Gas Infrastructure Advice – Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector

Report Prepared for Infrastructure Victoria

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Executive Summary

In line with international commitments to keep global temperatures well below 2°C under the Paris Agreement, and the recognition that greenhouse gas emissions are causing unprecedented climate change, the Victorian Government established a target for the state to reduce emissions by 45–50% below 2005 levels by the end of 2030, and to achieve net zero by 2050.

Victoria has the largest domestic gas consumption of any of eastern Australian jurisdiction, with over 50% of the state's consumption coming from residential users. In response to structural changes in the eastern Australian gas markets and the Victorian Government's net zero emissions commitment, households and businesses are adopting measures to reduce gas consumption. The Victorian Government is seeking advice from Infrastructure Victoria as to the impact this will have on Victoria's existing gas infrastructure and any decisions that need to be made to ensure that existing gas infrastructure can be optimised for future scenarios.

Northmore Gordon and Energeia were engaged by Infrastructure Victoria to investigate potential energy efficiency measures to reduce or replace gas demand in the residential, commercial, and industrial sectors, and to determine the potential benefits and costs associated with uptake of these measures in Victoria.

Northmore Gordon and Energeia identified six clear energy efficiency opportunities that would deliver significant gas reduction for acceptable financial returns. These are improved heat recovery, upgrades to burners and boilers, air to air heat pumps, air (and water) to water heat pumps, draught sealing, and electrification of cooking with induction. Across the industrial, commercial, and residential sectors these opportunities delivered a combined annual gas reduction potential of 112.4 PJ by 2040, an overall energy efficiency reduction of 87 PJ by 2040, and a net greenhouse gas emissions reduction of 3,980 kilotonnes CO2e in the year 2040.

The following summarises the methodology approach and key results from the Cost Benefit Analysis.

Industrial and Large Commercial Sector

Scope and Approach

- Northmore Gordon developed gas consumption estimates and business as usual forecasts for large gas users – industrial and large commercial facilities consuming greater than 10 TJ per annum.
- Industrial sub-sector gas consumption and forecasts were developed using a combination of AEMO gas forecasting data, Victorian NGERS data, limited public datasets, and Northmore Gordon's own experience of individual large facilities in the state.
- Estimates of individual facility numbers was derived from the National Pollutant Inventory and the Australian Bureau of Statistics "Counts of Australian Businesses" dataset for businesses with an operating revenue of > $10 Million.
- The sub-sector gas consumption and facility number estimates were used to model the total annual potential impacts of each of the top ranked energy efficiency options in terms of energy efficiency, gas savings, and CO_2 savings

Total Market Size

- Bottom up modelling of large gas users, found the current level of gas consumption in industrial sector to be 54.5 PJ and 12.7 PJ in large commercial sector. The estimated sector totals were within 5% of the reported values in the AEMO forecasting data.
- The largest gas consuming sub-sectors were found to be Food and Beverage Manufacturing (16.2 PJ), Pulp and Paper (9.2 PJ), Petroleum and Coal Product Manufacturing (7 PJ), Non-Metallic Mineral Product Manufacturing (7PJ) and Basic Chemical and Chemical Product Manufacturing (6.4 P).

Options Analysis and Ranking

- The top consuming industrial and large commercial gas users were assessed for suitable gas energy efficiency measures, based on desktop research and Northmore Gordon's direct experience.
- Costs and benefits were developed from recent reference projects undertaken by Northmore Gordon and then extrapolated to the entire dataset.
- The top ranked energy efficiency activities for Industrial sectors were:
    1. Heat Recovery – with a total 10.6 PJ gas reduction potential, wide applicability to across the industrial sub-sectors, and good benefit to cost ratio (BCR) of 4.7
    2. Burner and boiler upgrades – 6.6 PJ gas reduction potential, wide applicability across the industrial sub-sectors, and excellent BCR of 8.8
    3. Low Temperature Heat Pumps – 7.9 PJ gas reduction potential, BCR of 3.9, and a strategic role to play in key industrial sub-sectors such as Food and Beverage Manufacturing with lower temperature process heating.
- For Large Commercial the proposed shortlisted energy efficiency activities were[1]:
    1. Reverse cycle chillers and packaged units – 3.76 PJ gas reduction potential and wide applicability to the large commercial sub-sectors
    2. Low temperature heat pumps – 3.34 PJ gas reduction potential and strategic role to play in key large commercial sub-sectors, such as Aquatic Centres.
    3. Burner and boiler upgrades – Whilst achieving only a low 0.9 PJ gas reduction potential, it benefited from a high ease of implementation and short term timeframe for implementation

Potential Victorian Impact

- If fully implemented, Northmore Gordon's modelling showed that the top ranked energy efficiency options would deliver the following potential annual impacts to all industrial and large commercial sub-sectors by 2040:
    1. 22.5 PJ in gas reduction
    2. 20 PJ in energy efficiency
    3. 965.9 kilotonnes of CO2 emissions

Small and Medium Sized Commercial Sector

Scope and Approach

- Energeia updated its commercial stock and turnover model using the latest information in the public domain
- The stock and turnover model estimates the total annual energy consumption by fuel, end use and commercial sub-sector
- The model was used to estimate total annual potential impacts of each of the initial list of potential energy efficiency activities in terms of energy efficiency, gas savings and CO_2 savings.
- In total, the model covers 50 million m^2 of commercial building floor area in Victoria across:

[1] Large Commercial Cost Benefit Analysis modelling was incorporated into the Industrial sector results.

- Offices, standalone (excludes high density commercial offices)
- Hospitals
- Aged Care
- Hotels, small scale
- Law Courts
- Public Buildings
- Retail
- Restaurants
- Schools, including public and private schools
- Tertiary
- Warehouses.

Total Market Size

- Modelling of the current level of gas consumption by commercial segment, end use and fuel found the total potential market to be 20.7 PJ. Energeia's total estimated market potential is lower than AEMOs 2021 GSOO, with a discussion of data gaps in Section 4.1.3
- The commercial segments in Victoria have been modelled by Energeia with the largest constituents estimated to be Schools at 4.2 GJ, Restaurants at 3.3 GJ, Offices at 3.1 GJ, Hospitals at 2.5 GJ and Tertiary at 2.2 GJ in 2021. Most consumption in these segments occurs from space heating and water heating end uses with 57% and 21% of consumption on average, respectively.

Options Analysis and Ranking

- Desktop research identified a range of insulation and electrification options for water heating, space heating and cooking appliances as the highest potential energy efficiency activities.
- The potential impacts on a per thousand m^2 basis of each option and associated cost-benefit impacts were estimated and used to rank each option, which resulted in the following ranking:
  1. Space heating electrification with heat pumps – 220 GJ of potential and 190 GJ of energy efficiency savings make this the top ranked option, despite a modest benefit to cost ratio (BCR) of 2
  2. Water heating electrification with heat pumps – At 82 GJ of energy savings and 66 GJ of gas savings this option is almost one third of the top ranked option, with a BCR of 2.3
  3. Cooking electrification with induction cooktops – Energy savings of 52 GJ and gas savings of 28 GJ are attractive, however, the BCR is negative and so is CO_2 emissions until post 2034[2].
  4. Draught Sealing – Ranked lowest in part due to relatively high costs in a commercial setting, as well as the relatively smaller overall impact of 13 GJ in energy efficiency and gas savings.

Potential Victorian Impact

- If fully implemented, Energeia's modelling showed that the top three options would deliver the following potential annual impacts across water heating, space heating and cooking end uses by 2040:
  1. 18.8 PJ in gas reduction
  2. 14.5 PJ in energy efficiency
  3. 614 kilotonnes of CO_2 emissions.

[2] Energeia recommends cooking energy efficiency measures despite its negative financials in 2021 due to its market potential; it is the third largest gas end use and decarbonisation is not possible without addressing it. Its economics and CO2 profile change by 2030. See Section 4.3.2 for further justification

Residential Segment

Scope and Approach

- Energeia updated its residential stock and turnover model using the latest information in the public domain.
- The stock and turnover model estimates the total annual energy consumption by fuel, end use and residential building class.
- The model was used to estimate total annual potential impacts of each of the initial list of potential energy efficiency activities in terms of energy efficiency, gas savings, CO_2 savings and health benefits.
- In total, the model covers all 2.5 million residential dwellings in 2021 in the following building classes:
    - Class 1 includes detached and townhouses
    - Class 2 includes apartments.

Total Market Size

- Modelling of the current level of gas consumption in residential buildings found total potential market to be 82.8 PJ. As noted previously, Energeia's estimates of total gas consumption are below AEMOs most recent GSOO. Energeia has included a discussion of the data limitations in Section 5.1.3.
- The residential sector is the largest gas consuming customer segment in Victoria, with most consumption occurring in space heating, water heating and cooking end uses. Energeia modelling found end use weightings to be 60%, 36% and 4% respectively.

Options Analysis and Ranking

- Desktop research identified a range of insulation and gas appliance electrification options for water heating, space heating and cooking, which are the largest residential gas end uses of gas.
- The potential impacts on a per average household basis of each option and associated cost-benefit impacts were estimated and used to rank each option, which resulted in the following ranking for Class 1 residential dwellings:
    1. Space heating electrification with heat pumps – Space heating electrification is again the number one ranked option with total 29.9 GJ and 33.2 GJ of potential energy efficiency and gas savings, respectively and a BCR of 1.2
    2. Water heating electrification with heat pumps – This option delivers the second highest potential market impacts at 11.1 GJ in energy savings and 19.1 GJ in gas savings, and a slightly higher BCR than space heating of 2.0.
    3. Draught Sealing – Residential draught sealing has the highest BCR of any option at 5.0, but is ranked 3rd in part due to the relatively smaller overall impact of 6.0 GJ in energy efficiency and gas savings

Potential Victorian Impact

- If fully implemented, Energeia's modelling showed that the top three options would deliver the following potential annual impacts by 2040:
    1. 71.1 PJ in gas reduction
    2. 52.5 PJ in energy efficiency
    3. 2,400 kilotonnes of CO_2 emissions

Contents

1 Introduction

1.1 Background

The Victorian Treasurer has requested that Infrastructure Victoria provide advice on the nature and timing of decisions regarding the gas transmission and distribution networks for Victoria in a future where:

- Victoria's carbon emission reduction targets are achieved;
- Sufficient and suitable energy and chemical feedstocks are available for domestic, commercial and industrial use; and
- An option is available for hydrogen and/or biomethane to be part of the future energy mix.

The advice being sought from Infrastructure Victoria comprises:

- Development of two or more appropriate scenarios for a net zero emissions energy sector in 2050 and assessment of the relative economic, social and environmental impacts of those scenarios.
- Assessment of the implications for gas production, electricity generation, and transmission and distribution networks under the 2050 scenarios developed.
- Identification of the infrastructure decisions that need to be made, and the timing of those decisions, under each scenario, to ensure opportunities for the existing gas infrastructure can be optimised (including the extent to which gas infrastructure can be used for hydrogen, carbon capture and storage and/or biomethane).
- Assessment of the cost and reliability impact of key infrastructure decisions identified above, including considerations to minimise the social, environmental and economic costs to businesses, industry and the community.
- Analysis of the key uncertainties, trigger points and interdependencies associated with the infrastructure decisions identified above, including any significant risks and mitigation options.
  Identification of the role of the Victorian Government, including to optimise the utilisation of existing gas infrastructure.

1.2 Objectives

Northmore Gordon and sub-contractors Energeia have been engaged to assist Infrastructure Victoria's understanding of the potential costs and benefits of existing energy efficiency activities and identify additional potential actions to reduce or replace the gas demand in the residential, commercial and industrial sectors in Victoria. The desktop study objectives were:

- Identify and rank activities offering the greatest net benefit targeting the overall gas use in all sectors (residential, commercial and industrial) that are currently poorly taken up or not covered in the VEU program.
- Based on the ranking, determine the top three energy efficiency activities targeting gas use for each sector (residential, commercial and industrial).
- Determine the potential benefits and costs of the identified energy efficiency activities targeting gas use on a small-scale level for households, businesses and industry as well as on a large-scale level for Victoria in the short-, mid- and long-term (2030/ 2040/ 2050).
- Identify significant uncertainties, barriers or enablers (economic, technological, social, environmental, regulatory or policy) relevant to the identified energy efficiency targeting gas use.

- To the extent possible, assess the impacts of improved energy efficiency activities on health for households and the society through improved thermal comfort and room air quality.

1.3 Our approach

Northmore Gordon is a leading energy and carbon consultancy helping large business in industry and the built environment reduce costs while becoming more sustainable enterprises. We have decades of experience in strategy development and energy efficiency opportunity identification and support for industrial businesses, with specific capability in emissions reduction of complex industrial energy systems. This study draws from this experience and recent policy work in Victorian and NSW gas markets in order to:

- Develop bottom-up estimates of sub-sector gas demand and facility/building stock and turnover models in Victoria for industry, commercial, and residential sectors.
- Identify and quantify to a broad level of accuracy suitable energy efficiency activities which can reduce gas consumption in the industrial, commercial, and residential sub-sectors
- Rank suitable gas energy efficiency activities according to gas reduction achieved, ease of implementation, scale of capital cost, and timeframe for implementation
- Shortlist three energy efficiency activities for each of the major user category – industrial, commercial and residential
- Prepare a Cost Benefit Assessment (CBA) at an individual facility level and then scaled to the whole of Victoria for each of these shortlisted energy efficiency activities, over a 2030, 2040, 2050 timeframe.

Northmore Gordon has partnered with specialist energy consultancy Energeia who have extensive experience in Cost Benefit Assessments and policy advisory services for government, particularly in the “mass market” sectors of residential and small to medium enterprise .

Energeia’s role in the project is to apply their bottom-up stock and turnover models to inform an assessment of the top energy efficiency opportunities for gas in mass market premises, i.e. residential and Small and Medium Size Enterprises (SMEs).

Energeia will build on its recent experience modelling electrification impacts and opportunities for the Victorian Department of Environment Land Water and Planning as part of a National Construction Code focused engagement, and subsequently for a larger project feeding into a potential Regulatory Impact Statement focused on mandating rooftop solar PV for new Class 1 dwellings. These projects were not focused on existing premises, but the datasets were developed in order to estimate the impact of the policy scenario on electricity and gas infrastructure.

1.3.1 Study limitations

- The CBA and energy savings are based on the best available information and provide a strategic assessment of achievable outcomes. However, the actual outcomes achieved in practice may differ due to current data limitations, context specific implementation constraints, behavioural change, market forces and the inherent uncertainty related to all forecasts.
- The cost benefit analysis (CBA) does not include consideration of upstream and downstream gas pipeline and network costs associated with decreases/increases in volume/demand.
- The CBA does not include pipeline/network augmentation requirements or associated costs and cost recovery implications for decreases/increases to volume/demand or changes to shipping alternative gases.

- Gas and electricity tariff structure changes in response to significant changes to volume and demand arising from the gas substitution roadmap, are excluded from the CBA.
- The energy efficiency opportunity analysis does not include consideration of gas powered generation (GPG) or usage of gas in gas operations, e.g. pipeline compressors
- Capital cost are be based on existing reference prices and high level budget estimates from recent project work. I.e. Quotes for the work were not be obtained nor any detailed design undertaken to develop more accurate price estimates.
- The analysis does not include modelling of peak demand outcomes on the gas markets and adequacy of short term supply.
- Consideration of gases other than methane, such as ethane, propane (LPG), is out of scope

2 Victorian Gas Usage Analysis

2.1 Gas sector forecasts

Victorian wide gas consumption was derived from the Australian Energy Market Operator (AEMO) National Electricity and Gas Forecasting Portal using the 2021 Gas Statement of Opportunities (GSOO). The GSOO data provides multiple scenarios for forecast growth, including faster and slower economic growth, higher and lower levels of decarbonisation, and increased adoption of hydrogen as a substitute to natural gas. The Central Scenario data was chosen as the most representative of Business As Usual.

The AEMO data already disaggregates gas consumption into the top-level categories based on its tariff classifications:

- Gas Powered Generation being large electricity generators operating on natural gas[3]
- Tariff V being residential and small commercial gas users below 10 TJ
- Tariff D being industrial and large commercial gas users over 10TJ

The AEMO data further disaggregates industrial into “large” for facilities over 500 TJ and “small to medium” for facilities between 10 TJ and 500 TJ.

In this study we have considered “large commercial” to be any facility which has a gas consumption over 10 TJ but is not classified as industrial. Commercial facilities in the tariff V category are taken as the Small to Medium Enterprise (SME) businesses consuming less than 10 TJ per annum and falling within the publicly available datasets for building stock. Small to medium commercial therefore encompassed:

- Offices, standalone (excludes high density commercial offices)
- Hospitals
- Aged Care
- Hotels, small scale
- Law Courts
- Public Buildings, including galleries, museums, libraries (excluding aquatic centres)
- Retail
- Restaurants
- Schools, including public and private schools
- Tertiary, including TAFE and Universities
- Warehouses

It is noted that there will be some overlap and gaps between the two categories of commercial, however the focus of this study is on the overall cost benefit analysis of discrete energy efficiency opportunities, not on a comprehensive baseline for Victoria’s gas users.

[3] Gas Powered Generation is excluded from consideration in this study.

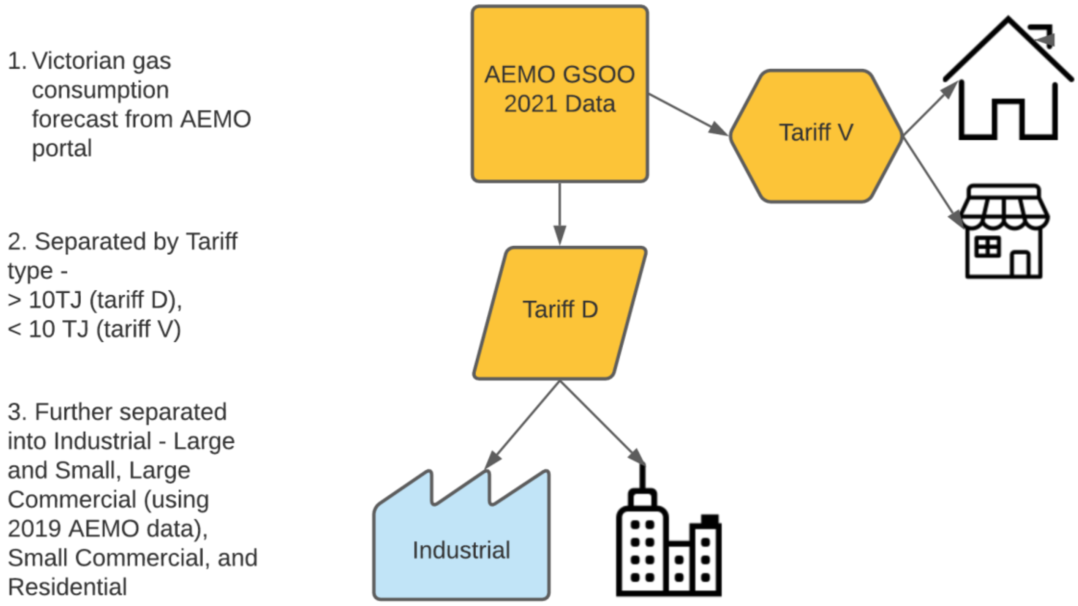

Figure 1: Methodology for developing top down gas usage forecasts

Prior to 2020 AEMO segmented large gas consumption into two categories – “manufacturing” and “other”. Manufacturing incorporated both small and medium to large industrial facilities, whereas “other” is interpreted by AEMO to be large commercial facilities, such as large hospitals, universities, entertainment venues (e.g. casinos), large commercial office, etc. As there are notable differences in suitable energy efficiency measures between industrial and large commercial facilities, the 2019 AEMO data was used to separate out “large commercial” from the “small industrial” category reported in the 2021 GSOO data.

No recent studies have been undertaken into Victorian residential and small commercial facility gas consumption and the AEMO dataset does not disaggregate the two customer types from Tariff V. The 2015 Residential Energy Baseline Study by EnergyConsult does provide a state by state forecast for gas consumption and this was used as a initial estimate of gas usage in residential.

Table 1 provides the 2021 estimate for gas consumption in Tariff D and Tariff V facilities.

Table 1: Further segmentation of AEMO data for large gas users (2020)

Sector	Consumption
Medium to Large Industrials (Tariff D, > 500 TJ)	33.8 PJ
Small Industrials (Tariff D, > 10 TJ)	18.3 PJ
Large Commercial (Tariff D, > 10 TJ)	12.7 PJ
Small Commercial (Tariff V, < 10 TJ)	31.4 PJ
Residential (Tariff V, < 10 TJ)	93.3 PJ
Total	189.5 PJ

Source: Northmore Gordon

Figure 2 presents the total Victorian gas consumption forecasts used in this study. As noted in Section 2.2 the data presented is derived from the AEMO GSOO 2021 data, available from

AEMO's National Electricity and Gas Forecasting Portal. The key takeaways from analysis of the AEMO data and underlying assumptions include:

- Residential gas consumption prior to 2019 was forecasted to grow off the back of updated population projections, but after 2019 AEMO data indicates a flat trajectory
- Any increase in gas consumption in the residential and commercial sectors is being offset by improved energy efficiency of equipment and fuel switching (electrification).
- A short-term issue is arising in gas supply availability which could lead to shortfalls on winter peak days
- Industrial consumers remain sensitive to energy costs, and closure of industrial facilities remains an ever-present risk if energy costs are high.
- Manufacturing expansion continues to be driven by sectors that consume relatively lower gas than historical industrial users. Lower gas prices alone are not expected to drive significant increases in consumption.
- Consequently, Medium to Large Industrial gas consumption has an average forecast decline of 0.69% per annum over the 20 year period, but Small Industrial gas consumption has a small forecast annual average increase of 0.38% over the same period.
- Realistic forecasts on industrial sector growth relies on a more detailed assessment of drivers, including the role of the pandemic in onshoring or offshoring businesses in the overall supply chain.

