG appliances to electrical appliances are also substantial. More efficient electrical appliances (induction cookers and heat pump water heaters in particular) are more expensive to purchase than LPG alternatives and are also more expensive to install in houses that are currently using LPG appliances. This results in substantially higher upfront costs for electrical appliances. Amortising these higher upfront costs over the lifetime of these appliances (assumed to be 10 years) at a discount rate of 7% results in an additional annualised cost for electrical appliances of around $850/annum.

Considering both energy bills and appliance costs, based on our assumptions, continuing to use LPG appliances remains lower cost for our representative household in Victoria until the 2040s, at which point using LPG appliances and using electrical appliances are very similar in cost.

A summary of our residential case study is provided in **Table 1**, for a customer choosing today between replacing existing, end-of-life LPG appliances with new LPG appliances or replacing existing, end-of-life LPG appliances with new higher-efficiency electrical appliances.

As seen in **Table 1**, the upfront cost of electrical appliances is materially higher, so that even though energy bills over the next 10 years will be lower on average with higher efficiency electrical appliances, the total cost over 10 years is lower if the customer remains with LPG appliances.

These lower energy bills from switching to electricity are based on AEMO's forecast of retail electricity prices, which are for electricity prices to fall over the next 10 years. We note, however, that expectations following recent market events are that retail electricity prices will increase materially, at least in the near term.

Table 1 also shows total emissions over the next 10 years for the two options. Emissions are higher if the customer continues to use LPG appliances, relative to higher-efficiency electrical appliances, by around 5 tCO2e over the 10 years. This is a result of the rapid reduction in emissions intensity forecast by AEMO for the Step Change scenario over the next 10 years. Under the Progressive Change scenario, emissions are still higher if the customer continues to use LPG appliances, but the difference is smaller (around 2 tCO2e over the 10 years).

Table 1: Summary of results – customers that choose **higher-efficiency** electrical appliances

	Upfront appliance cost *	Annualised appliance cost	Average annual bill 2023 to 2032 (real dollars)	Average total annual cost (2023 - 2032)	Total emissions over 10 years
LPG and electricity case					
Cooking (LPG hub)	$1,200.00				
Space heating (LPG indoor flued heater)	$2,799.00				
Water heating (LPG instantaneous)	$1,900.00				
Total	$5,899.00	$839.88	$2,565.19 **	$3,405.08	35.38
Electricity only case					
Cooking (induction)	$2,346.67				
Space heating (RCAC, two room)	$4,925.00				
Water heating (heat pump)	$4,600.00				
Total	$11,871.67	$1,690.26	$1,846.86	$3,537.12	30.71 ***

** includes removal of existing appliance, new appliance purchase and installation)*

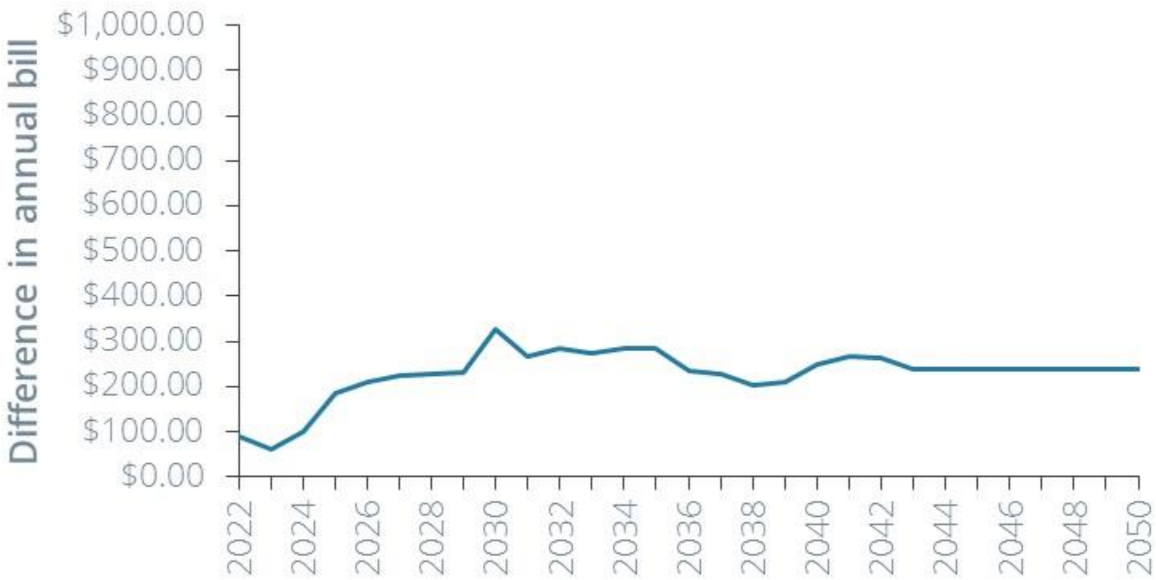
*** includes LPG costs and electricity bills*

**** Step Change scenario*

Outcomes for customers that choose **lower-efficiency** electrical appliances

Based on our assumptions, we find that our representative household in Victoria that chooses lower-efficiency electricity appliances would face lower energy bills by switching from LPG appliances to electrical appliances, but the relative difference compared to LPG will be much lower. While LPG is cheaper than electricity (per unit of energy) this benefit of LPG use is outweighed by the lower energy consumption that is enabled by more efficient electrical appliances, even for lower-efficiency electrical appliances. The savings in energy bills are shown in **Figure 4**, based on the assumption that wholesale bioLPG, rDME and renewable LPG will have a cost premium of 50% relative to conventional LPG. Based on this, the energy cost savings initially amount to around $100/annum, increasing to around $250/annum by the 2040s.