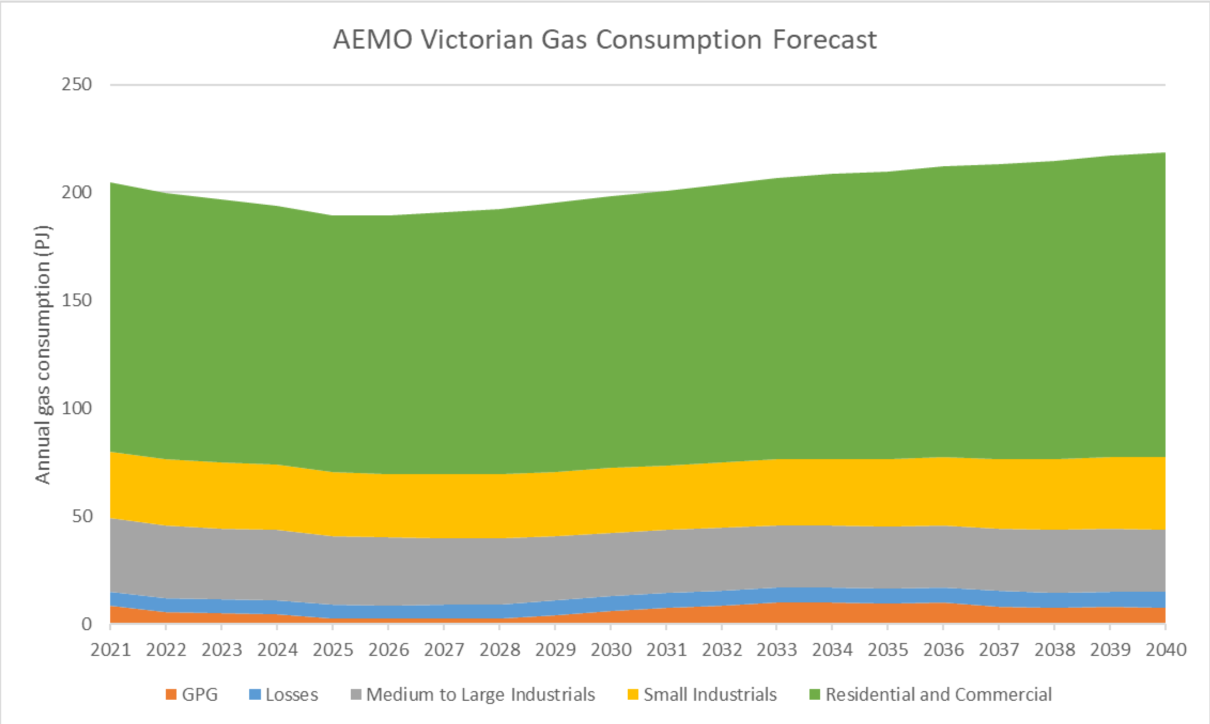

Figure 2: Forecast Victorian Gas Consumption to 2040[4]

Source – AEMO Gas Statement of Opportunities 2021

2.2 Victorian Energy Upgrades Program

The Victorian Energy Upgrades (VEU) is a program developed by the Department of Environment, Land, Water and Planning (DELWP) and administered by Essential Services

[4] Note GPG is Gas Powered Generation

Commission (ESC) in accordance with Victorian Energy Efficiency Target Act 2007 and regulations. The VEU program commenced on 1 January 2009 and is legislated to continue until 2029.

Large energy retailers are required to acquire and surrender Victorian Energy Efficiency Certificates (VEECs) to meet annual targets set in Victorian legislation. VEECs are created from calculated emissions abatement arising from approved energy saving activities. Their sale to liable entities creates a market which incentivises energy efficiency projects that are adopted in residential homes and commercial and industrial businesses.

Table 2 presents a summary of all gas related activities under the VEU program. Note that cooking appliances are not presently covered in the VEU program.

Table 2: Summary of all existing and historic gas related activities under VEU program

Activity Category	Activity Description	Status	Result	Residential/Business
Space conditioning activities	Activity 11- Ceiling insulation (revoked 9/12/18)	Historic	Reduce gas demand	Residential
	Activity 12 - Underfloor insulation	Existing	Reduce gas demand	Residential
	Activity 13 - Double glazed window	Existing	Reduce gas demand	Residential
	Activity 14 - Thermally efficient window product	Existing	Reduce gas demand	Residential
	Activity 15 - Weather sealing	Existing	Reduce gas demand	Residential
Gas Efficiency Activities	Activity 37 Replacement of a gas-fired steam boiler with a high efficiency gas-fired steam boiler	Existing	Reduce gas demand	Business
	Activity 38 Replacement of a gas-fired water boiler or water heater	Existing	Reduce gas demand	Business
	Activity 39 Installation of an electronic gas/air ratio control	Existing	Reduce gas demand	Business
	Activity 40 Installation of a combustion trim system	Existing	Reduce gas demand	Business
	Activity 41 Replacement of a gas-fired burner	Existing	Reduce gas demand	Business
	Activity 42 Installation of an economizer	Existing	Reduce gas demand	Business
Project-based activities	PBA measurement and verification	Existing	Reduce or increase gas demand	Business
	PBA Benchmark Rating Method	Existing	Reduce electricity and gas demand	Business
Water heating, and space heating and cooling activities	Activity 1A – Water heating – Gas/LPG storage replacing electric resistance	Existing	Increase gas demand	Residential/Business
	Activity 1B – Water heating – Gas/LPG instantaneous replacing electric resistance	Existing	Increase gas demand	Residential/Business
	Activity 1F – Water Heating – Gas/LPG boosted solar replacing electric resistance	Existing	Increase gas demand	Residential/Business
	Activity 3A – Water heating – Solar replacing gas/LPG (revoked 30/6/14)	Historic	Reduce gas demand	Residential/Business
	Activity 3B – Water heating – Gas/LPG boosted solar replacing gas/LPG	Existing	Reduce gas demand	Residential/Business
	Activity 5 – Space heating – Ducted gas replacing ducted gas (revoked 9/12/18)	Historic	Reduce gas demand	Residential/Business
	Activity 5 - Space heating - Ducted gas heater	Existing	Reduce or increase gas demand	Residential/Business

	Activity 6 - Space heating - Ducted gas replacing central electric resistance heater (revoked 9/12/18)	Historic	Increase gas demand	Residential/Business
	Activity 9 - Space heating - Gas/LPG space heater (revoked 9/12/18)	Historic	Reduce or increase gas demand	Residential/Business
	Activity 9 - Space heating - Gas/LPG room heater	Existing	Reduce or increase gas demand	Residential/Business
	Activity 20 - High efficiency ducted gas heater (revoked 9/12/18)	Historic	Increase gas demand	Residential/Business
	Activity 28 - Gas heating ductwork	Existing	Reduce gas demand	Residential/Business

Source – Essential Services Commission

Given the historically high Scope 2 emissions factors from the Victorian electricity grid and the lower availability of high efficiency heat pump and air-conditioning appliances, the VEU has primarily incentivised fuel switching from electricity to gas. This is shown in the analysis presented in Table 3 for registered VEEC creations under deemed Space and Water Heating Activities.

Table 3: VEEC creations from Space and Water Heating activities since 2009

Activity	Impact	Sum of Installations	Sum of registered VEECs	Share of activities in category	Share of registered VEECs in category
Double glazed window	Fabric upgrade	1	81	~%	0%
Weather sealing	Fabric upgrades	333,358	1,102,255	99.6%	95%
Replacing an electric appliance for another electric appliance	Elec to Elec	38,216	1,474,499	33%	31%
Replacing/ upgrading an electric appliance with a solar appliance	Elec to solar	18,907	865,365	17%	18%
Replacing a gas appliance for an electric appliance (none so far)	Gas to Elec	0	0	0%	0%
Replacing/ upgrading a gas appliance with a solar appliance	Gas to solar	8,676	90,715	8%	2%
Replacing an electric appliance for a gas appliance	Elec to Gas	37,381	2,249,198	33%	47%
Replacing a gas appliance for another gas appliance	Gas to Gas	10,795	123,807	9%	3%
Upgrading ductwork	Gas efficiency	29	538	0%	0%
Installing in new premises	None to Gas	157	1,083	0%	0%
Grand Total		447,519	5,907,460	100%	100%

Source - VEU Registry, accessed April 2021

Since 2015 changes in the electricity sector from increased renewable energy uptake and the closure of aging coal fired power stations have significantly reduced emissions from electricity use. As part of its obligations for setting new certificate targets, DELWP released a Regulatory

Impact Statement (RIS) in December 2019 which proposed a rapid fall in the electricity emission factor. These emissions factors reductions were subsequently adopted in the Victorian Energy Efficiency Target Regulations. It also including setting new targets of 6.5 million certificates for 2021 and a gradual increase of the set target on a yearly basis to 7.3 million certificates for 2025.

Table 4: Updated Electricity Emissions Factors for the VEU

2020	2021	2022	2023	2024	2025
1.095	0.9546	0.8142	0.6738	0.5334	0.393

Source – Victorian Energy Upgrades Specifications – Version 10

Over the past ten years lighting activities have dominated the VEU program and created over 92.5% of all certificates under the scheme. As energy efficient LED lighting has become cost effective without government subsidy, the compliance hurdle has been increased and the number of certificates eligible to be created have heavily discounted. To meet the projected certificate targets to 2025 will require a significant increase in creation from non-lighting activities. Similarly, the proposed reduction in electricity emissions factors will require activities that involve reduction of gas consumption and fuel switching from gas to electricity to do the heavy lifting.

Moving forward the VEU program has a significant role to play in encouraging gas demand side reduction measures, via deemed gas reduction or electrification activities and measurement and verification approaches.

3 Industrial and Large Commercial

3.1 Market Sizing

This section sets out the approach undertaken by Northmore Gordon to develop bottom-up estimates for gas consumption for each industrial and large commercial sub-sector and review the viable energy efficiency activities for each of these sub-sectors.

3.1.1 Methodology

Gas consumption estimates by user type and sub-sector were developed using a bottom-up approach as shown in the Figure 3.

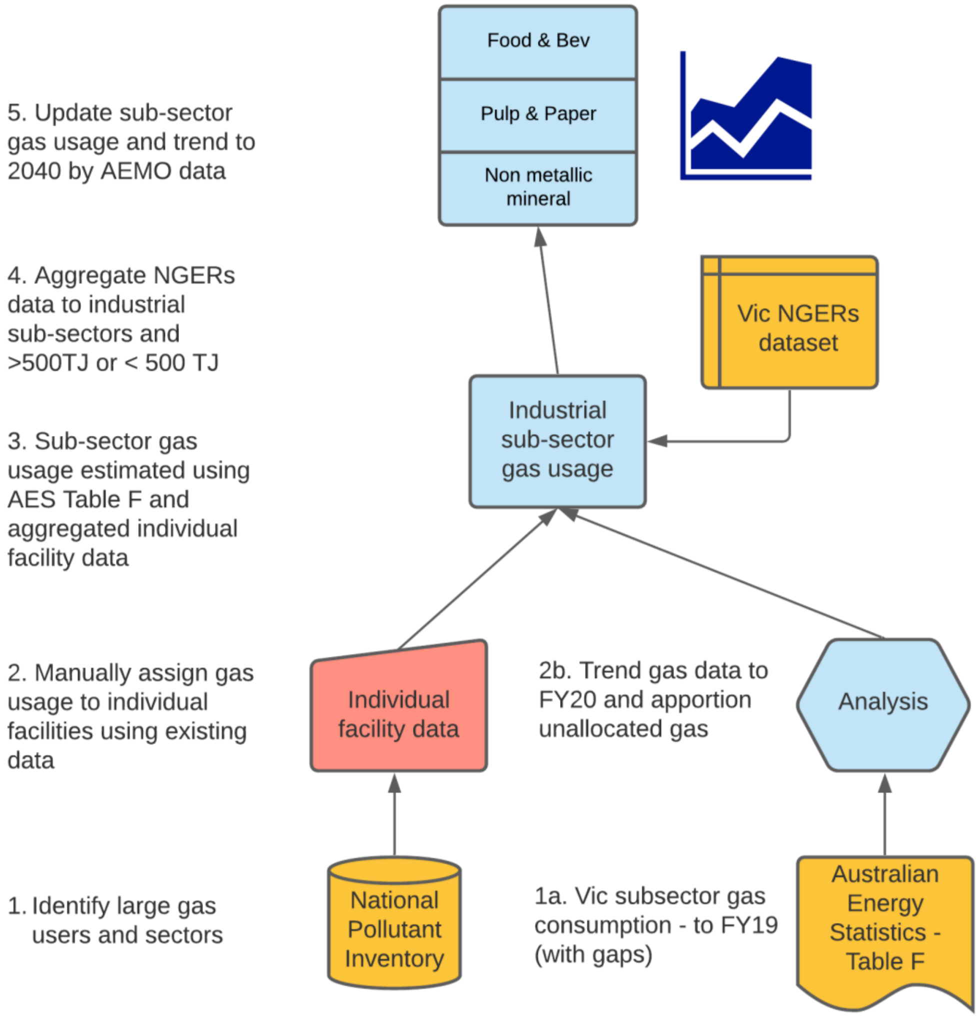

Figure 3: Victorian Gas Consumption analysis and Sub-sector breakdown

The bulk of gas usage in industrial facilities is in process heating, with a smaller percentage of gas used as a chemical feedstock. Figure 4 taken from the 2019 ARENA funded “Renewable Energy Options for Industrial Process Heat” study presents a breakdown of process heating energy use (all energy sources) by industry sub-sector and temperature ranges.

Gas reduction opportunities for the above industrial and large commercial sub-sectors was taken from a range of sources including Northmore Gordon's experience in industrial and large commercial energy systems and publicly available reports. Considered gas reduction opportunities included energy efficiency to improve the utilisation of existing gas equipment, and fuel switching to transition gas equipment to alternative fuels such as electricity and bioenergy.

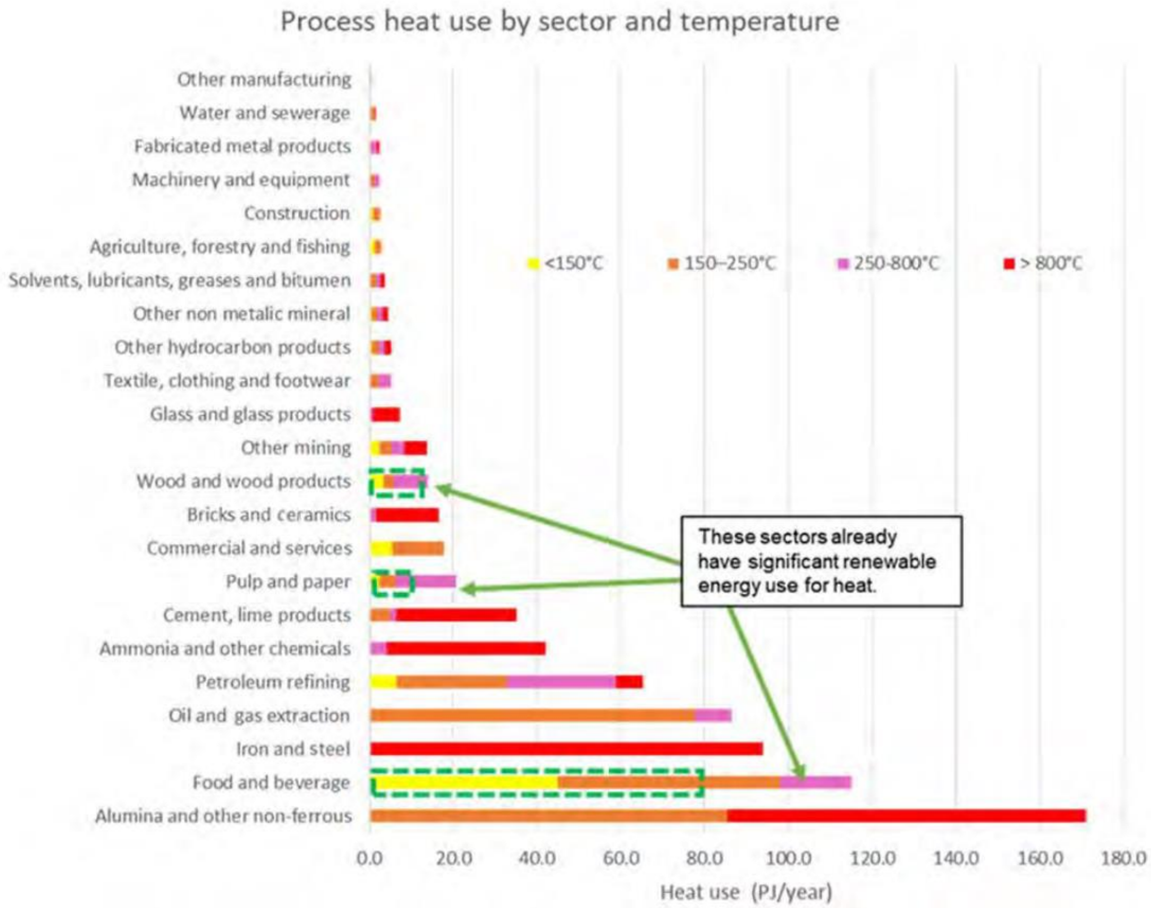

Figure 4: Industrial process heating by temperature range and sector

Source - Renewable Energy Options for Industrial Process Heat Report

Energy efficiency activities including fuel switching opportunities were mapped onto the relevant industrial sub-sectors with broad estimates for gas reduction potential, ease of implementation, and timeframe for adoption based on Northmore Gordon's experience and existing published reports.

Whilst many opportunities for electrification of process heating exist, there has been limited demonstration of the potential benefits, with only a few small scale projects having been undertaken in selected sectors, while others have seen no activity at all. Much of the higher temperature process heating opportunities require considerable investment and further commercialisation development before they can be broadly adopted. Consequently opportunities are presented categorised according to their timeframe for adoption as follows:

- Short term: 0 to 5 years
- Medium term: 5 to 15 years
- Longer term: > 15 years

Short term opportunities are those where the technology is readily available, demonstrated, and implementable without retooling the facility. Medium term opportunities are those where the technology is readily available, demonstrated and implementable (i.e. there are no known technical barriers to implementation), but adoption requires significant investment and re-tooling of the facility. Longer term opportunities are those that require, as yet proven technologies and/or significant rebuilding of the facility to implement. These longer term opportunities may require further research, development and deployment, and significant lead times for planning.

3.1.2 Key Inputs and Assumptions

3.1.2.1 Bottom-up sub-sector consumption and forecasts

Very limited public data is available on industrial or large commercial sub-sector gas consumption. The process undertaken to develop a bottom up estimate of sub-sector gas usage involved:

1. Accessing the National Pollutant Inventory (NPI)[5] for financial years 2018, 2019, 2020 to identify the larger manufacturing facilities, their location, and ANZSIC classification (to the four digit level)
2. Taking known large gas users from the NPI and manually assigning gas consumption to each user using publicly available data, and confidential data Northmore Gordon has on file.
3. Extrapolating Australian Energy Statistics (AES) Table F data to calendar year 2020 using the existing trend in data for previous years. The AES published in 2020 by Department of Industry Science Energy and Resources (DISER) provides two digit level ANZSIC industry sector end uses of energy (Table F) at the state and national level. The data excludes entries in categories at the state level for confidentiality reasons where only a small number of facilities exists in each category.
4. Estimating gas consumption for each sub-sector (at the two digit level) preferentially using the AES Table F data where available, then using the manually estimated consumption for industrial sub-sectors with sufficient data points, with final sub-sectors estimated by apportioning the remaining AES Table F unallocated gas consumption based on the ratio of NPI facility counts in that sector compared to the total remaining NPI facility counts.
5. Using National Greenhouse and Energy Reporting Scheme (NGERS)[6] data for Victoria to obtain aggregated gas usage for each sub-sector. During the project Northmore Gordon was given access to NGERS data for Victoria and using the Energy Dataset filtered by fuel "natural gas distributed in a pipeline; the year 2019/2020; and "consumption" energy context, gas usage was aggregated for each sub-sector to the three-digit level.
6. Further aggregation of sub-sector gas usage to the two-digit level was undertaken and separated into the AEMO designated categories:
   - > 500 TJ – Medium to large industrials
   - <500 TJ and >10 TJ – Small industrials
7. Noting that a portion of industrial and large commercial facilities are below the reporting thresholds for the NGERS (25,000 tonnes CO_2e per facility and 50,000 tonnes at the organisation level) the totals derived from Stage 1 was used preferentially for some sectors. This was particularly the case for food and beverage manufacturing, and textile manufacturing, which are known to have many smaller facilities.

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[5] The National Pollutant Inventory is a publicly accessible online database that presents information on emissions of 93 specified substances from facilities. All Australian industrial facilities which meet the reporting criteria and thresholds are required to report their emissions and waste transfers.
[6] The National Greenhouse and Energy Reporting Scheme is a national framework for large facilities and organisations to report on their greenhouse gas emissions and energy usage when they are over designated thresholds.

8. It was assumed that the total gas consumption per sub-sector for facilities greater than 500 TJ in the NGERS dataset was exhaustive, i.e. no facilities consuming this much gas were not captured in the NGERS reporting. Consequently, this represented the Medium to Large Industrials portion for each sub-sector and the remainder of the industrial sub-sector totals derived above was Small Industrials. Large commercial did not include any facilities greater than 500 TJ.
9. Sub-sector gas usage was extrapolated to 2040 using the annual growth rate trend to 2040 for the two Tariff D categories – Medium to Large Industrials and Small Industrials in AEMO's GSOO data. Large Commercial was trended using the same annual growth rate as Small Industrials.

Note that differences exist between the business ANZSIC category used in NPI versus NGERS which can be misleading. For example, several "fabricated metal manufacturing" facilities are classified as "primary metal manufacturing" in NGERS data because the main activity of the national business is the dominant category in their national reporting. For example, Bluescope has a large iron smelting facility in NSW and this is their largest energy consumer, but the Western Port facility in Victoria is fabrication facility only. Consequently the two metal manufacturing categories were combined into a single category "Primary metal and fabricated metal product manufacturing" for the purposes of this study.

The Australian Bureau of Statistics (ABS) 8165.0 data set "Counts of Australian Businesses, including Entries and Exits, June 2016 to June 2020" was used to cross reference the National Pollutant Inventory facility counts for each sub-sector. The dataset "Businesses by Main State by Industry Class by Turnover Size Ranges" was consulted for the estimated number of businesses in each sub-sector category. Reviewing the ABS dataset there is a significant number of businesses in each sub-sector, for example in the category of Food and Beverage Manufacturing the ABS lists 4,087 businesses as operating at the end of the 2020 Financial Year. Further analysis shows that 2,396 of these businesses are non-factory based bakeries, "other" food product manufacturing, and "wine and other alcoholic beverage manufacturing" facilities, none of which would fall under industrial or large commercial gas users. To better estimate the number of large manufacturing facilities in the ABS dataset, the count of facilities was limited to those with an operating revenue of $10 Million or greater. The resulting count of facilities from the NPI dataset and the ABS dataset, along with each sector and sub-sector's ANZSIC Classification, is given in Table 5. The data in this table is used to extrapolate cost and benefit modelling to the whole of Victoria for facilities consuming greater than 10 TJ of gas per annum.

Table 5: Estimates of facility counts of large gas users in Victoria as of 2020

Sub-sector	ANZIC Code (two digit level)	Count of large facilities (NPI)	Count of large facilities (ABS)
Division A - Agriculture	1 - 5	49	238
Division B - Mining	6 - 10	61	38
Division C - Manufacturing			1268
Food, beverage and tobacco product manufacturing	11 - 12	124	242
Textile, leather, clothing and footwear manufacturing	13	9	52
Wood product manufacturing	14	12	60
Pulp, paper and converted paper product manufacturing	15	13	32
Printing (including the reproduction of recorded media)	16	18	46
Petroleum and coal product manufacturing	17	22	18
Basic chemical and chemical product manufacturing	18	58	95

Polymer product and rubber product manufacturing	19	34	95
Non-metallic mineral product manufacturing	20	21	68
Primary metal and metal product manufacturing	21	12	57
Fabricated metal product manufacturing	22	20	147
Transport equipment manufacturing	23	7	120
Machinery and equipment manufacturing	24	2	193
Furniture and other manufacturing	25	0	43
Division D - Electricity, gas, water and waste services	26 - 29	225	151
Division E - Construction	30 - 32	0	1600
Division F - Wholesale trade	33 - 38	72	1923
Division G - Retail trade	39 - 43	0	1271
Division H - Accommodation and food services	44 - 45	0	291
Division I - Transport, postal and warehousing	46 - 53	15	525
Division J - Information media and telecommunications	54 - 60	1	107
Division K - Financial and insurance services	62 - 64	0	887
Division L - Rental, hiring and real estate services	66 - 67	0	471
Division M - Professional, scientific and technical services	69 - 70	0	943
Division N - Administrative and support services	72 - 73	2	485
Division O - Public administration and safety	75 - 76	0	41
Division P - Education and training	80 - 82	0	170
Division Q - Health care and social assistance	84 - 87	32	235
Division R - Arts and recreation services	89 - 92	0	99
Division S – Other services	94 - 96	0	104

Source – ABS 8165.0 and NPI dataset

3.1.2.2 Food and Beverage

Food and beverage manufacturing is the industrial sector with highest gas consumption. As shown in the graphic below, gas is almost entirely used for process heating below 250°C.

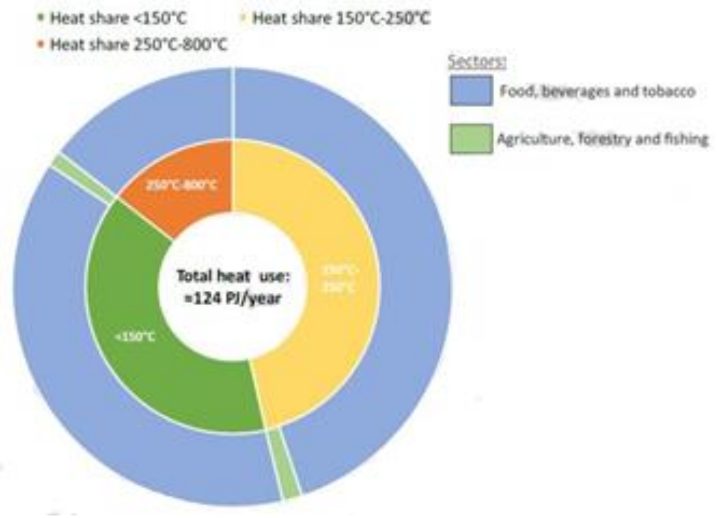

Figure 5: Breakdown of process heating in the Food, Beverage, and Tobacco industry

The food and beverage sector is under pressure across the supply chain to set emissions reduction targets and demonstrate action towards decarbonisation. Whilst food and beverage manufacturing covers a diverse range of product types, the overall processes are such that decarbonisation is comparatively easier than many other industrial sectors who find carbon abatement harder to achieve. Gas is generally used to fire steam boilers and hot water generators, or produce hot air.

Short term options

Air sourced heat pumps supplying hot water at 90°C or below are already commercially available and being adopted in specific applications.

Co-firing biogas in boilers from anaerobic wastewater treatment systems and the use of biomass as a fuel for steam boilers is commonplace and several food and beverage businesses have invested in these systems in recent years in response to high gas prices. Examples include McKain Foods in Ballarat Vic[7] and MSM Milling[8] in Manildra NSW.

From experience simple low cost gas efficiency measures are also a good source of emission reductions in this sector as many sites do not have a structured energy team focused on extracting operational cost savings. This is mainly due to the limited focus on energy efficiency that was applied historically as sites operated on low gas prices and had limited incentives for small efficiency gains. These include boiler and burner improvements, as well as steam pipe lagging, improved condensate return, oxygen trim controls on burners.

Medium term options

For higher temperature applications waste heat driven heat pumps and mechanical vapour recompression systems can be utilised to displace systems that traditionally relied on low-cost steam. Microwave and electric resistance heating are also suitable in direct heating applications. Successful adoption of these technologies requires detailed assessment of heat flows in the facility and increased availability of “off the shelf” heat pump systems that are suited to these higher temperatures.

3.1.2.3 Pulp and Paper

The Maryvale Pulp Mill owned by Opal Australia is the single largest gas user in Victoria. Visy operates several recycled paper mills in the state, and both Visy and Opal operate paperboard manufacturing facilities. In addition to these facilities Victoria also has two tissue manufacturing facilities that also consume appreciable quantities of gas.

Most wood fed pulp mill facilities use the Kraft method which generates black liquor as a biomass by-product which is then re-used at the facility in Combined Heat and Power plants to generate steam and electricity. Gas is used to supplement the CHP plants, as well as for process heating in lime kilns which are part of the pulp process. Paper and board manufacturing occurs by taking the resulting pulp, spreading it evenly across moving screens, pressing it, and then drying it as it is fed along rollers.

Short term options

Similar to brickmaking, and wood product manufacturing there is significant heat recovery opportunities at pulp mill and recycled paper facilities. The process dissipates high amounts of heat , and only some of this heat is recovered and used. There are opportunities to optimise the existing process heating flows, through the application of process integration

[7] https://www.optimalgroup.com.au/projects/australian-first-for-mccain-foods-by-optimal/
[8] https://arena.gov.au/projects/msm-milling-biomass-fuel-switch/

methodologies, and reduce the amount of gas and biomass used. The biomass saved from improved heat recovery could be repurposed for other gas substitution activities.

Medium term options

Opportunities exist for reducing gas usage in the pulping process, primarily through the adoption of additional biomass/biogas. Controlling the electrical output from the CHP plants to the maximum amount of black liquor available is also an option to avoid the requirement for gas top up.

The recent Reliable Affordable Clean Energy (RACE) for 2030 work proposed that complete decarbonisation of the pulp sector is achievable by 2035, primarily through the optimised use of biomass and bioenergy in the process.

Long term options

Process heating in paper and board manufacturing is entirely below 150°C and alternatives such as infrared drying have been investigated. The Electrifying Industry Report by BZE presents a case study for electrifying paper using infrared technology. The transition from steam driven paper manufacturing to infrared would require significant capital investment, which is realistically only possible through government financial support or significant market pressure and paper price increases to transition to a zero emissions alternative.

3.1.2.4 Non Metallic Mineral – brickmaking, tile, cement, and glass

Victoria has a several large facilities in brickmaking, glass, and plasterboard manufacturing, which use significant quantities of natural gas, including:

- Owens Illinois Glass
- Oceania Glass
- CSR Gyprock
- Bradford Insulation
- Brickworks and PGH Bricks
- USG Boral and Knauf Plasterboard

Brick firing and glass production occurs in kilns or furnaces which are heated to over 1000°C, typically through combustion of gas.

Short term options

Whilst kilns and furnaces already employ a considerable amount of heat recovery, there are additional opportunities to enhance the heat recovery and further reduce gas consumption. An additional heat recovery opportunity is pre-heating the combustion air via a recuperator on the flue gas or diverting excess (clean) hot gas streams. Lower cost options involve increasing combustion air temperature from ambient to the rated temperature of the burners, however with more capital upgrades on the burner systems higher temperatures are possible. These and other heat recovery opportunities could yield 10 to 15% savings from kiln gas consumption. Another short-term option is the use of oxygen fuel burners rather than air, to remove non-combustible gases from the combustion air.

Long term options

Both the Renewable Process Heating Report and BZE Electrifying Industry Report identify an opportunity for microwave assisted kiln firing of bricks. Microwave heating is an established alternative to combustion based process heating, and is already used in some industries, albeit at smaller scales. Brick and tile kilns will need additional heat supplied to meet the temperature required and this can be supplied with electric resistance heating. However, to ensure uniformity of firing, the kilns will need to be rebuilt to a different shape.

3.1.2.5 Chemical and Chemical Product Manufacturing

Owing to Victoria's historical natural gas and ethane production capability from the Bass Strait, chemical manufacturing has been well established in the state. The main chemicals manufacturers in the state include:

- Polyethylene (Qenos facility in Altona)
- Superphosphate (Incitec Pivot in Geelong)
- Pharmaceuticals (CSL and others)
- Polyurethane (Huntsman)
- Vinyl related chemicals (Sunace)
- Paint (Dulux)
- Coatings (Dulux)

Note that only the Qenos facility uses gas as a chemical feedstock and this is more correctly ethane, which is out of scope for this study. The facility does, however, use appreciable amounts of methane (natural gas) in process heating in addition to the ethane used as feedstock. In response to diminishing gas supplies from the Bass Strait and subsequent rising gas prices, several chemical manufacturing businesses have closed or significant downsized Victorian operations. Even excluding ethane consumption, the Qenos facility is responsible for three quarters of the gas consumption in this category.

Short term options

Chemical manufacturing uses a considerable amount of process heat, particularly high pressure steam as well as furnace heating. These facilities typically operate on tight margins and are incentivised to adopt low cost efficiency measures and good heat recovery. Nonetheless opportunity still exists to reduce gas consumption through further heat recovery (including waste steam), high efficiency burners and other burner improvements, and standard gas efficiency measures such as steam pipe lagging and improved condensate return.

Long term options

With the future of the Altona Qenos facility in doubt[9], it is likely that significant reduction in gas consumption in this sector will be driven by exit of these businesses to other jurisdictions. For some chemical manufacturing facilities, the use of microwave heating offers a good alternative to gas combustion systems. As noted in the 2019 ARENA funded report "Renewable Energy Options for Industrial Process Heat "large-scale use of microwave heating … has long been limited due to the high cost of scaling up microwave-based synthesis". There are recent advances in this space and the adoption of microwave heating in some chemical applications is possible in the long term.

3.1.2.6 Fabricated Metal and Primary Metal Product Manufacturing

Victoria has several large fabricated metal product manufacturing facilities, including Bluescope in Western Port, Infrabuild's mills in Laverton and Geelong, and several smaller facilities including beverage can manufacturing. The Alcoa aluminium manufacturing facility in Portland also uses a reasonable amount of gas, which is presumed to be consumed in the anode production process.

Short term options

In the steel making and foundry industries gas fired ladle pre-heaters can be replaced with off the shelf electric heaters however it is not an economically viable investment. Typical gas consumption by the ladle heaters is 3% of the site gas consumption.

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[9] https://www.afr.com/companies/energy/refinery-shutdown-triggers-loss-of-150-chemical-jobs-20210519-p57t82

Most heat treatment of steel is performed at approximately 900°C and requires temperature uniformity. This is currently often done with high velocity burners. Conversion of all gas fired heat treatment furnaces to pulse firing would be a way to make inroads in the short term and achieve reduction in gas consumption of typically 25% to 30% (in heat treatment furnaces).

Electrification of heat treatment furnaces at lower temperatures (e.g. tempering) is easily done using electric resistance heating of the recirculating air.

Medium term options

Heating of steel billets in structural steel manufacturing facilities currently use gas fired heat furnaces which can be converted to electric induction however it is currently cost prohibitive. The footprint of this process is likely to be larger and a different shape to existing furnaces so may be difficult to retrofit and the correct design is required to avoid metallurgical issues. Significant feasibility work and capital investment is required to implement while the operating cost remains similar, so there is little incentive to pursue this without significant subsidies.

Some steel requires slow heating through some temperature ranges, and a “soaking” period. In these cases either a resistance heating approach or a combination of induction and resistance heating would be required.

Long term options

Electric arc furnaces for scrap recycling also have gas burners. These burners could be replaced with plasma arc technology, however there are no commercial examples and a significant amount of R&D and feasibility work would be required.

3.1.2.7 Sawmill and Wood Products

The RACE for 2030 study identified 5.5 PJ of process heating for temperatures below 150°C, across Australia in timber sawmills. There are several large timber sawmill facilities in Victoria and multiple small operations.

Short term options

Sawmills use gas and wood by-products for various stages in the process. The largest energy consuming process in sawmills is kiln drying which accounts for 70% of the process heating requirements. Kiln heat consumption can readily be reduced by the adoption of heat recovery processes, particularly from exhaust air. The RACE for 2030 work estimates integrated kiln dryers can reduce energy consumption by up to 35%.

Medium term options

It is also possible to introduce active dehumidification and heating using heat pump technology into a sawmill kiln, as shown in Figure 6. Northmore Gordon is already aware of some sawmills which use heat pump for kiln heating as replacement for electric resistance heating in Tasmania.

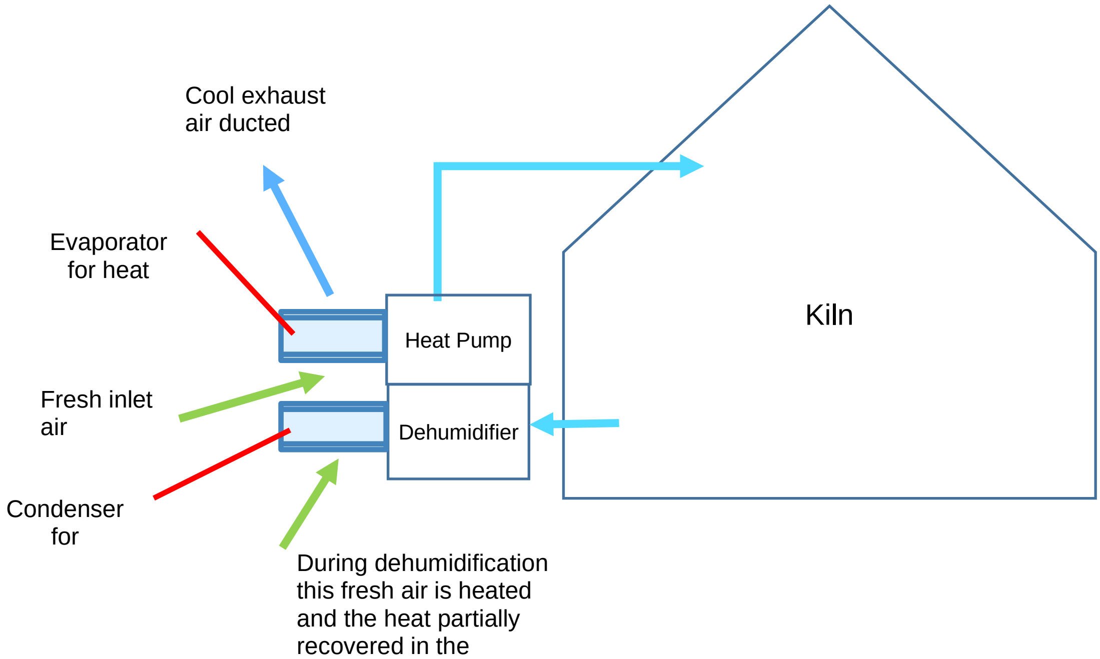


Figure 6: Heat pump dehumidification of a sawmill kiln

Source – Northmore Gordon

3.1.2.8 Large Commercial Offices

Approximately 50% of gas usage in commercial offices is used in Heating Ventilation and Air Conditioning (HVAC), 10% is domestic hot water, about 5% in cooking, and the remainder in specialised equipment (EY, 2020). Gas is used in HVAC for boilers servicing hot water loops for space conditioning systems, such as fan coil units or air handling units, and used in gas storage and instantaneous domestic hot water systems.

Short term options

Energy efficiency has delivered significant dividends in commercial office buildings, and while the higher grade (as classified by the Property Council of Australia) building stock has seen a range of improvements spurred on by schemes such as National Australian Built Environment Rating Scheme (NABERS) there are still significant opportunities in lower grade offices. Energy efficiency includes retrofitting building fabric upgrades, such as improved insulation, as well as installing more efficient condensing boilers for space heating.

Medium term options

Gas boilers supplying hot water used in space heating can be replaced with either heat pumps or reverse cycle chillers in the following two ways:

1. For systems that can be converted to lower temperature hot water (~40 to 60 degrees), boilers can be replaced with lower temperature reverse cycle chillers or direct expansion air-to-air units.
2. For systems that can't easily be converted to lower temperature and need to service high temperature hot water (80 degrees), boilers can be replaced with CO_2 heat pumps

Longer term options

As the availability of electric alternatives for specialised equipment increases it is expected that these can be converted from gas beyond 2035. There is a need for redundancy in offices to support essential services, such as fire pumps and backup generators. As battery technology improves this can be addressed via Uninterrupted Power Supplies (UPS) and Battery Energy Storage Systems.

3.1.2.9 Aquatic and Recreation Centres

Aquatic Centres are typically the largest energy consuming facility for local governments, and are excellent candidates for electrification via heat pump systems. Northmore Gordon has extensive experience working with Aquatic Centres, having audited over 10 facilities since 2016 and preparing the “Energy efficient water heating technology guide for aquatic centres” for the NSW government in 2019.

Pool water heating is typically 60 to 80% of an aquatic centres energy usage and while some facilities in Victoria operate with heat pump and cogeneration systems, the predominant heating technology is gas boilers supplying a secondary heating circuit. Table 6 is taken from the NSW Aquatic Centre guide prepared by Northmore Gordon and shows the comparison between different heating technologies for pool heating. Solar thermal provides an effective source of renewable heat but cannot be used as the sole source of heat. While the table shows gas fired cogeneration having a superior greenhouse emissions performance, this is based on comparison with grid electricity purchases and corresponding Scope 2 emissions taken from 2018 emissions factors. Electric heat pumps offer the best energy efficiency and, based on 2018 emissions factors, a superior emissions performance than gas boilers. Given the Victorian Renewable Energy Target and other government policies on energy and emissionshave forecast that emissions factors will fall significantly in the next decade, heat pump systems will have a superior carbon performance across the board.

Table 6: Heating technology comparison for aquatic centres

Heating technology	Rated efficiency[3]	Energy Source	To generate 1 GJ of heat			Maintenance costs
			Energy input (GJ gas or GJ electricity/ GJ heat)	Energy cost[4]($/ GJ heat)	GHG emission[5] (kg CO2/GJ heat)	
Gas Boiler	85%	Gas	1.18	$20.59	61	$
Electric heat pump	COP: 4	Electricity + Air/Water/ Ground...	0.25	$10.07	58	$$
Biomass boiler	80%	Biomass	1.25	$10.00	0	$$$
Solar thermal	50%	Sun	0.00	free	0	$
Gas fired co-generation (at 100% heat recovery)	45% thermal 30% electricity 75% overall	Gas	2.22	$12.04	-396	$$$

Source – NSW Department of Planning Industry and Environment

Short term options

Gas consumption can be reduced by a combination of measures, including tuning of equipment and improved controls. Northmore Gordon typically estimates 10% reduction in energy consumption from low to no cost measures in aquatic centres.

Medium term options

A wholesale program to replace gas boilers in aquatic centres with heat pumps would be capital intensive, with suitable commercial heat pumps in the range of $200-400k. Installing heat pumps to replace gas boilers and cogeneration system will deliver annual energy cost savings and typically delivers a payback in the range of 4 to 8 years without incentives. It is worth noting, that a similarly capital intensive program occurred in the second half of the

2000s, with Commonwealth Government funding supporting the implementation of cogeneration systems. Many of these cogeneration systems are ageing and have been plagued with difficulties due to poor integration into the pool heating systems. A program encouraging adoption of modern heat pumps may be timely given the need to replace these systems and plan for growth in population.

3.1.2.10 Hospitals and other Large Healthcare

Hospitals are complex facilities with utilities servicing critical functions, including surgical theatres. Whilst challenges exist in upgrading energy using equipment at hospitals, they are typically government owned and are expected to align with state government emissions reduction targets. The advocacy organisation Healthcare without Harm recently released the Roadmap for Healthcare Decarbonisation prepared by the consultancy Arup. For Australia it was assigned to a steep decline trajectory, requiring immediate, aggressive action to implement a rapid and deep decrease in emissions.

Short term options

Gas is used in hospitals to produce hot water used in amenities, such as showers and hand washing, as well as hot water used in theatres, laboratories and specialist equipment. Additionally, as with commercial office buildings, gas supplies boilers to produce hot water for space conditioning systems. Existing boilers in space heating systems and domestic hot water systems can be replaced with higher efficiency units, including condensing boilers

Medium term options

Hot water systems can also be retrofitted in a similar manner to large commercial offices with heat pump or reverse cycle chillers. Some older hospitals have reticulated steam systems for sterilisation, which can be removed entirely to make way for standalone autoclave sterilisations systems.

3.1.2.11 Large Retail

Large retail facilities – shopping centres, and supermarkets are often high energy users compared to others sectors within the built environment

Short term options

Major supermarket chains have invested significantly in energy efficiency in recent years, and while there is always room for improvement much of the low hanging fruit has been addressed. The most likely area for benefit is in smaller facilities and facilities in less population dense regions. The 2013 Zero Carbon Australia Buildings Plan by Beyond Zero Emissions identified that if the measures already implemented by the best performing supermarkets were implemented across the remaining building stock energy improvements of 35 to 50% were achievable. There are interactive effects between different energy systems in supermarkets and energy efficiency measures can create unintended impacts on other energy systems. This introduces some uncertainty as to the level of gas savings that can be achieved by energy efficiency measures.

Medium term options

Larger retail facilities are typically conditioned via electrically driven packaged units, with minimal gas usage. Gas use will be more dominant in smaller retailer facilities in space heating, domestic hot water, and cooking. Consequently, fuel switching via the adoption of heat pumps for domestic hot water and reverse cycle chillers for space conditioning systems can yield significant reduction in gas usage. With sufficient incentives it could be possible to electrify retail gas usage within the next 10 to 15 years.

3.1.3 Key Results

This section presents the key results from the Victorian gas consumption analysis for large gas users over 10 TJ per annum.

3.1.3.1 Bottom up analysis of sub-sector gas consumption

Using the method set out in Section 2.2, industrial and large commercial was estimated for each sub-sector. Industrial facilities are considered to include manufacturing and mining, but do not include self-consumption of natural gas in oil and gas exploration and mining, or gas consumption in electricity generation (Division D). Large Commercial was separated into the categories provided based on the prevalent categories in NGERS data and grouped according to facility type rather than business activity (which is the classification approach in ANZSIC). Other commercial includes Agriculture, Construction Services, Airports and other specialised transport services, large entertainment facilities such as casinos and sport stadiums, and other miscellaneous types)

From the bottom up analysis estimated Large Commercial gas consumption equalled the values derived from the top down analysis, and Industrial gas consumption was accurate to within 5%.

The largest gas consuming industrial sub-sectors were found to be Food and Beverage Manufacturing, Pulp and Paper (with the Maryvale Paper Mill representing two thirds of this sector's gas consumption), Petroleum and Coal Product Manufacturing, Non-Metallic Mineral Product Manufacturing, and Basic Chemical and Chemical Product Manufacturing. In Large Commercial sub-sectors, Aquatic Centres, Healthcare, and Large Education (mainly Universities) were the largest consuming gas categories.

Table 7: Estimated 2020 gas consumption for each industrial and large commercial sub-sector

Industry sector (ANZSIC Sub-Division Level)	Gas Consumption
Food, beverage and tobacco product manufacturing	16.21
Pulp, paper and converted paper product manufacturing	9.20
Petroleum and coal product manufacturing	7.09
Non-metallic mineral product manufacturing	6.99
Basic chemical and chemical product manufacturing	6.41
Primary metal and fabricated metal product manufacturing	4.21
Textile, leather, clothing and footwear manufacturing	3.21
Wood product manufacturing	0.73
Polymer product and rubber product manufacturing	0.15
Printing (including the reproduction of recorded media)	0.11
Mining (combined sub-divisions)	0.08
Transport equipment and machinery and equipment manufacturing	0.07
Total Industrial	***54.5 PJ***
Other Large Commercial	3.8
Aquatic Centre/other Public Services	3.6
Health care and social services	2.0
Large education	1.3
Commercial office	1.1
Large retail	0.9
Total Large Commercial	***12.7 PJ***

Source – Northmore Gordon analysis

Extrapolating the resulting sub-sector consumption by the trends in the AEMO GSOO 2021 data for Medium to Large Industrial and Small Industrial leads to the forecast business as usual gas consumption for each sub-sector given in Figure 7.