Figure 4: Savings in energy bills from switching from LPG to lower-efficiency electrical appliances



Source: Frontier Economics analysis

For a scenario in which wholesale bioLPG, rDME and renewable LPG will have a cost premium of 25% relative to conventional LPG, the energy cost savings will initially be around the same level of $100/annum but remain around $100/annum in the long-term. For a scenario with a cost premium of 100%, those savings will initially be around the same level of $100/annum but will reach around $550/annum in the long-term.

While our assumptions suggest that there will be bill savings even for customers that choose lower-efficiency electrical appliances (albeit significantly lower savings that for customers that choose higher-efficiency electrical appliances) there are also additional appliance costs from switching from LPG appliances to lower-efficiency electrical appliances. For lower-efficiency electrical appliances, the additional upfront costs are in total, relatively modest, at around $600, or around $100/annum when amortised over the lifetime of these appliances (assumed to be 10 years) at a discount rate of 7%.

Considering both energy bills and appliance costs, based on our assumptions, continuing to use LPG appliances is higher cost for our representative household in Victoria.

A summary of our residential case study is provided in **Table 2**, for a customer choosing today between replacing existing, end-of-life LPG appliances with new LPG appliances or replacing existing, end-of-life LPG appliances with new lower-efficiency electrical appliances.

As seen in **Table 2**, the upfront cost of electrical appliances is slightly higher, but the forecast savings in energy bills over the next 10 years are greater, so that total costs will be higher on average if the customer remains with LPG appliances.

As for the case study with a customer choosing higher-efficiency electrical appliances, these lower energy bills from switching to electricity are based on AEMO's forecast of retail electricity prices, which are for electricity prices to fall over the next 10 years. We note, however, that expectations following recent market events are that retail electricity prices will increase materially, at least in the near term.

Table 2 also shows total emissions over the next 10 years for the two options. Emissions are lower if the customer continues to use LPG appliances, relative to lower-efficiency electrical appliances, by around 10 tCO2e over the 10 years. This is even with the rapid reduction in emissions intensity forecast by AEMO for the Step Change scenario over the next 10 years. Under the Progressive Change scenario the additional emissions from using lower-efficiency electrical appliances are even higher (around 16 tCO2e over the 10 years).

Table 2: Summary of results – customers that choose **lower-efficiency** electrical appliances

	Upfront appliance cost *	Annualised appliance cost	Average annual bill 2023 to 2032 (real dollars)	Average total annual cost (2023 - 2032)	Total emissions over 10 years
LPG and electricity case					
Cooking (LPG hub)	$1,200.00				
Space heating (LPG indoor flued heater)	$2,799.00				
Water heating (LPG instantaneous)	$1,900.00				
Total	$5,899.00	$839.88	$2,565.19 **	$3,405.08	35.38
Electricity only case					
Cooking (induction)	$1,733.33				
Space heating (RCAC, two room)	$1,197.00				
Water heating (heat pump)	$3,590.00				
Total	$6,520.33	$928.35	$2,353.53	$3,281.88	44.98 ***

** includes removal of existing appliance, new appliance purchase and installation)*

*** includes LPG costs and electricity bills*

**** Step Change scenario*

Rooftop solar and battery storage

We note that in this case study we assume the average Victorian residential LPG customer does not have rooftop solar panels installed and does not have battery storage.

In principle, customers that have rooftop panels installed may be able to make greater use of the electricity generated by these panels (rather than exporting it to the grid) by electrifying their LPG use. This could improve the payoff on their rooftop panels. In practice, however, it is likely that LPG use is not well correlated with times of generation from rooftop solar panels. LPG is used by residential households for cooking, water heating and space heating. These appliances all tend to be used more in the morning and evening than during the daytime, and more in the winter than the summer. This means that customers are less likely to be using these appliances at times when rooftop solar panels are generating at high enough levels to export to the market.

We would also expect that AEMO's forecasts of future retail electricity prices account for the expected high level of investment in renewable generation over the coming decade, so that these electricity prices already assume that pricing during the day (when customers with rooftop solar panels would make use of the electricity generated by these panels) will be relatively low. This will reduce the relative benefit from rooftop solar panels

It is possible, of course, that customers with rooftop solar panels could also install a battery so that they would be able to make use of the electricity generated by these panels even during the evening (when they are likely to make greater use of the cooking, water heating and space heating appliances). However, the cost of residential batteries is currently very high, and investing in these batteries is unlikely to pay off for many residential customers.

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