Large industrial facilities that participated in the EPA Environment and Resource Efficiency Plan (EREP) program are exempt from the Victorian Energy Upgrades program and paying VEEC charges on their bills. At present these facilities have to opt in to the VEU program in order to access the program to fund energy upgrades.

There is a proposal for all industrial facilities to be included in the VEU, unless they demonstrate they have an active energy management program. A decision on this has been deferred to 2024 by DEWLP.

A review of large manufacturing gas users from the NGERS dataset, indicates at least 80% of all large industrial gas users are excluded from the VEU program representing about 25 PJ of gas usage or just under half of all industrial gas consumption. Additional gas users are exempt, including wastewater services and some large commercial services facilities, suggesting the figure is more like 30 PJ.

The deferral of a decision to incorporate exempted large industrial facilities in the VEU removes an important incentive and support program to those businesses looking to improve energy efficiency and reduce GHG emissions. In the absence of such an incorporation, alternative government support mechanisms are required, such as direct grant funding. It is worth noting that the NSW Energy Saver Scheme (ESS) does not exempt large facilities from participating in the scheme, rather it allows Emissions Intensive Trade Exposed businesses to apply on a yearly basis for a rebate on their certificate obligation (typically 90%). A similar model could be adopted with good effect in Victoria, allowing those businesses to access project funding through VEECs.

3.1.3.2 Energy efficiency activities for industrial and large commercial sub-sectors

A summary of the identified energy efficiency activities for gas consumption in the Industrial and Large Commercial sectors was prepared drawing from the high level overview of each of the priority sub-sectors. These summaries of suitable energy efficiency activities, their gas reduction potential on a per facility basis and a Victorian wide basis, their timeframes for adoption, and ease of implementation are presented in Table 8 and Table 9. Based on Northmore Gordon's experience, energy efficiency activities were extrapolated to the sectors not reviewed in detailed, e.g. Polymer product, Textile, Mining.

In consultation with Infrastructure Victoria, Northmore Gordon shortlisted three energy efficiency activities for industrial and large commercial. A preliminary ranking of Energy efficiency activities was undertaken according to the following:

- Total gas reduction potential – higher potential preferred
- Ease of implementation – easier implementation preferred
- Timeframe for adoption – earlier adoption preferred

The shortlisted energy efficiency activities are used in the Cost Benefit Analysis at the individual facility level and at the Victorian wide scale.

The shortlisted energy efficiency activities chosen for Industrial were:

- Low temp heat pumps
- Heat recovery
- Burner and boiler upgrades

For Large Commercial the proposed shortlisted energy efficiency activities were:

- Reverse cycle chillers and packaged units

- Low temperature heat pumps
- Burner and boiler upgrades

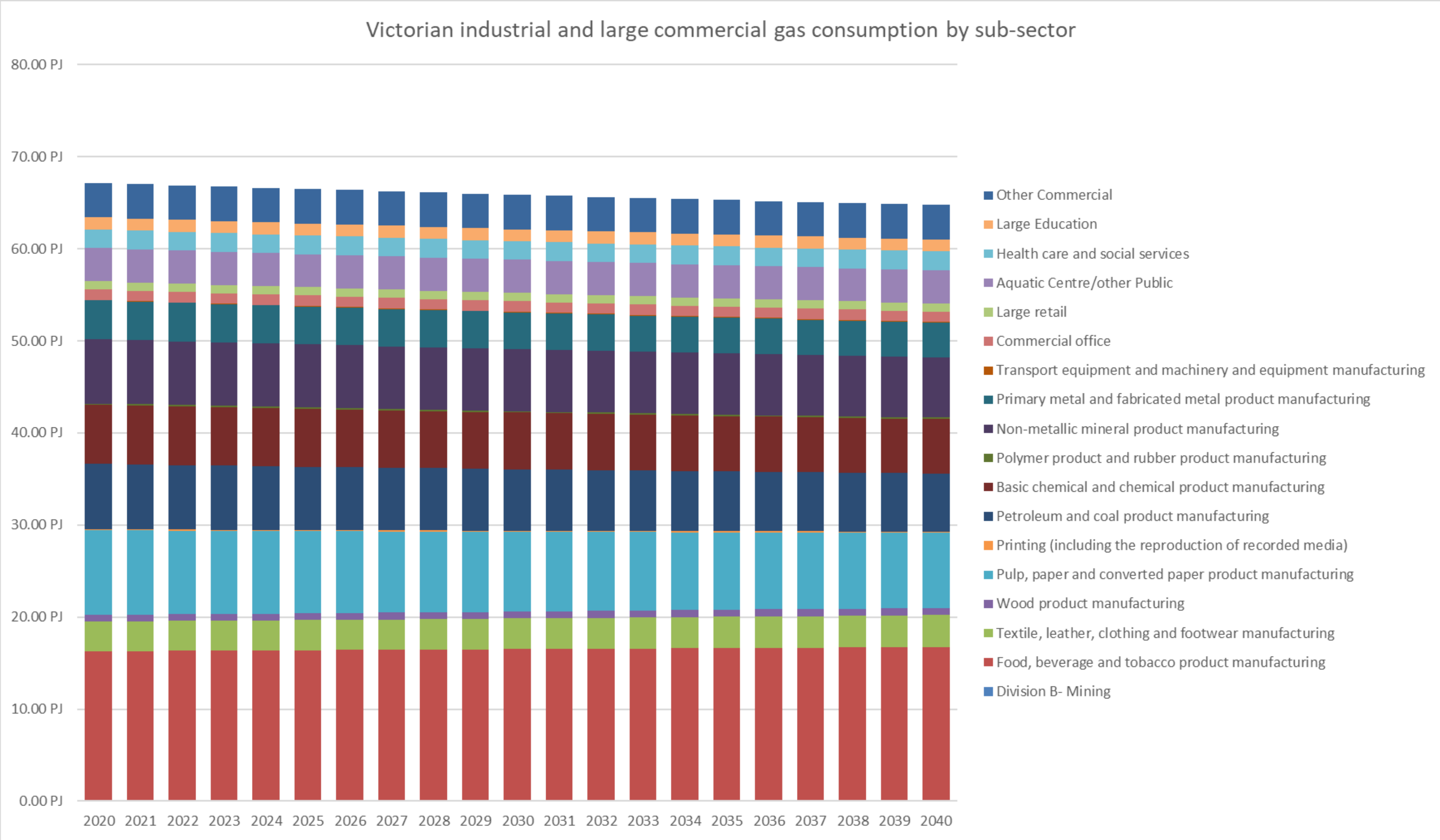


Figure 7: Forecast business as usual gas consumption for industrial and large commercial by sub-sector

Source – Northmore Gordon

Table 8: Proposed energy efficiency activities for industrial gas users

Energy efficiency activity	Applicable sectors	Reduction potential range	Total Potential (PJ)	Timeframe	Ease of impleme ntation	Initial Rank
Heat recovery	Non metallic mineral, timber and wood products, food and beverage, pulp & paper, fabricated metal and metal product, most other industrial facilities	10-25%	10.6	Short term	Moderate	1
Burner and boiler upgrades	Food and beverage, textile, non-metallic mineral, timber and wood products, fabricated metal and metal product, petroleum, and coal product, pulp and paper,	5-15%	6.63	Short term	High	2
Low temperature heat pumps (below 90°C)	Food and beverage, timber and wood products, textile, basic chemical and chemical product	20-40%	7.91	Short to Medium term	High	3
Biomass and biogas	Non metallic mineral, wood products, pulp & paper, food and beverage, textiles	25-100%	36.34	Medium term	High	4
Low cost gas efficiency activities	Food and beverage, textile, pulp & paper, timber and wood products, most other industrial facilities	0-5%	2.19	Short term	High	5
High temperature heat pumps and MVR (>90)	Food and beverage, textile, mining	20-40%	10.68	Medium term	Moderate	6
Electrification of ladle heating and lower temp furnaces	Fabricated metal and metal product manufacturing, polymer product	5-50%	0.29	Short term	High	7
Furnace improvements	Fabricated metal and metal product, non metallic mineral, polymer product (e.g. coatings)	10-25%	2.18	Short term	Moderate	8
Microwave and electric resistance heating	Non metallic mineral, chemical, food and beverage	20-100%	16.64	Long term	Low	9
Electric induction furnaces	Fabricated metal and metal product manufacturing	0-40%	1.68	Medium term	Low	10
Infrared drying	Paper and board, printing	25-50%	2.34	Long term	Low	11

Source – Northmore Gordon

Table 9: Proposed energy efficiency activities for large commercial gas users

Gas Reduction Opportunity	Applicable sectors	Reduction potential (per sector)	Total Reduction Potential	Timeframe	Ease of implementation	Initial Rank
Reverse cycle chillers and packaged units	Office, retail, aquatic centre, healthcare, education, other commercial	20-50%	3.76	Short to medium term	High	1
Low temperature heat pumps (<90)	Office, aquatic centres, healthcare, other commercial	10-70%	3.34	Short to medium term	Moderate	2
Burner and boiler upgrades	Office, aquatic centre, healthcare, education	5-10%	0.9	Short term	High	3
Building fabric upgrades	Office, retail, aquatic centre, education	10-25%	1.63	Short term	Moderate to low	4

Source – Northmore Gordon

3.2 Cost Benefit Assessment

3.2.1 Methodology

To develop an assessment of the Victorian wide cost and benefits of the shortlisted energy efficiency opportunities the methodology was followed as set out in Figure 8.

As set out in the original project scope the Cost Benefit Assessment (CBA) was to be prepared first based on an individual scale for each energy efficiency activity and then scaled to the Victorian state over the 2030, 2040, and 2050 horizons. During the course of the study it became apparent that economic modelling beyond 2040 added no marginal insights into the costs and benefits associated with each energy efficiency activity, but did add significantly to the uncertainty associated with the results. As a consequence, a decision was made to limit the analysis timeframe to 2040.

3.2.1.1 Reference Projects

Each of the industrial sub-sectors has broad differences in terms of their production operations and equipment and consequently implementation of each energy efficiency opportunities will be tailored to each sub-sector.

In order to overcome these challenges, Northmore Gordon first developed individual reference case CBAs for the three energy efficiency opportunities against three chosen industrial sub-sectors:

- Low temp heat pumps → Food manufacturing
- Heat recovery → Non-metallic mineral manufacturing
- Burner and boiler upgrades → Fabricated metal and primary metal product manufacturing

These reference case CBAs were drawn from actual energy efficiency opportunity development work undertaken in energy audit and feasibility studies conducted by Northmore Gordon. The reference cases enabled quantification of real world capital expenditure and energy savings that could be calibrated to the complete dataset.

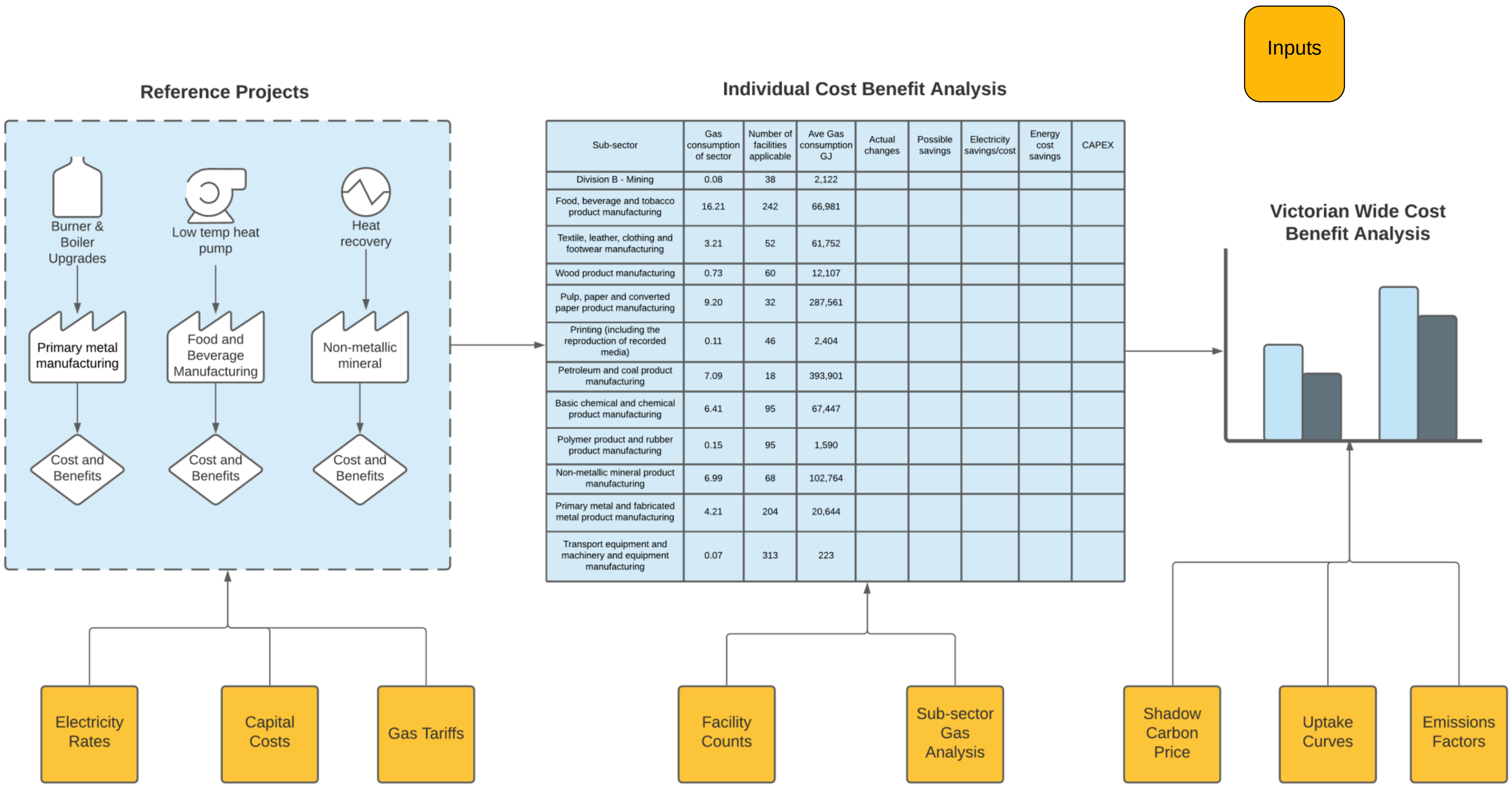
3.2.1.2 Individual Cost Benefit Analysis

The actual reference cases validated the potential costs, benefits, and simple payback associated with the energy efficiency activities shortlisted. However, Northmore Gordon had to rely on inhouse knowledge and experience to apply the three energy efficiency activities to every industrial and large commercial sub-sectors. The Individual Cost Benefit Analysis involved:

- Using the ABS facilities counts for industrial (with turnover greater than $10 Million) and the NGERS facility counts for large commercial for each sub-sector and the total gas consumption in each sub-sector to estimate an individual facility average gas consumption for every sub-sector. This average gas consumption was validated against the individual facility level data used in the gas usage sector analysis
- Tailoring the actual changes implemented for each energy efficiency activity to every industrial and/or large commercial sub-sector and calibrating the actual gas savings and capital expenditure to those changes and sub-sectors
- Estimating non-trivial interactive electricity increases or decreases on a per facility basis

The complete sub-sector individual cost benefit analysis results are presented in Appendix A.

Note that energy efficiency activity “reverse cycle chillers and packaged units” was combined with the low temperature heat pumps activity for the CBA.



Sub-sector	Gas consumption of sector	Number of facilities applicable	Ave Gas consumption GJ	Actual changes	Possible savings	Electricity savings/cost	Energy cost savings	CAPEX
Division B - Mining	0.08	38	2,122					
Food, beverage and tobacco product manufacturing	16.21	242	66,981					
Textile, leather, clothing and footwear manufacturing	3.21	52	61,752					
Wood product manufacturing	0.73	60	12,107					
Pulp, paper and converted paper product manufacturing	9.20	32	287,561					
Printing (including the reproduction of recorded media)	0.11	46	2,404					
Petroleum and coal product manufacturing	7.09	18	393,901					
Basic chemical and chemical product manufacturing	6.41	95	67,447					
Polymer product and rubber product manufacturing	0.15	95	1,590					
Non-metallic mineral product manufacturing	6.99	68	102,764					
Primary metal and fabricated metal product manufacturing	4.21	204	20,644					
Transport equipment and machinery and equipment manufacturing	0.07	313	223					

Figure 8: Cost benefit assessment methodology

3.2.1.3 Victorian Wide Cost Benefit Analysis

The final Victorian wide CBA was then developed by scaling the individual facility CBA results to the total set of large facilities by applying uptake models for the adoption of each of the energy efficiency activities to 2040.

The analysis assumes that capital upgrades are adopted once in each facility over the 20 year period with tranches of facility upgrades occurring in line with the energy efficiency activity uptake assumptions. This produced an implementation timeframe over 20 years whereby activities were steadily adopted by industrial and large commercial facilities, leading to the resulting outputs for Victorian wide gas reduction, energy savings, capital expenditure, and greenhouse gas (GHG) emissions abatement. The energy and emissions savings that result occur each and every year during the 20 year period, varied for the modelled emissions factors and electricity and gas tariffs. The GHG emissions were then monetised using a shadow carbon price to account of the indirect benefits of avoided GHG emissions.

Overall financial analysis of the Victorian wide CBA involved calculation of Benefit to Cost Ratios, Internal Rate of Return, and total Capital Expenditure. All financial analysis was done in real terms, i.e. adjusting for inflation.

3.2.2 Key Inputs and Assumptions

3.2.2.1 Uptake Curves

Understanding the baseline level of adoption of the shortlisted energy efficiency activities in industrial and large commercial facilities is beyond the scope of this study and would be a significant undertaking. However the level of gas reduction potential of each energy efficiency activity in each industrial and large commercial sub-sector was broadly calibrated based on Northmore Gordon's understanding of the existing level of adoption of these measures. For example Burner and Boiler Upgrades and Heat Recovery had a lower potential in Petroleum and Coal Product Manufacturing facilities because the industry historically has had a much greater incentive and capacity to invest in higher efficiency equipment.

The CBA did not model retirement of implemented energy efficiency activities at the end of the life, but instead assumed a level of uptake of the proposed energy efficiency activities over 20 years. The uptake curves modelled by Northmore Gordon are presented in Figure 9.

Uptake curves where prepared based on Northmore Gordon's experience considering a range of factors, including:

- the current existence of the energy efficiency activities in each industrial and large commercial sub-sector (noting that all facilities will have varying levels of heat recovery and boiler and burner efficiency)
- the current rates of adoption of the energy efficiency activities in response to energy prices and market competition (between facilities)
- anticipated levels of adoption assuming some form of government incentive (financial and non-financial) is offered to encourage businesses to invest in the energy efficiency activity
- the likely pace and timeframe of adoption for burner and boiler upgrades, noting that these tend to be lower cost, and easier to implement
- the likely pace and timeframe of adoption of heat recovery activities, noting that these are more complex but have a greater cost saving
- the likely pace and timeframe of adoption of low temperature heat pumps and reverse cycle chillers, noting that there are still limited off-the-shelf options available to businesses today, but this anticipated to improve over time.

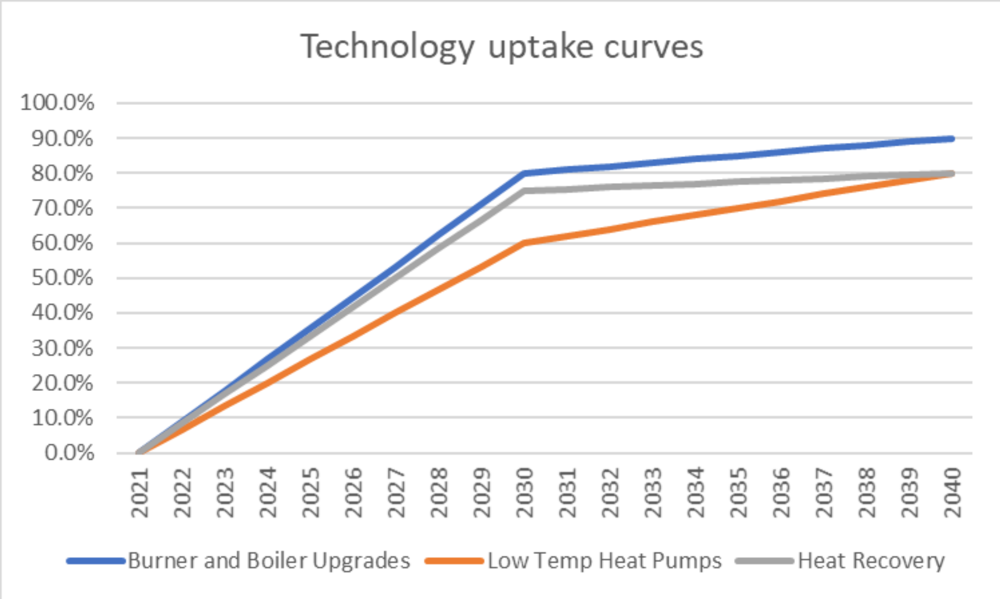


Figure 9: Energy efficiency activity uptake curves for the shortlisted activities

Source – Northmore Gordon

3.2.2.2 Energy prices

3.2.2.2.1 Electricity prices

Electricity prices used for the cost benefit analysis were prepared. Updated Victorian wholesale prices were obtained through the live traded ASX Energy Market[10], accessed on 14 September 2021. Calendar year traded contracts and live price information was used for Calendar Year 2022 (Cal 22); Calendar Year 2023 (Cal 23) & Calendar Year 24 (Cal 24). Peak wholesale prices were developed using the live market data which has the equivalent peak contract prices for Cal 22; Cal 23 & Cal 23. The wholesale off peak prices were calculated from the time weighted averages of peak versus off-peak hours applied by the National Energy Market wholesale market contracted time periods. Wholesale price forecasts beyond 2024 were taken from internally developed forecasts up to 2040.

The actual energy charge experienced by an end customer would be uplifted by a retailer to create a retail price. A 15% retail margin is estimated which includes profit margin, shape premium, risk premium & credit premium.

Note that the 15% assumption is based on a typical large market customer as the customer load shape is unknown, customer credit position is unknown, as is who the wholesale counterparties may be.

Environmental rates were taken from forward certificate markets as of 3 September 2021 as follows:

- Large Generation Certificates (LGCs) rates from recognised certificate brokers and a Renewable Power Percentage of 18.54%. A $10 floor price was set for LGCs as long term forward prices show near zero values and Northmore Gordon's view is LGC prices will hold some real value out to 2030 when the scheme ends. The primary driver for this value is the use of LGCs within renewable energy power purchase agreements to validate the energy as "green".

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[10] https://www.asxenergy.com.au/futures_au/V

- Small Technology Certificates (STCs) Rates are capped at $40.00, model assumes retailer is charging $40.00 per certificate. The current Small Technology Percentage of 28.8% was applied.
- The current spot market price and Cal 22 price is persistently high at $83 per VEEC. VEECs only have a trading market out to Cal 23 which have traded at $67.50, this price was maintained for the length of the analysis period (adjusted for inflation).
- The VEET percentage of 17.26% for electricity was applied and maintained throughout the analysis period.
- All certificate prices are in today's terms and needed to be adjusted to remove inflation in subsequent years.
- A retail margin of 15% was applied to the resulting environmental charges

Indicative network charges were taken from the latest Powercor Pricing Proposal for 2021-2022, using the Large Low Voltage Transmission Tariff. The low voltage tariff was selected as it gave a more conservative estimate of electricity prices and was better representative of the spread of industrial and large commercial energy users. Beyond the current regulated pricing period for Distribution Network Service Providers (DNSPs) a 1% real year on year increase was assumed to escalate network charges. Savings arising from reduction in Peak Demand charges were not considered in the CBA modelling.

The actual annual electricity price series used in the CBA modelling was developed by summing the peak and off-peak components and then preparing a weighted average using the Victorian retail peak (7am to 7pm weekdays) and off-peak (all other times) time of use periods.

Table 10: Large market electricity prices used in cost benefit analysis

Period	Energy Charges		Environmental Charges			Market Charges		Network Charges		
	PK	OP	STC	LGC	VEEC	ASC	MC	PK	OP	Demand /KVA
Cal 22	$87.98	$38.34	$13.25	$6.50	$16.47	$0.30	$0.80	$40.00	$27.90	$155.88
Cal 23	$79.84	$34.50	$13.25	$5.62	$13.39	$0.30	$0.80	$40.02	$28.10	$138.00
Cal 24	$82.37	$32.40	$13.25	$4.93	$13.39	$0.30	$0.80	$41.40	$28.90	$132.00

Source – Northmore Gordon analysis

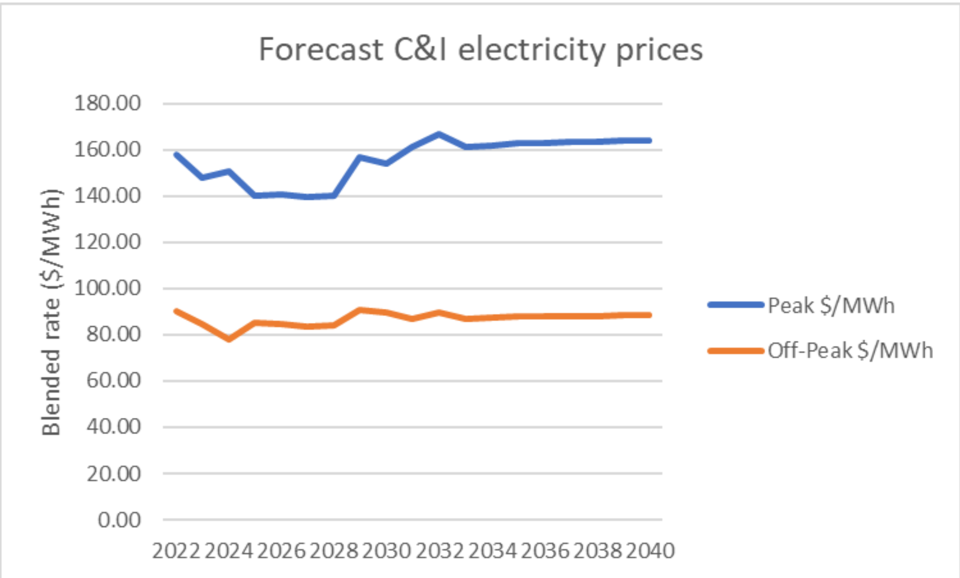


Figure 10: Electricity price forecasts used in the industrial and Large Commercial CBA

Source – Northmore Gordon

3.2.2.2.2 Gas prices

Gas prices used for the cost benefit analysis were prepared. Updated Victorian wholesale prices were obtained through the live traded ASX Energy Market[11], accessed on 3 September 2021. Calendar Year traded contracts and live price information was used for Calendar Year 2022 (Cal 22); Calendar Year 2023 (Cal 23). For 2024 through to 2040 wholesale gas prices were taken from Gas Price Projections for the 2021 AEMO GSOO. As per the commentary under electricity prices a 15 % retail margin was applied to the wholesale prices to estimate the actual charge paid by the end customer.

Network charges were taken from the latest Australian Pipeline Association (APA) Victorian Transmission System annual pricing proposal for Metro Melbourne withdrawal locations. As with electricity DNSP charges, gas transmission charges were escalated by 1% year on year.

In Victoria the only environmental charge levied on gas users (excluding exempt users) is the Victorian Energy Upgrades program liability. Environmental rates were taken from forward certificate markets as of 3 September 2021 as follows:

- The VEET percentage of 0.87% for gas was applied and maintained throughout the analysis time period.
- A retail margin of 15% was applied to the resulting environmental charges

Table 11: Large market gas prices used in cost benefit analysis

Period	Wholesale	Retail Margin	Environmental
Cal 22	$8.28	$1.24	$0.72
Cal 23	$9.10	$1.37	$0.72
Cal 24	$9.50	$1.43	$0.72

Source – Northmore Gordon analysis

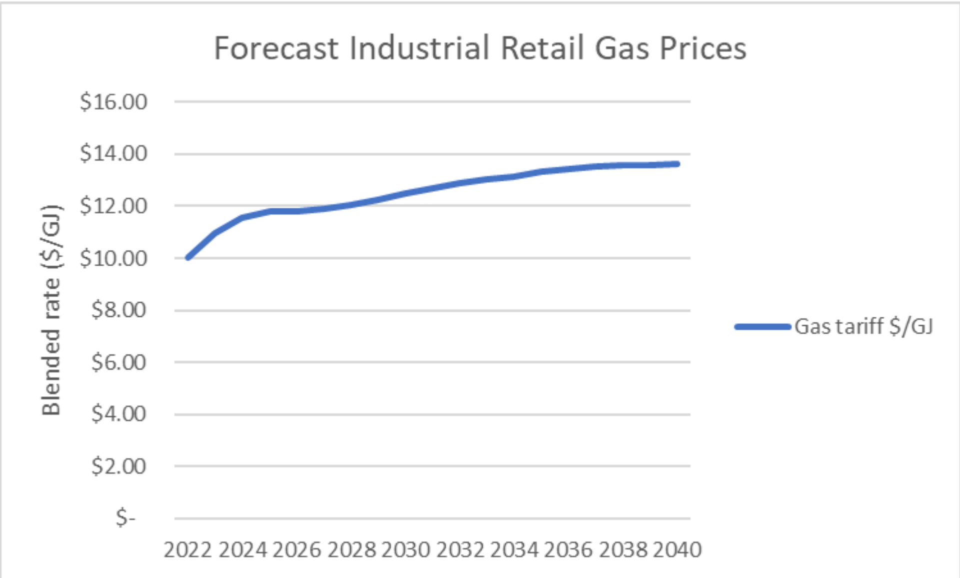


Figure 11: Gas price forecasts used in the Industrial and Large Commercial CBA

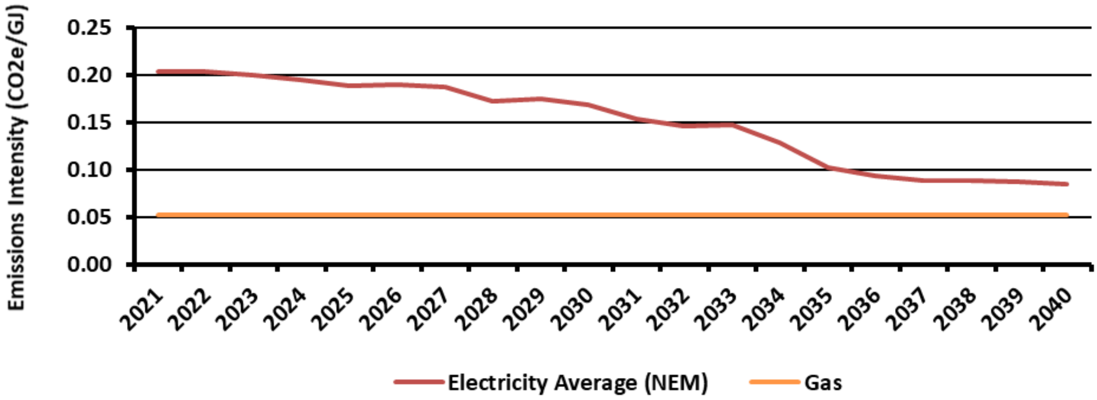
Source – Northmore Grordon

[11] https://www.asxenergy.com.au/futures_gas

3.2.2.3 Emissions factors

The carbon intensity of fuel sources is the predominant determinant of emissions saved from higher energy efficiency. The average emissions intensity of gas and electricity fuel sources assumed is shown in Figure 12.

Figure 12 – Emissions Intensity by Fuel Source



Source – AEMO Integrated System Plan 2020

Electricity grid emissions intensity was taken from the AEMO ISP (2020) Central Scenario and is forecast to fall over time as more zero-emissions generation technology such as solar photovoltaics (PV) and wind are commissioned in the National Energy Market (NEM). Gas emissions factors were taken from the National Greenhouse Accounts Factors published by DISER.

It is noted that CO2 intensity of incremental electricity consumption in Victoria would potentially be much lower if it were supplied by renewable energy.

3.2.2.4 Shadow Carbon Price

A shadow carbon price has been adopted in the CBA modelling to account for the benefits associated with GHG emissions reduction. The use of internal or shadow carbon prices is becoming common place amongst large energy users to acknowledge the value of carbon reduction projects in a world where emissions reduction targets and policies are widespread. For example the European Union is proposing a carbon border adjustment mechanism (CBAM) on imports of goods and services.. Imports of carbon intensive products will have to pay for the cost of an equivalent amount of certificates under the EU Emissions Trading Scheme for the associated Scope 1 emissions. The current EU carbon price is more than A$80 a tonne of emissions.

The 2019 Victorian Energy Efficiency Target Amendment Regulatory Impact Statement[12] modelled a societal cost of carbon as part of the associated cost benefit analysis, citing previous studies by EY and Jacobs. The resulting carbon price used was in the range of $50/tonne to $200/tonne.

At present Australia does not have a compulsory carbon price or tax mechanism, however an increasing number of businesses are adopting net zero emissions targets or becoming Carbon Neutral certified under the Climate Active Standard. Under the Climate Active standard businesses can offset emissions using Australian Carbon Credit Units (ACCU), as well as some internationally recognised emissions certificates. Whilst the primary market for ACCU is

[12] The RIS established targets for the period 2021 to 2025 under the Victorian Energy Upgrades (VEU) program.

the Emissions Reduction Fund, a secondary market exists to allow voluntary purchases to occur and to allow for ERF auction parties to make good on contracts.

Forward Delivery	Volume (Last Trade)	Price	Date	Volume (Daily)	Change
Spot	5k	$24.25	10/09/2021		0.00
Jan-22	10k	$19.05	3/06/2021		0.00
Feb-22	10k	$25.30	10/09/2021		0.00
Apr-22	20k	$25.65	10/09/2021		0.00
Feb-23	**10k**	**$26.30**	**13/09/2021**	**10k**	**0.00**
May-23	20k	$24.60	8/09/2021		0.00
Total				10k	

Figure 13: Spot and forward ACCU contract prices on the secondary market

Source – High Voltage Brokers, accessed September 14

In the absence of a compulsory carbon price mechanism, and not to overinflate the value of carbon abatement, a shadow carbon price of $25/tonne of CO_2e was chosen for this study.

3.2.2.5 Financial Metrics

The study employed a 7% discount rate for the calculation of payback periods and internal rates of return, which is consistent with the Victorian Government Department of Treasury Guidelines[13].

An inflation rate of 2% was used to adjust for inflation, where prices were listed as nominal.

Not data is available about the equipment turnover rates in industrial and large commercial facilities. Equipment lifetimes for the proposed energy efficiency activities are generally 10 to 15 years. To simplify the analysis savings were presumed to persist until 2040 rather than replacements being costed in during the 20 year analysis.

3.2.3 Key Results

3.2.3.1 Reference Projects

3.2.3.1.1 Burner and Boiler Upgrades – Metal Foundry

A metal foundry in Victoria operated 6 annealing furnaces, which were heated using natural gas. Previously the burners combusting gas and air were operated with 28% excess air. Efficient combustion occurs at 10% excess air, beyond this there is no additional benefit because the energy needed to heat up the additional air is lost in the flue gas. Heat treatment furnaces are usually set up with 10% excess air at high fire using high velocity burners. Reducing the air flow to 10% excess air would result in a significant improvement in burner efficiency.

Reducing excess air in the burner is achieved by installing a VSD on each combustion air fans and using the fan speed to control the air flow to the optimum.

[13] Victorian Government Department of Treasury and Finance (2013), 'Economic Evaluation' https://www.dtf.vic.gov.au/investment-lifecycle-and-high-value-high-risk-guidelines/stage-1-business-case

Estimated Cost	Gas Savings (p.a.)	Electricity Savings/Costs	GHG Emissions Reduction (tonnes p.a.)	Energy and Carbon Cost Savings ($ p.a.)	Payback Period (Years)
$60,000	7,500 GJ (10% of gas usage)	21 MWh	408.9	$98,000	< 1 year

The reference project illustrates that burner and boiler upgrades deliver good financial returns, and a small investment ($60,000 in this case) can deliver significant gas reduction at industrial facilities.

3.2.3.1.2 Low Temperature Heat Pumps – Food Manufacturer

A Victorian food manufacturing business melted ingredients at a temperature of between 50°C and 80°C prior to use in subsequent processing and refining. Liquid ingredients were stored in jacketed storage tanks, heated with hot water generated off a steam heat exchanger. All process heating at the site was delivered via reticulated steam produced in two boilers at approximately 10 Bar. A feasibility study was conducted by Northmore Gordon in 2020 into installing a low temperature heat pump to replace some of the heat energy from the steam boilers.

The proposed project involved installing an Ammonia heat pump to generate 60°C hot water supplying the heated storage tanks using heat rejected from water chillers operating on site. The Australian Alliance for Energy Productivity (A2EP) has developed a Heat Pump Scoping Tool, and Northmore Gordon re-engineered the original numbers from the feasibility study using this tool.

Estimated Cost	Gas Savings (p.a.)	Electricity Savings/Costs	GHG Emissions Reduction (tonnes p.a.)	Energy and Carbon Cost Savings ($ p.a.)	Payback Period (Years)
$828,000	48,500 GJ (57% of gas usage)	-1,800 MWh	2,500	$287,000	3.2 years

Whilst the capital price is high for heat pump replacement of gas heating systems, it can deliver significant reduction in gas consumption at facilities like this food manufacturing business. It does require additional electricity consumption to operate, but well designed heat pump integration to achieve high Coefficients of Performance deliver a net GHG emissions reduction.

3.2.3.1.3 Heat recovery – Non-metallic minerals

A brick manufacturer in Western Australia uses natural gas to fire kilns in which bricks are fired at over 1100°C. The combustion air supplied to the kilns was 100% fresh air at ambient temperature. Cold air is blown over bricks at the end of the kilns in a “rapid cooling” section and the resulting hot air is ducted to either the start of the kiln to pre-heat incoming air or to a tunnel dryer. Whilst a large portion of the waste heat from the rapid cooling exhaust air is already utilised an opportunity existed to utilise some of the heat from the clean air stream for mixture with fresh air in the combustion burner air intake. This could be simply achieved though modifying the ductwork downstream of the rapid cooling fan to direct some heat to mix with fresh air at the combustion air intake.

Estimated Cost	Gas Savings (p.a.)	Electricity Savings/Costs	GHG Emissions Reduction (tonnes p.a.)	Energy and Carbon Cost Savings ($ p.a.)	Payback Period (Years)
$450,000	20,515 GJ (5% of gas usage)	0 MWh	1,049	$205,900	2.2 years

This project illustrates that, while reasonable amounts of heat recovery are already utilised in industrial facilities there are still significant opportunities available. In this case a significant reduction in gas usage ($200,000 savings per annum) is possible with a 2 year payback.

3.2.3.2 Victorian-Wide Cost Benefit Analysis Results

The following sections report on the results of our cost-benefit-assessment modelling in terms of estimated benefit-costs, net savings and payback periods by energy efficiency activity for each industrial and large commercial sub-sector.

3.2.3.2.1 Burner and Boiler Upgrades

The resulting cumulative gas savings for Burner and Boiler Upgrades is given in Figure 14 and GHG emissions savings and annual cashflows are shown in Figure 15. Note that the Net Cashflow presents the net of accrued year on year cost savings and capital expenditure (CAPEX), and annual CAPEX is also provided for reference.

Financial performance for the Victorian Wide CBA are:

- Internal Rate of Return: 143%
- Total Capital Cost: $144.45M
- Benefit to Cost Ratio: 8.8
- Annual GHG emissions reduction by 2040: 300 kilotonnes

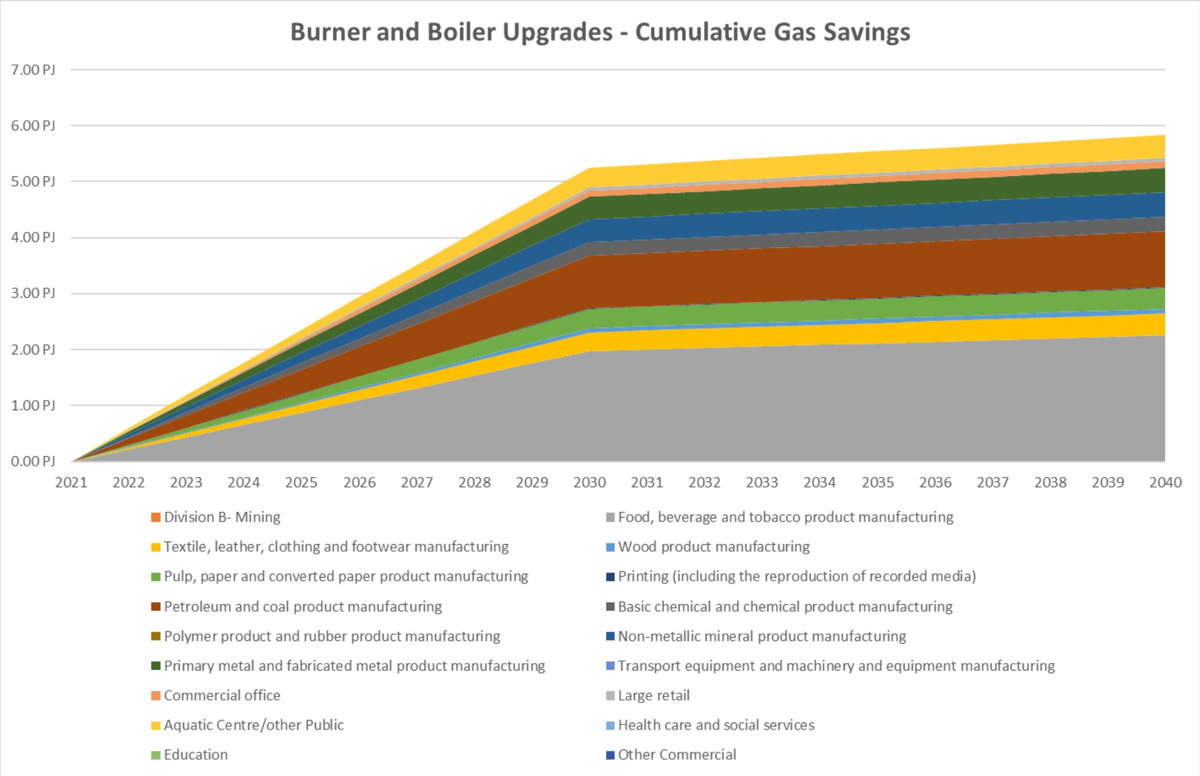


Figure 14: Modelled gas savings for burner and boiler upgrades energy efficiency activity

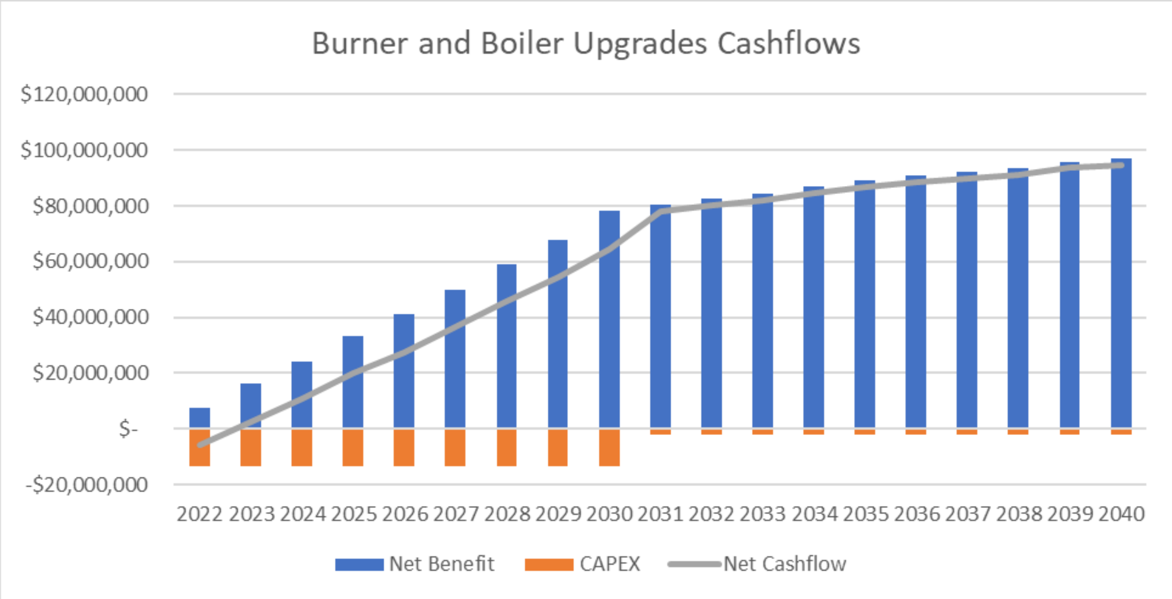


Figure 15: Annual capital expenditure and accumulated benefits for burner and boiler upgrades

3.2.3.2.2 Low Temperature Heat Pump

The resulting cumulative gas savings for Low Temperature Heat Pumps is given in Figure 16 and GHG emissions savings and annual cashflows are shown in Figure 17. Note that the Net Cashflow presents the net of accrued year on year cost savings and capital expenditure (CAPEX), and annual CAPEX is also provided for reference.

Financial performance for the Victorian Wide CBA are:

- Internal Rate of Return: 40%
- Total Capital Cost: $363.98M
- Benefit to Cost Ratio: 3.9
- Annual GHG emissions reduction by 2040: 440 kilotonnes

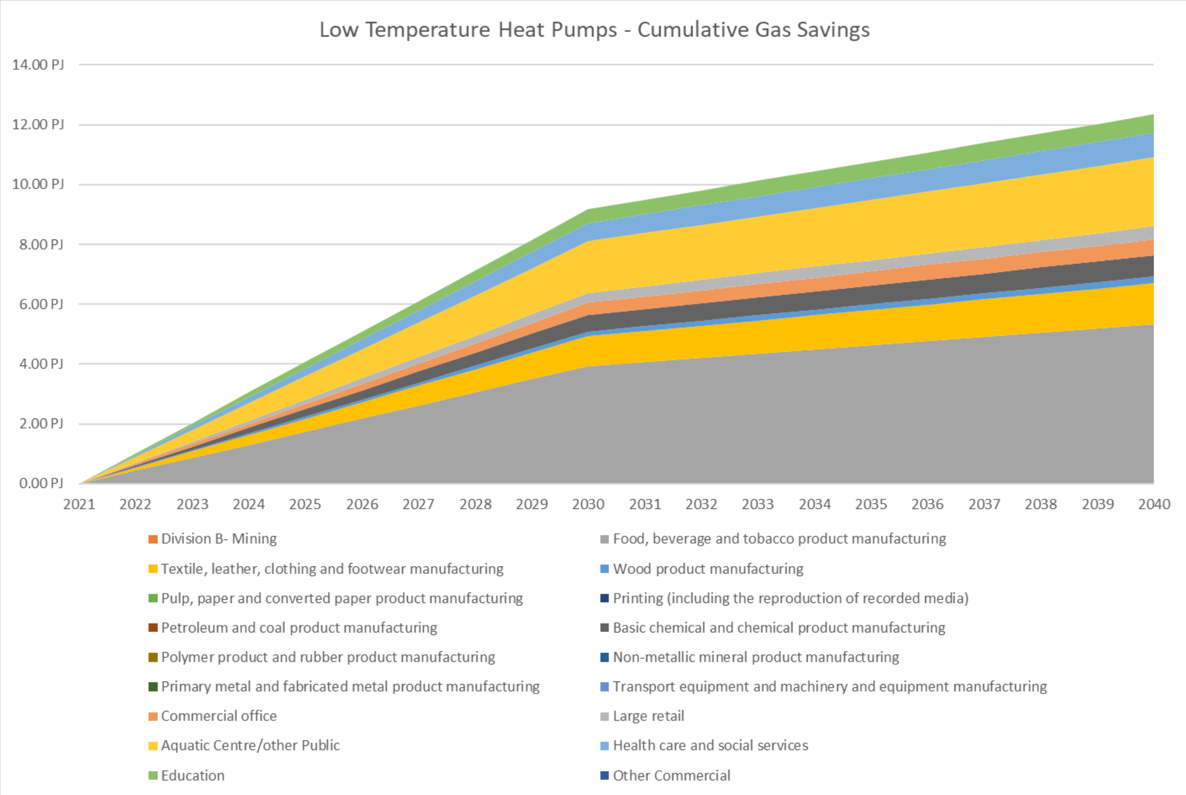


Figure 16: Modelled gas savings for low temperature heat pumps energy efficiency activity

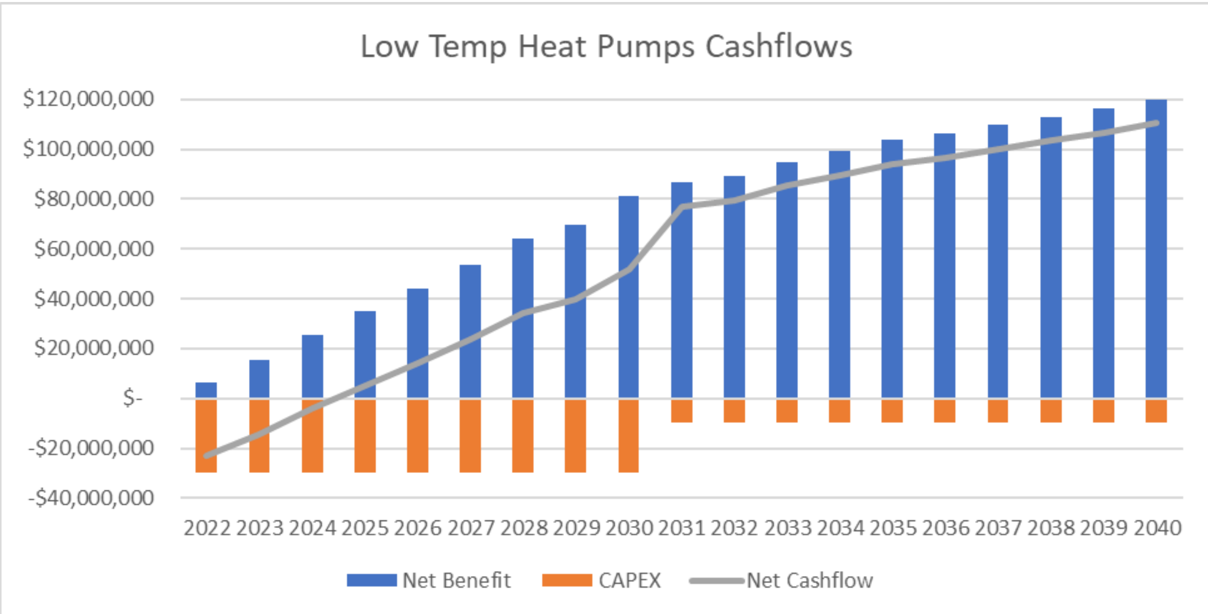


Figure 17: Annual capital expenditure and accumulated benefits for low temperature heat pump activities

3.2.3.2.3 Heat Recovery

The resulting cumulative gas savings for Heat Recovery is given in Figure 18Figure 16 and GHG emissions savings and annual cashflows are shown in Figure 19. Note that the Net Cashflow presents the net of accrued year on year cost savings and capital expenditure (CAPEX), and annual CAPEX is also provided for reference.

Financial performance for the Victorian Wide CBA are:

- Internal Rate of Return: 48%
- Total Capital Cost: $206.95M
- Benefit to Cost Ratio: 4.7
- Annual GHG emissions reduction by 2040: 225 kilotonnes

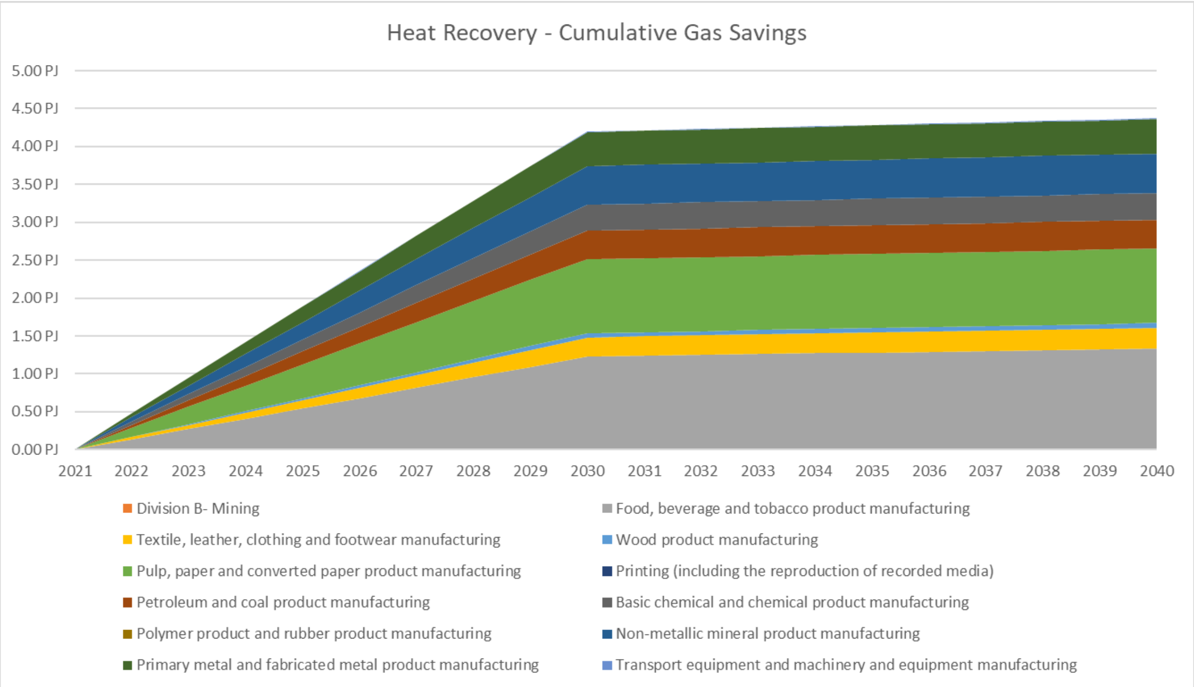


Figure 18: Modelled gas savings for heat recovery energy efficiency activity

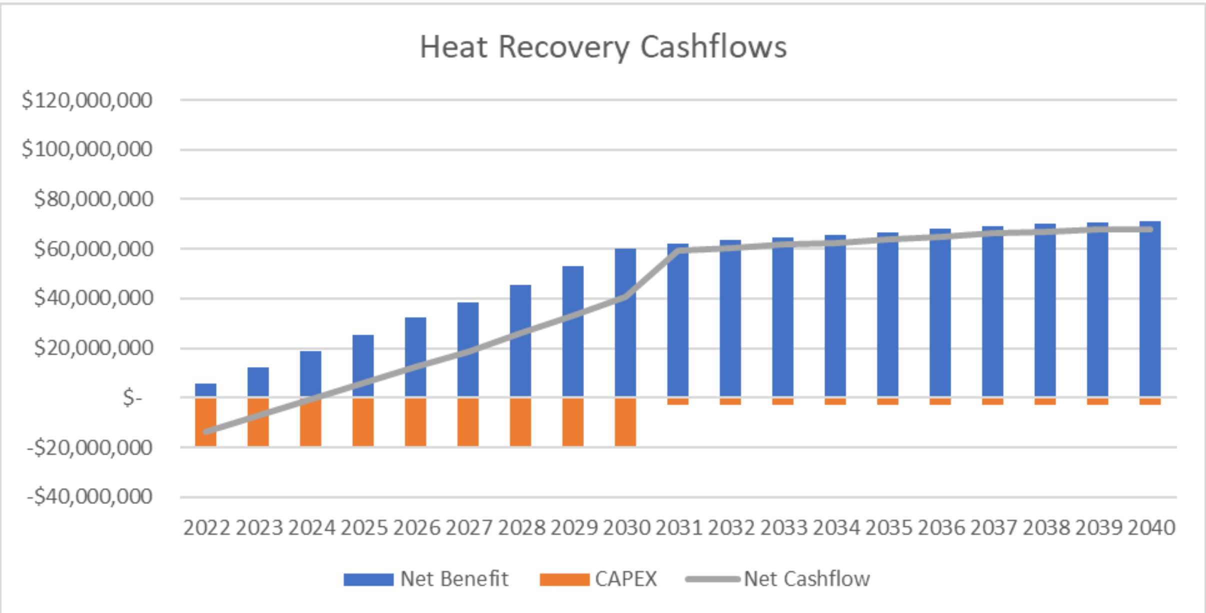


Figure 19: Annual capital expenditure and accumulated benefits for heat recovery activities

3.3 Ranking

The purpose of this study is to identify the best energy efficiency opportunities for Infrastructure Victoria to recommend to the Victorian Government for implementation as part of their net zero carbon strategy. In addition to the ranking undertaken for shortlisting energy efficiency activities Northmore Gordon has ranked the top three energy efficiency incorporating the results from the Victorian wide Cost Benefit Analysis. The following sections explain the methodology used and the results of the assessment.

3.3.1 Methodology

Northmore Gordon developed a ranking system to evaluate the short-listed energy efficiency opportunities in terms of their potential energy efficiency and economic impacts for industrial gas customers. The following ranking criteria were included in the assessment:

- **Total Gas Impact** – Gas savings from each measure was calculated, with larger total gas savings ranked higher.
- **Total GHG emissions Impact** – accounting for changes in grid emissions factors over the 20 year analysis period, measures which delivered the best emissions outcome by 2040 were ranked higher.
- **Cost Effectiveness** – Benefit Cost Ratios (BCRs) were calculated for each activity, with higher BCRs ranked higher.

The market potential and CBA analysis were used to assess each energy efficiency opportunity against the above criteria[14]

Ranking	End Use	Indicator	Total of Segments
1	Burner and Boiler Upgrades	Total Annual Gas Potential (PJ)	5.83
		Total Annual Energy Savings Potential (PJ)	~6.00
		Total Annual CO2 Potential (kt CO2)	300.6
		Annuitized Cost	$7.6M
		Overall BCR	8.8
		Average Customer Payback	3.0
2	Low Temperature Heat Pumps	Total Annual Gas Potential (PJ)	12.34
		Total Annual Energy Savings Potential (PJ)	10.01
		Total Annual CO2 Potential (kt CO2)	440.0
		Annuitized Cost	$19.2M
		Overall BCR	3.26
		Average Customer Payback	7.4
3	Heat Recovery	Total Annual Gas Potential (PJ)	4.37
		Total Annual Energy Savings Potential (PJ)	4.37
		Total Annual CO2 Potential (kt CO2)	225.3
		Annuitized Cost	$10.9M
		Overall BCR	4.66
		Average Customer Payback	4.2

[14] Note that were the Small to Medium Commercial and Residential sectors are presented on a per facility basis the Industrial and Large Commercial analysis is presented on a total Victorian wide basis.

Whilst the initial ranking of energy efficiency opportunities for industrial and large commercial indicated Heat Recovery was the top measure the further Victorian wide CBA clearly demonstrated Burner and Boiler Upgrades to deliver the best economic outcome. Across the whole of Victoria, assuming a broad level of uptake Burner and Boiler upgrades deliver an impressive Benefit to Cost ratio and high IRR.

Low Temperature Heat Pumps are also a critical energy efficiency activity for consideration by Infrastructure Victoria. It delivers a significant reduction in gas consumption across the state – 12.34 PJ and the largest net GHG emissions abatement. Financial returns from investment in Low Temperature Heat Pumps is a moderate 3.6 year BCR and individual customer level paybacks are relatively high. However, they offer a strategically important role in the overall decarbonisation of industry and commercial facilities, as they allow for elimination of gas usage from entire processes. This contrasts with Burner and Boiler Upgrades which carry the risk of locking in dependence on gas usage into the future, which carries with it uncertainties associated with rising gas prices and supply availability.

As noted in the Market Sizing analysis, a significant portion of large gas users are exempt from accessing the Victorian Energy Upgrades program. At present these users need to “opt-in” to the scheme in order to access certificate funding for energy efficiency activities, however this carries with it the consequent responsibility to pay for VEEC charges on their energy bills. Northmore Gordon recommends Infrastructure Victoria investigate alternative pathways for financial and non-financial incentives to encourage adoption of the energy efficiency opportunities identified. Alternative funding models could include programs like the NSW Net Zero Industry and Innovation Program which includes $350 Million of funding to work with “hard to abate” sectors and support investment in large transformational projects, such as electrification of industrial processes.

4 Small and Medium Sized Commercial Sector

This section reports on the results of Energeia's analysis of the impact of gas energy efficiency opportunities for small-medium enterprises (SMEs). Energeia utilised data from the Commercial Baseline Study[15] to estimate total gas consumption in the commercial sector by segment and end use, effectively defining the scope of SME segments addressed in this section. Differences in data sourcing between Northmore Gordon are expected to lead to minor overlaps in segment definitions, as identified further below. More information on the Commercial Baseline Study segments can be found in Appendix C.

Following initial desktop research of the most prospective gas energy efficiency opportunities and Victorian Energy Updates Program (VEU) measures and related activities, Energeia, in consultation with Infrastructure Victoria and Northmore Gordon, developed an initial list of potential gas energy efficiency activities to assess. The short-listed activities were then modelled to determine their gas and energy savings potential and associated costs and benefits. The results of the analysis were then used to rank the short-listed activities using key criteria including gas and energy savings, CO_2 savings and customer financial savings.

This section outlines the methodology, key inputs and assumptions, and results of the commercial sector analysis of gas energy efficiency opportunities for Infrastructure Victoria.

4.1 Market Sizing

Energeia developed estimates of potential market sizing for each of the short-listed energy efficiency opportunities using our bottom-up, stock and turnover model of existing commercial premises in Victoria. Energy and gas savings potentials were estimated using assumed appliance stock, lifetimes and relative efficiencies.

The following section covers Energeia's modelling methodology, key inputs and assumptions, and modelling results in terms of aggregate gas, energy and carbon emissions savings for commercial dwellings.

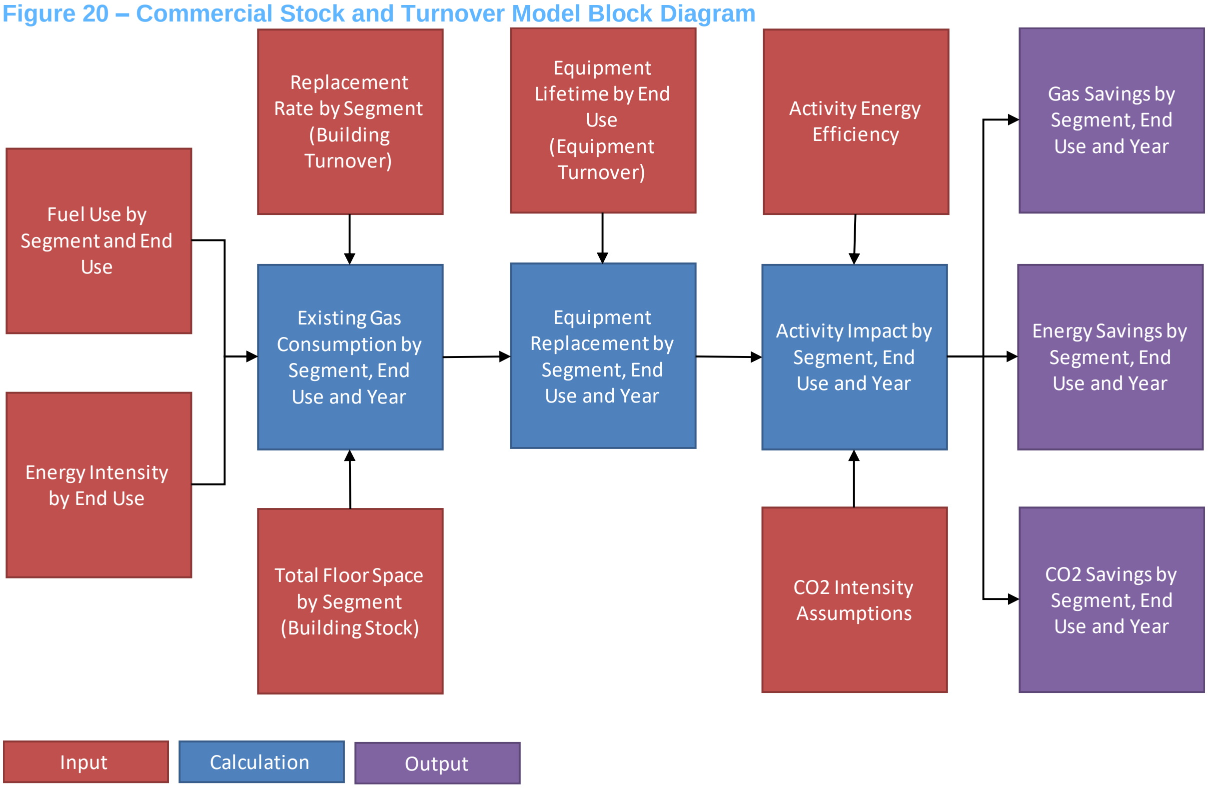
4.1.1 Methodology

Energeia's approach to sizing the potential aggregate impact of each energy efficiency measure in Victoria was to configure our bottom-up stock and turnover model to generate the total potential energy efficiency and gas savings impact of each measure if fully implemented. Energeia's stock and turnover model uses the key inputs summarised in the block diagram below to estimate energy savings, gas savings, CO_2 savings and financial savings over time by commercial segment. The modelling methodology is summarised in Figure 20

Key inputs including total gross floor area (GFA) by segment, gas intensity by segment and gas consumption by end use are used to develop estimates of existing gas appliance stock in Victoria. Equipment lifetimes by end use drive the turnover of stock at end of life which are used to estimate the aggregate savings potential by activity and commercial segment. The model outputs gas and net energy savings. CO_2 savings are estimated from the emissions intensity of fuel sources used.

[15] Council of Australian Governments (2012) 'Baseline Energy Consumption and Greenhouse Gas Emissions in Australia https://www.energy.gov.au/sites/default/files/baseline-energy-consumption-part_1-report-2012.pdf

Figure 20 – Commercial Stock and Turnover Model Block Diagram



Source: Energeia

4.1.2 Key Inputs

The key inputs indicated in Figure 20 were collected by commercial segment where available. Energeia's desktop research and consultation with Northmore Gordon identified available input data for the following commercial segments:

- Offices, standalone (excludes high density commercial offices)
- Hospitals
- Aged Care
- Hotels, small scale
- Law Courts
- Public Buildings, including galleries, museums, libraries (excluding aquatic centres)
- Retail
- Restaurants
- Schools, including public and private schools
- Tertiary, including TAFE and Universities
- Warehouses

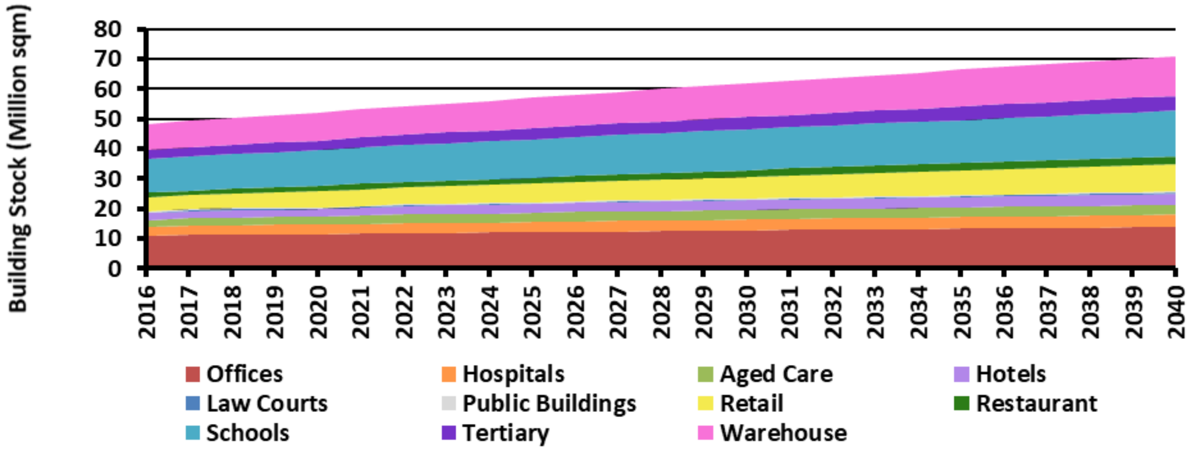
Overlap between the methodology of Northmore Gordon and Energeia exists in some segments, including Tertiary. The implication of this overlap is that Energeia and Northmore Gordon's analysis both provide modelling of gas energy efficiency opportunities, however the outcomes are not additive.

The following sections report on the key modelling inputs and assumptions indicated in Figure 20.

4.1.2.1 Building Stock

Building stock is a key input into Energeia's stock and turnover model. Building stock, defined here as Gross Floor Area (GFA), is a key driver of modelled size of the gas market as total gas usage is determined from the total building area and energy intensity per area for each segment. Forecasts of building stock shown in Figure 21 are generated using trended data.

Figure 21 – Total State-Wide Building Stock Estimate by Segment



Source: COAG (2012), Strategy. Policy. Research (2019), Sustainability Victoria (2018). Note: Pre-2021 indicates historic data

The net building stock remaining each year to target with potential energy savings activities are based on the estimated building stock in 2020, less the annual premise replacement activity. Energeia estimates that by 2040, there will be 71m sqm of commercial building stock in Victoria, with schools making up the largest portion of this at 15.2m sqm.

4.1.2.2 Premise Replacement Rates

The premise replacement rate drives the speed at which building stock is demolished and rebuilt. A dwelling replacement rate of 1% has been used based on other major studies[16]. Premises which are replaced are subject to contemporary energy efficiency standards including the National Construction Code (NCC) and are out of scope for this study.

4.1.2.3 Gas Intensity

Gas intensity is used in Energeia's model to generate annual gas consumption given GFA by commercial segment. Energeia estimated gas intensity by commercial segment using a mix of building sample data[17], a major Victorian study[18] and a US-sourced[19] building model.

The results of our estimation of gas intensity by key commercial segment is reported in Figure 22, which shows restaurants to have the highest gas intensity of the included segments, which is likely due to their use of gas for water heating, space heating and cooking. These estimates were held constant across the forecasted period.

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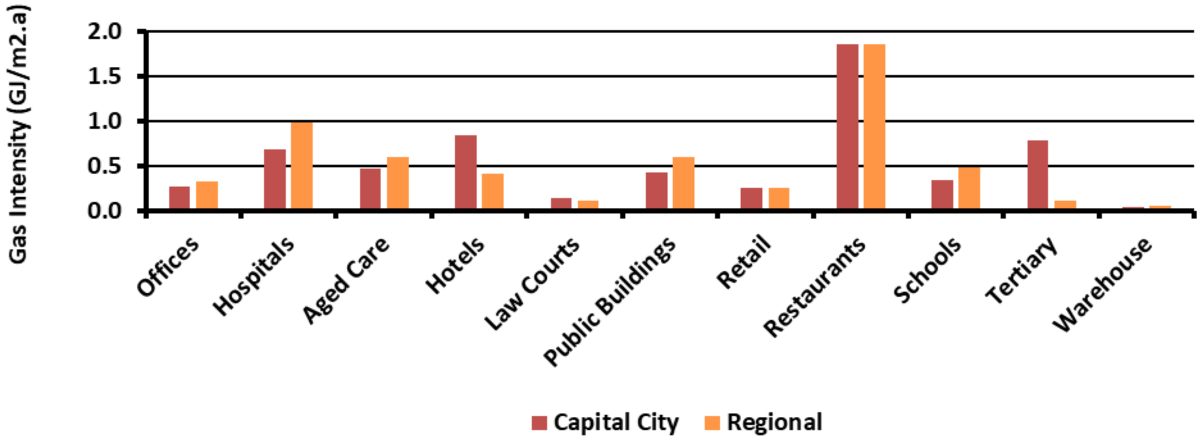
[16] Strategy. Policy. Research. (2019) 'Electrification Opportunities in Victoria's Commercial Sector' pg 5 https://www.vic.gov.au/sites/default/files/2020-02/Appendix_7_Electrification_Commercial.pdf
[17] Council of Australian Governments (2012) 'Baseline Energy Consumption and Greenhouse Gas Emissions in Australia https://www.energy.gov.au/sites/default/files/baseline-energy-consumption-part_1-report-2012.pdf
[18] Strategy. Policy. Research. (2019) 'Electrification Opportunities in Victoria's Commercial Sector' https://www.vic.gov.au/sites/default/files/2020-02/Appendix_7_Electrification_Commercial.pdf
[19] US Energy Information Administration (2012) 'Commercial Buildings Energy Consumption Survey' https://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption#e1-e11

Figure 22 – Assumed Metropolitan and Regional Gas Intensity Estimates for Commercial Segments



Source: Commercial Baseline Study (2012), EIA (2012), Strategy. Policy. Research (2019)

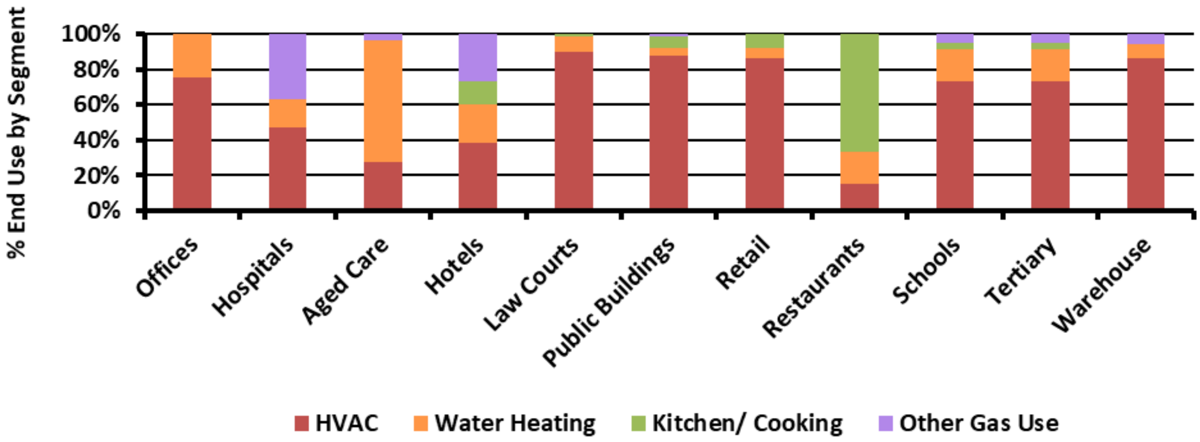
Victorian and Australian building sample data was used for all segments other than aged care, retail, restaurants, and warehouses. Of these, a Victorian study was used for aged care and warehouse estimates, and the US-sourced model was used for retail and residential.

4.1.2.4 Gas End Use Splits by Segment

End use splits allocate reported gas consumption by segment across end uses. Energeia estimated the split in gas consumption by end use for each building type from a mixture of reported Victorian and Australian building samples[20] and a US-sourced[21] building model.

Figure 23 reports the final the end use splits used by Energeia by commercial segment. These assumptions were held constant over time.

Figure 23 – Assumed Combined Gas End Use Breakdown for Commercial Segments



Source: Commercial Baseline Study (2012), EIA (2012)

[20] Council of Australian Governments (2012) 'Baseline Energy Consumption and Greenhouse Gas Emissions in Australia https://www.energy.gov.au/sites/default/files/baseline-energy-consumption-part_1-report-2012.pdf
[21] US Energy Information Administration (2012) 'Commercial Buildings Energy Consumption Survey' https://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption#e1-e11

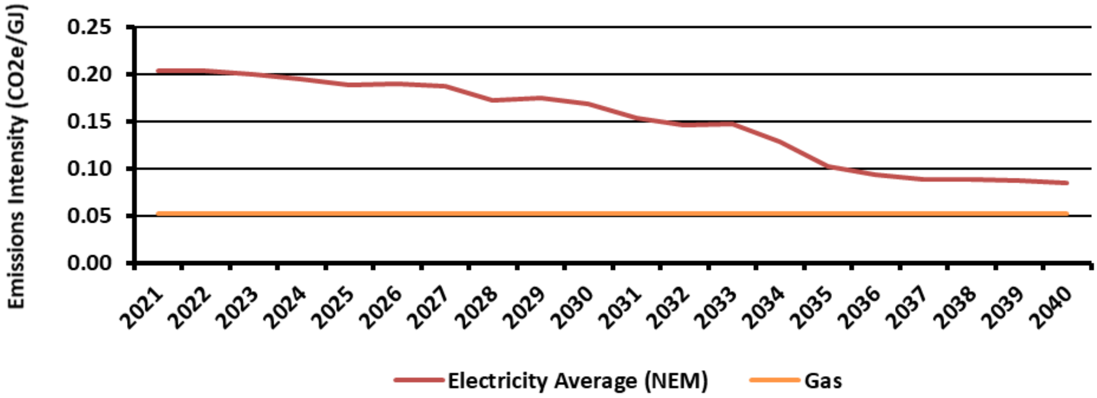
Estimates were developed for space heating, water heating, cooking, due mainly to the availability of data. Other gas uses includes commercial pool and spa heaters[22], dryers, or combined heat and power systems[23]. Analysis of other gas end uses was excluded due to lack of data availability rather than size of gas usage.

It is worth noting that the warehouse split was estimated using the US building model due to the lack of Australian sample points, the remaining splits are all based on Victorian or Australian data.

4.1.2.5 Average CO_2 Intensity

The carbon intensity of fuel sources is the predominant determinant of emissions saved from higher energy efficiency. The average emissions intensity of gas and electricity fuel sources assumed is shown in Figure 24.

Figure 24 – Emissions Intensity by Fuel Source



Source: AEMO ISP (2020)[24]

Aligning with the key inputs and assumptions in the Industrial and Large Commercial section (section 3.2.2.3), electricity grid emissions intensity, which is taken from the AEMO ISP (2020) Central Scenario, is forecast to fall over time as more zero-emissions generation technology such as solar photovoltaics (PV) and wind are commissioned in the National Energy Market (NEM), however, gas is still anticipated to burn more cleanly on a per GJ basis over the forecast period to 2040.

Energeia notes the potential for CO_2 intensity of incremental electricity consumption in Victoria to be much lower if it were supplied by renewable energy.

4.1.2.6 Appliance Lifetimes

Energeia's model uses appliance turnover to drive end-of-life replacements, meaning that gas appliances with shorter expected lifetimes could be replaced with more energy efficient equipment at a greater pace. The inputs utilised were primarily developed through primary Energeia research of appliance industry websites[25]. As this is a market potential study, Energeia applied a 100% energy efficient appliance uptake rate, with purchases smoothed over 10 years centred around existing appliance end of life.

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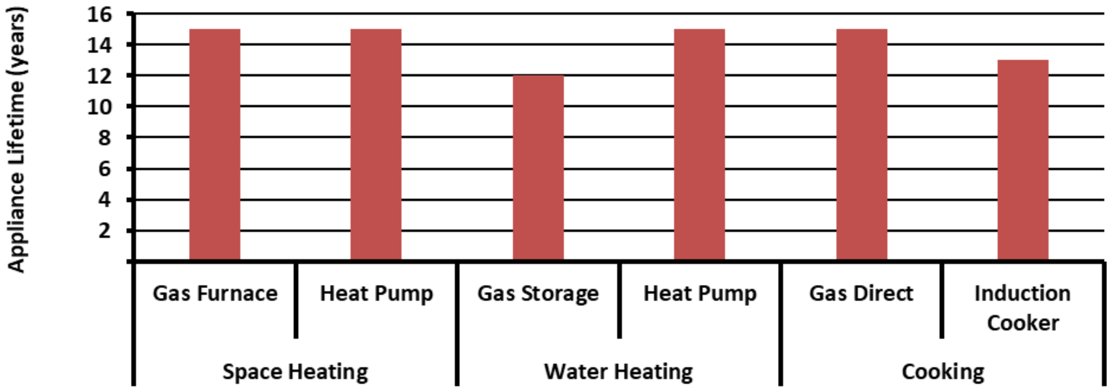
[22] Rheem Thermal (undated), 'Rheem Commercial Pool Heating' https://rheemthermal.com.au/commercial-pool-heating/
[23] US Energy Information Administration (2020) 'Use of Natural Gas' https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php
[24] AEMO (2020). 'Appendix 4. Energy Outlook' https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--4.pdf?la=en
[25] For example, Australian Hot Water (2021), https://australianhotwater.com.au

The assumed appliance lifetimes by end use and fuel type are shown in Figure 25 below.

Figure 25 – Appliance Lifetimes by End Use and Fuel Type



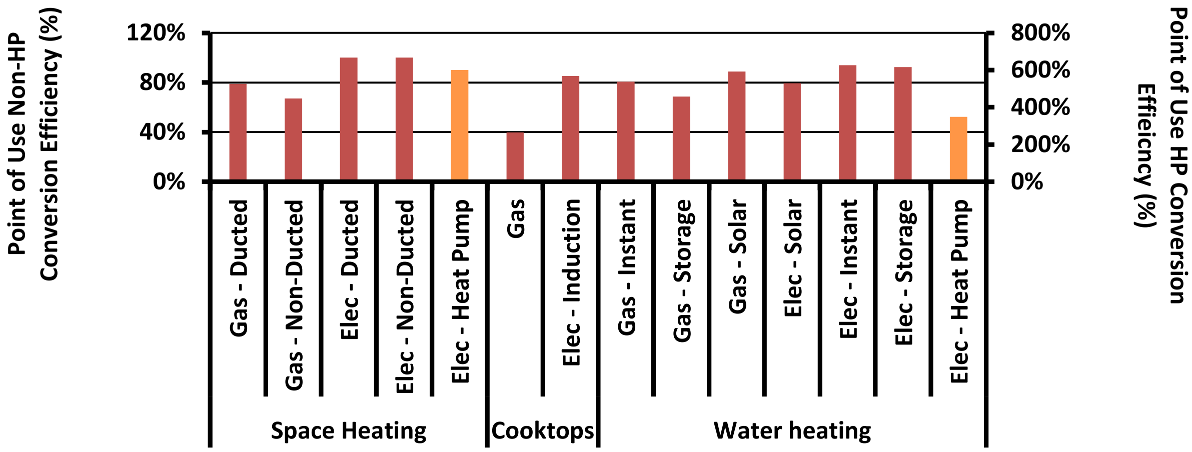
Source: Energeia Research

The above assumptions were cross-checked with other published reports in the public domain to validate them.

4.1.2.7 Appliance Energy Efficiency

Appliance energy efficiency is used to estimate the impact of a potential energy efficient appliance technology when replacing an existing appliance of a given technology. Energeia has assumed the appliance efficiencies found via desktop research and validation with the Victorian Department of Environment, Land, Water and Planning (DELWP), which are reported in Figure 26.

Figure 26 – Appliance Efficiencies by End Use and Fuel Type



Source: Energeia Research, Note: Red = Non-Heat Pump tech (left axis), Orange = Heat Pump tech (right axis)

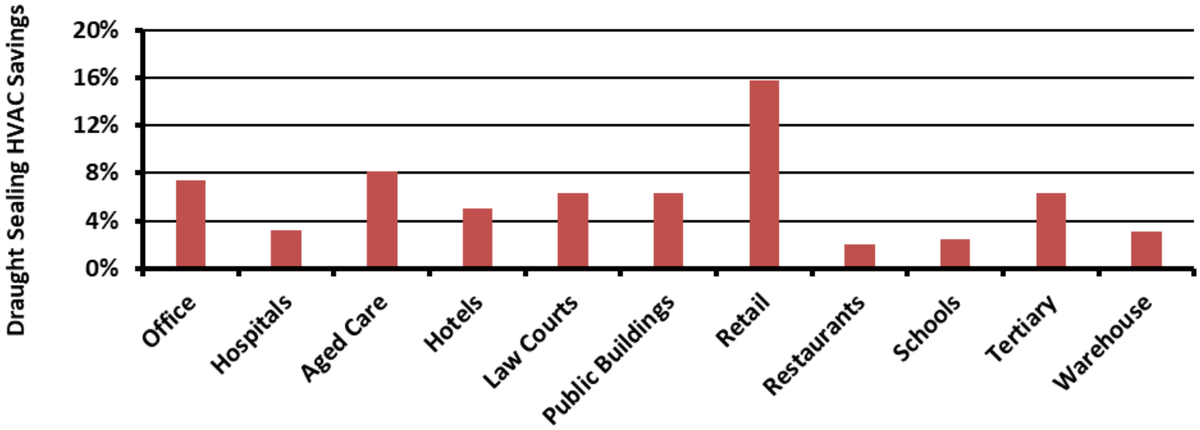
Energeia assumed that electric space and water heating heat pumps and induction cooktops would be installed to replace gas appliances.

4.1.2.8 Draught Sealing Energy Efficiency

Draught sealing reduces premise energy consumption for space heating through better insulation, improving temperature regulation.

Energeia's desktop research of insulation impacts and costs for the commercial sector found that almost no information has been published in the public domain in the last 5-10 years. We did find information from 2010[26], which estimated the impact of insulation, specifically draught sealing impacts, across the commercial sector as a whole[27], which we have used to generate the estimates shown in Figure 27. These estimates were held constant over the modelling period.

Figure 27 – Assumed Draught Sealing HVAC Energy Saving Potential by Segment



Source: ClimateWorks (2010), Energeia Analysis

The same source was used to develop an estimate of the cost of draught sealing in commercial premises, which is reported in the cost-benefit-assessment section below. The cost benefit analysis is developed to determine final rankings inputs to the key outputs below.

4.1.3 Key Results

The following sections report on the results of modelling total gas consumption by end use and commercial segment and the potential impacts of the short-listed energy efficiency and/or electrification activities on energy and gas consumption and CO_2 emissions over the modelling period.

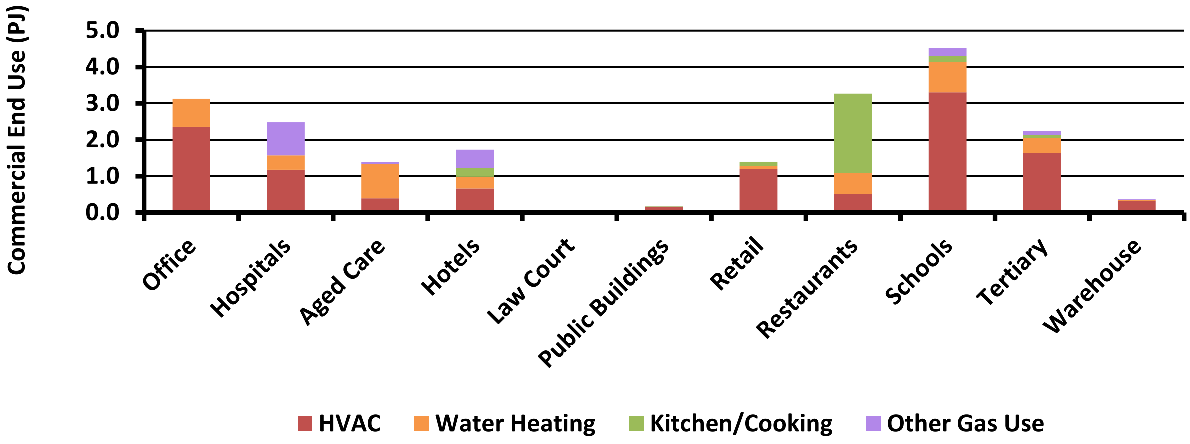
4.1.3.1 Gas Consumption by Segment and End Use

Energeia's bottom-up modelling results for gas consumption by end use and segment in 2020 are shown in Figure 28. Total gas consumption reaches 20.7 PJ across all considered segments[28].

End use gas consumption was estimated based on the researched gas intensity of use for each segment on a GFA basis and aggregated by the estimated building stock.

[26] ClimateWorks (2010), 'Low Carbon Growth Plan for Australia'. pg 69. https://www.climateworksaustralia.org/resource/low-carbon-growth-plan-for-australia/
[27] No studies found with more detailed investigation into commercial insulation – i.e., wall, floor or ceiling insulation
[28] The 2021 AEMO GSOO states that Victoria's residential and commercial gas consumption totals 124 PJ in 2021. Our bottom-up modelling has accounted for 103.5 PJ (20.7 PJ commercial plus 82.8 PJ residential gas consumption), with the discrepancy driven by the overlap between the commercial and industrial segments in building stock data. Energeia elected not to balance consumption to the GSOO due to lack of information on the segments and end uses which were not correct.

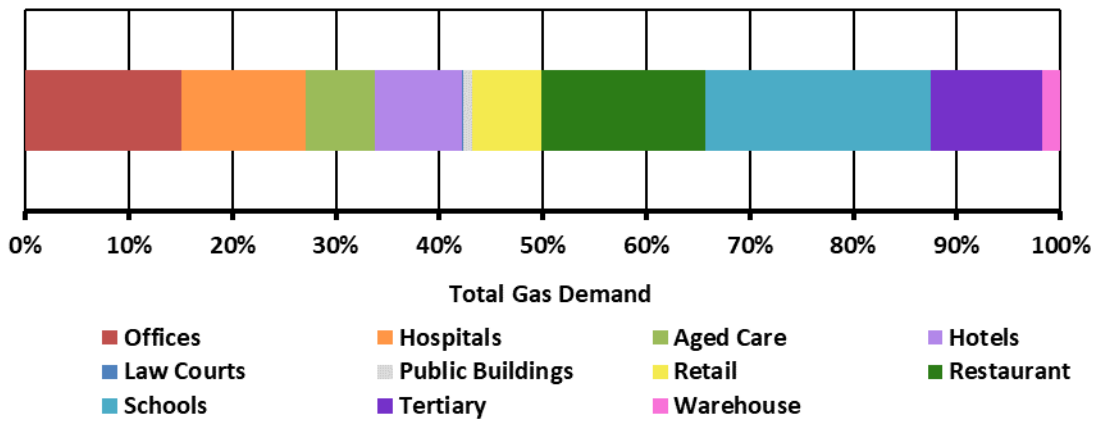
Figure 28 – Commercial Gas Consumption by End Use and Segment (2020)

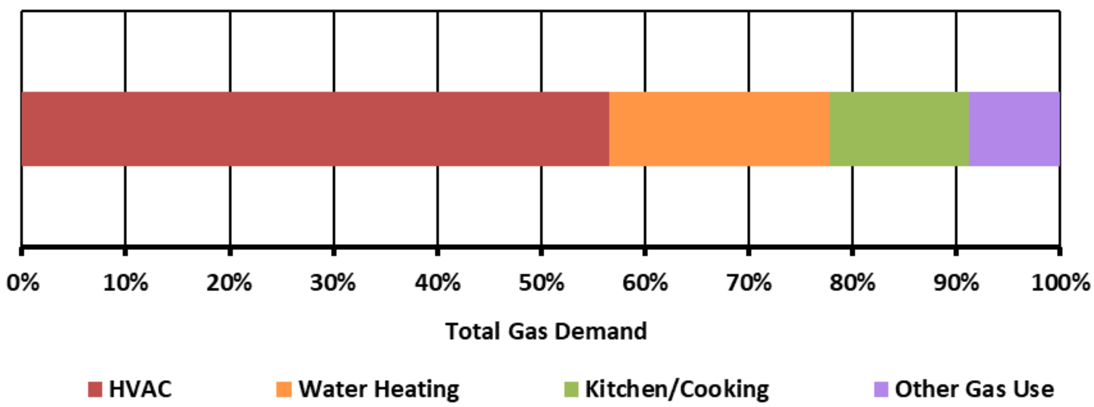


Source: Energeia Modelling

Figure 29 shows the breakdown of total energy consumption by both segment and end use. Consumption by commercial segment is more evenly distributed, with Schools, Offices and Restaurants being the top three gas users, responsible for 22%, 16% and 15% of total consumption respectively. Overall, the modelling shows that HVAC contributes the highest percentage at 57% of the total gas use in the commercial sector, followed by water heating and cooking.

Figure 29 – Current Commercial Total Gas Consumption by Segment and End Use



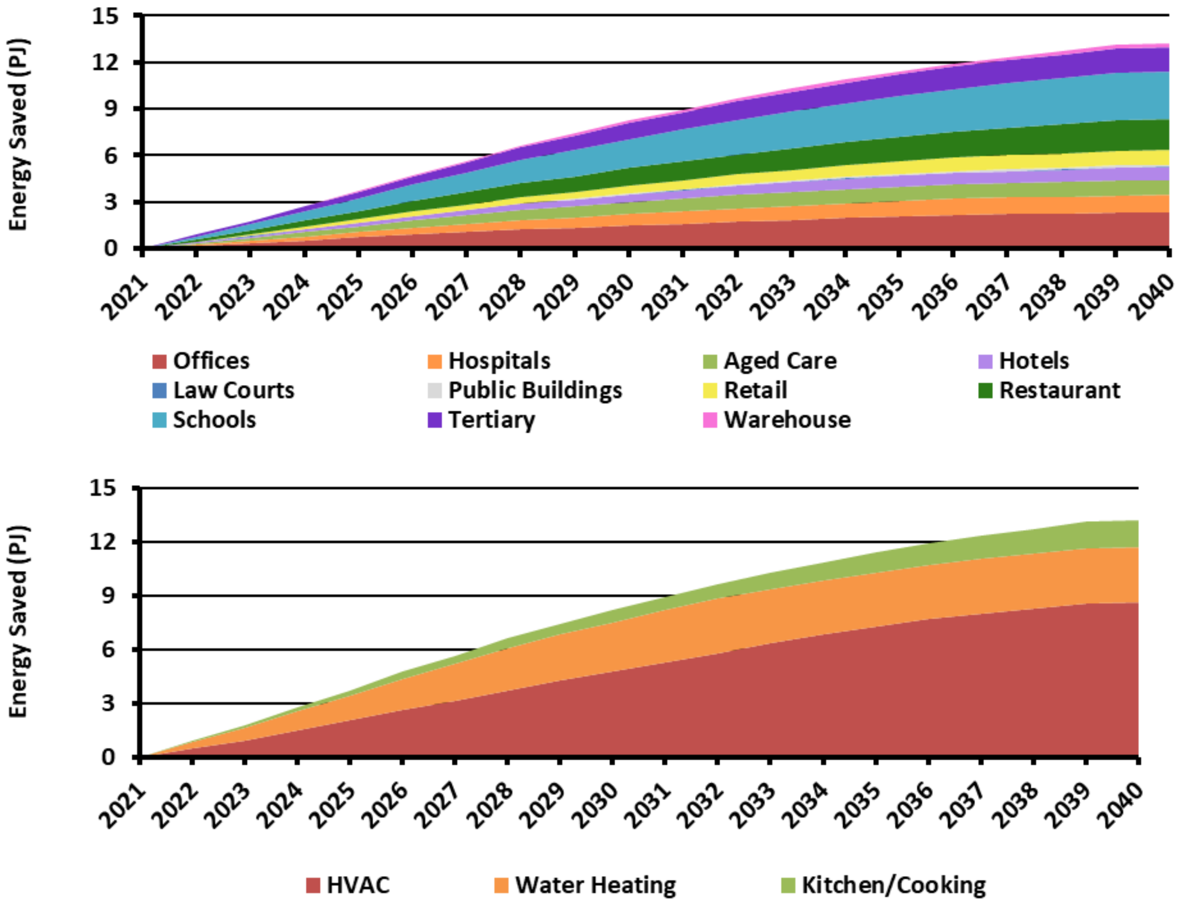


Source: Energeia Modelling

4.1.3.2 Energy Savings by Segment and End Use

Reported energy savings reflect the net energy savings from electrification, accounting for decreased gas consumption and increased electricity consumption. Estimated net energy savings, assuming 100% application of the top three commercial energy efficiency activities[29] of switching to electric space heating, water heating and cooking, is shown in Figure 30. Energeia's modelling results show annual total energy savings reaching 9.3 PJ by 2030 and 14.5 PJ by 2040.

Figure 30 – Forecast Commercial Annual Energy Savings by Segment and End Use



Source: Energeia Modelling

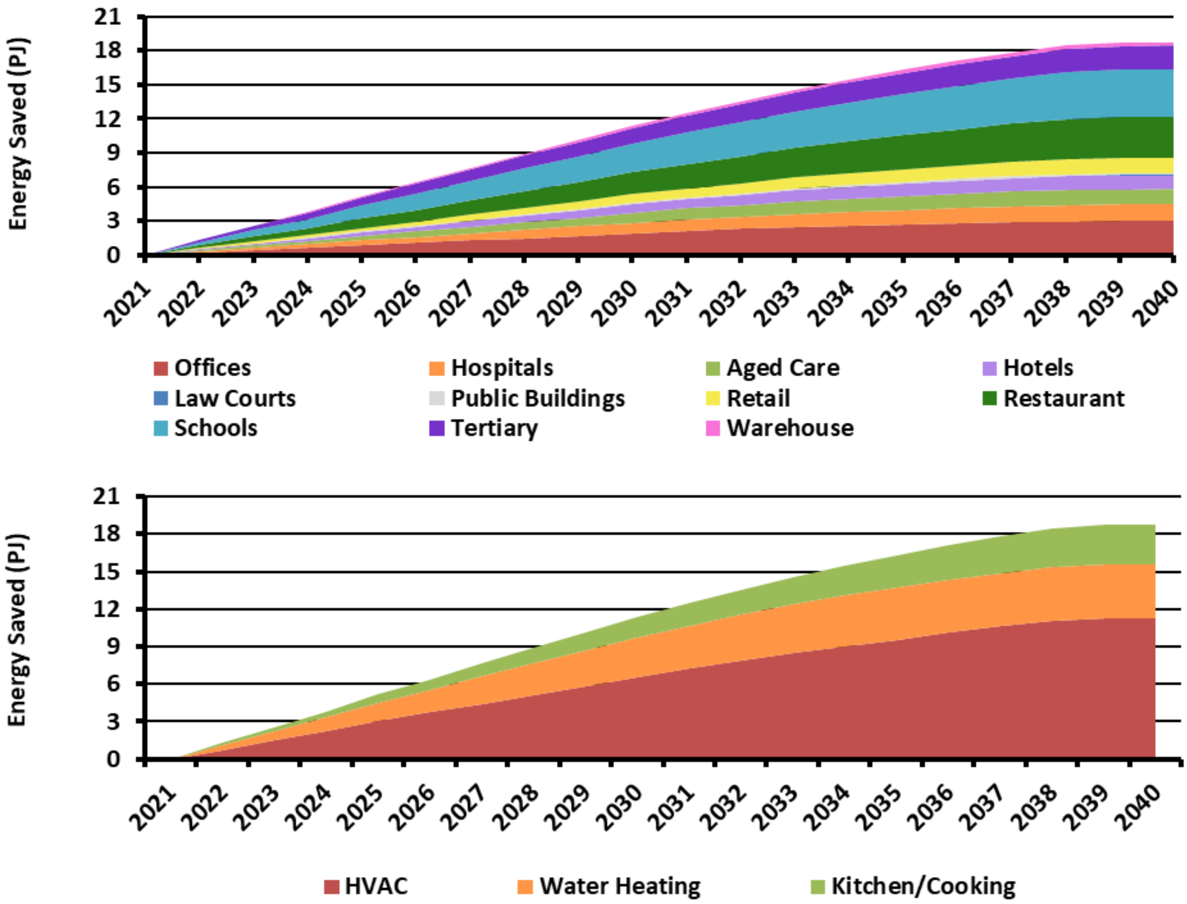
Energeia's modelling results indicate that electrification of heating will have the largest potential impact on energy savings with schools contributing the highest portion of total annual savings. As Schools, Offices and Restaurants have been identified as the top three gas users, most energy savings can be made in these segments which account for 23% 18% and 14%, respectively, of savings by 2030, and 23%, 17%, 15% by 2040. Overall, HVAC, water heating and kitchen/cooking account for 63%, 28% and 10%, respectively, of savings by 2030, and 60%, 24%, 12% by 2040.

4.1.3.3 Gas Savings by Segment and End Use

Modelled gas savings from the top three energy efficiency activities is reported in Figure 31, which shows total annual gas savings reaching 11.4 PJ by 2030 and 18.8 PJ by 2040.

[29] Despite attractive cost-benefit ratios, insulation was not including in the top three ranking due to its limited overall impact, see Section 4.3 for more details

Figure 31 – Forecast Commercial Annual Gas Savings by Segment and End Use



Source: Energeia Modelling

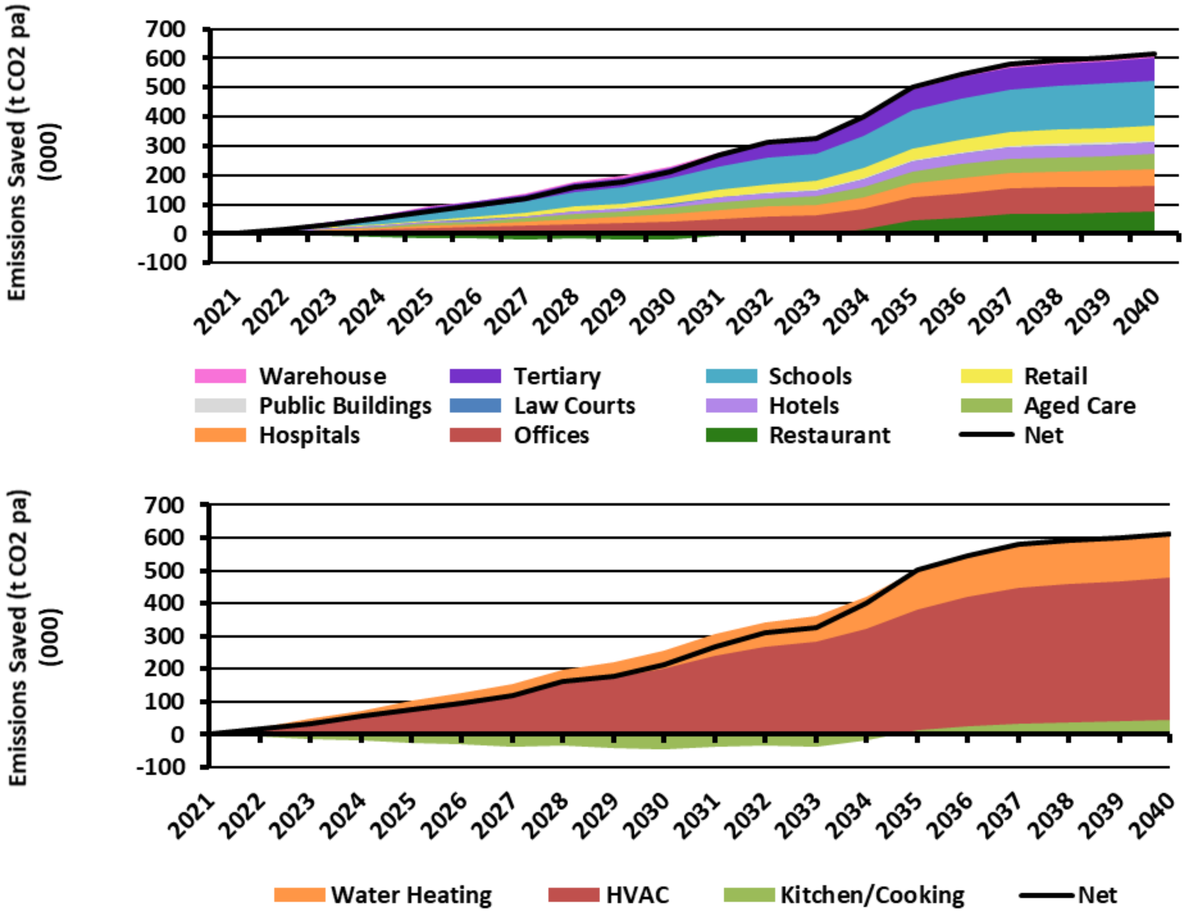
Total gas savings follows a similar trend to total energy savings, with Schools, Restaurants and Offices identified as the top three gas users. Most energy savings can be made in these segments which account for 23% 17% and 17%, respectively, of savings by 2030, and 22%, 19%, 16% by 2040. Similarly to energy savings, HVAC electrification contributes the highest impact to total gas savings potential. Overall, HVAC, water heating and kitchen/cooking account for 57%, 28% and 14% of the estimated savings, respectively, by 2030, and 60%, 23%, 17%, respectively, by 2040.

Overall, gas savings from electrification are higher than energy savings in energy terms as the latter reflects a netting off of the electric appliance efficiency while gas savings does not.

4.1.3.4 CO_2 Savings by Segment and End Use

Modelled CO_2 savings from the top three energy efficiency activities is reported in Figure 32, which shows total annual CO_2 savings reaching 211 kT per annum by 2030 and 614 kT by 2040. CO_2 savings are modelled as the net impacts of electrification, i.e. the reduction in emissions from gas consumption less the increase in emissions from electricity consumption.

Figure 32 – Forecast Commercial Turnover Annual CO_2 Savings by Segment and End Use



Source: Energeia Modelling, Note Restaurants would produce negative emission savings until 2033

The top three segments for emissions reductions are Schools, Offices and Tertiary. Savings in these segments can be attributed to 30% 20% and 17%, respectively, of total savings in 2030, and 25%, 16%, 13% in 2040. HVAC and water heating contribute 79% and 21%, respectively, by 2030, with cooking contributing a negative emissions savings prior to 2034, due to the relative efficiency gas to induction cooking, and the grid emissions factor used for this analysis as per Section 4.1.2. By 2040, contributions of HVAC, water heating and cooking equate to 71%, 22%, 7%, respectively.

Energeia notes that decarbonisation of the energy grid is the key driver of the steeper increase in emissions savings from 2033 onwards. Decarbonisation of the energy grid reduces the grid emission factor such that by 2036, yearly net emissions savings from the electrification of cooking become positive.

4.2 Cost-Benefit Assessment

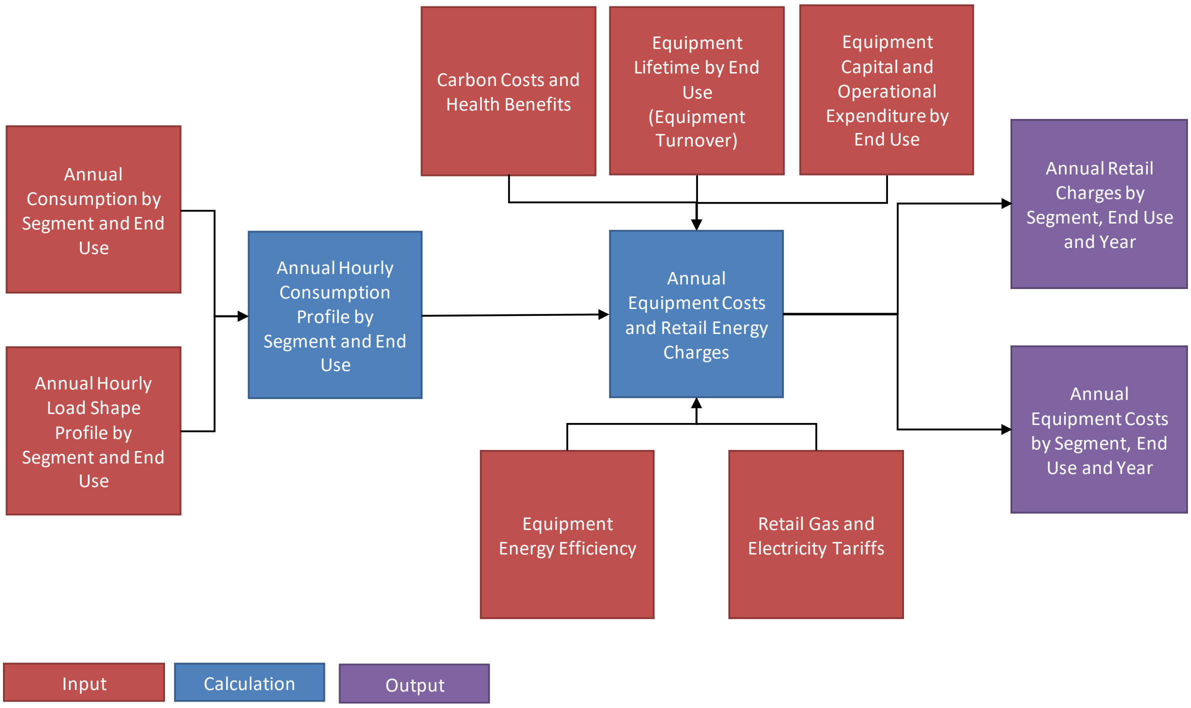
This section outlines Energeia's modelling methodology for assessing a customer's financial impacts of short-listed electrification and insulation activities by commercial segment.

4.2.1 Methodology

In order to assess the financial impact of energy efficiency activities on commercial dwellings, Energeia developed an energy cost-of-service model that estimated total costs including equipment and retail energy charges by end use for each in-scope commercial segment. Energeia used these costs to estimate the net savings of energy efficiency activities for each building sector and end use over time. The CBA is conducted over a 20-year time horizon to 2040, assuming the customer implemented the energy efficient appliance in year 1.

Figure 33 displays the model inputs, processing steps and outputs.

Figure 33 – Cost Benefit Assessment Methodology



Source: Energeia

Annual energy costs for each commercial segment by appliance and fuel type were estimated using actual retail tariffs, forecasted to 2040, and annualised appliance costs, which includes repurchasing. These costs were utilised to generate a present value of costs incurred from gas and electrification appliances over a period of 20 years. Payback periods and total savings with and without CO_2 costs were calculated by comparing alternatives.

4.2.2 Key Inputs

The key inputs indicated in Figure 33 were collected by commercial segment and end use appliance where available and are reported in the following sections.

4.2.2.1 End Use Load Profiles

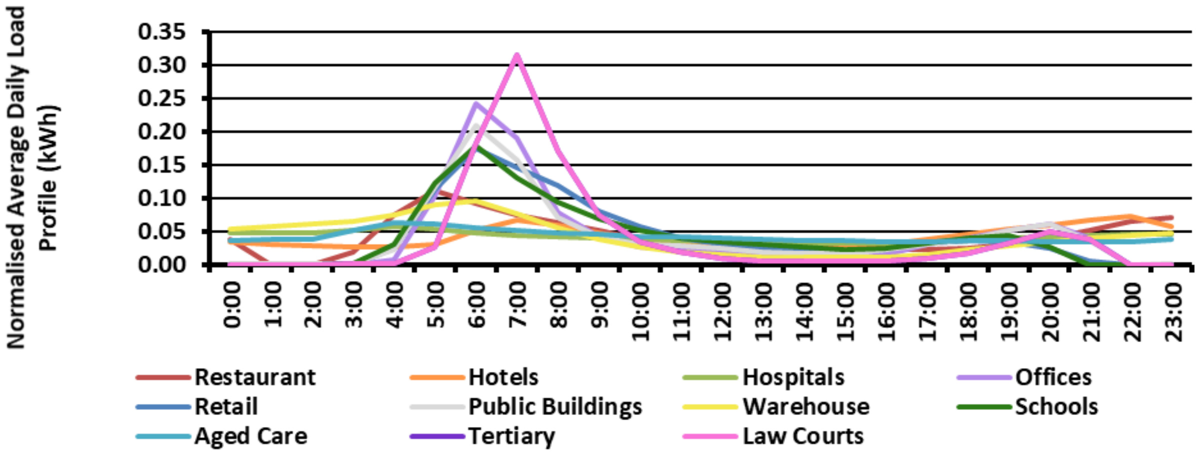
Energeia obtained load profile data from the US Department of Energy[30] (DOE)'s building model dataset[31]. This data was adjusted for climate and time zone variations to develop representative cold climate Australian load profiles. Gas-appliance load profiles were generated for the following appliances:

- Space Heaters
- Water Heaters
- Cooking appliances

The cold climate Australian-adjusted load profiles were calibrated by annual end-use consumption for each building sector, using Energeia's commercial market sizing model.

The average day appliance load shapes are shown in the figures below for space heating, water heating and cooking by end use.

Figure 34 – Space Heating Normalised Average Day Load Profile

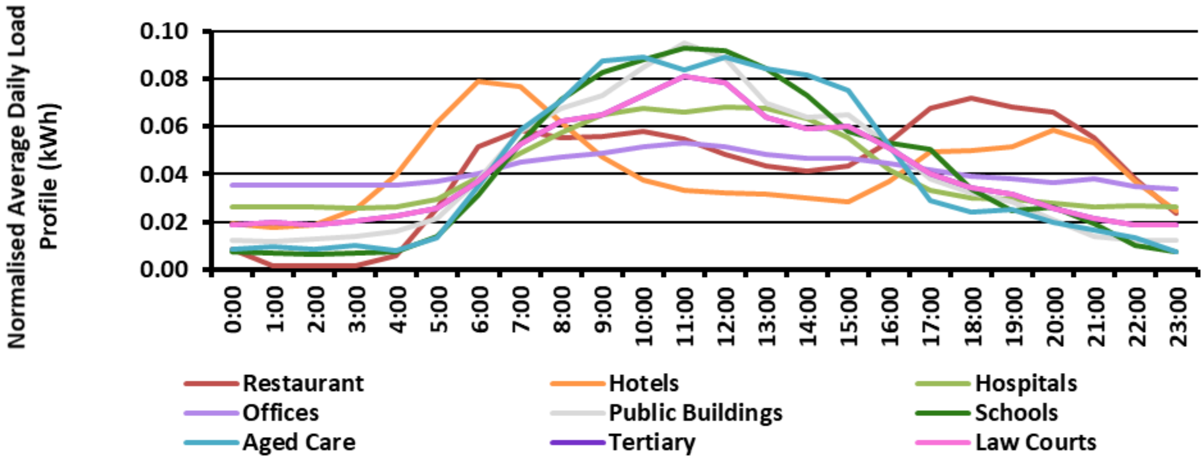


Source: Energeia, DOE (2012)

30 US Department of Energy (2014) 'Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States' https://data.openei.org/submissions/153

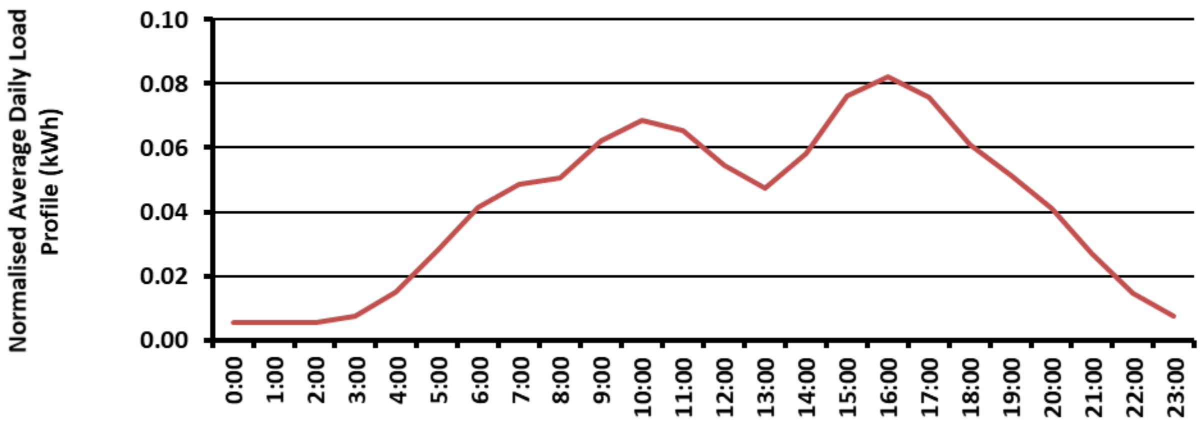
31 To the best of Energeia's knowledge, there are no publicly available end use load shape profiles for commercial customers from Australia

Figure 35 – Water Heating Normalised Average Day Load Profile



Source: Energeia, DOE (2012). Note: Retail and Warehouses have no water heating profile

Figure 36 – Cooking Normalised Average Day Load Profile



Source: Energeia, DOE (2012). Note: Figure indicates all segments, excluding Schools and Hospitals as no data was available

4.2.2.2 Activity Energy Efficiency

Each energy efficiency activity used the same impact assumptions as presented in the Commercial Market Sizing section.

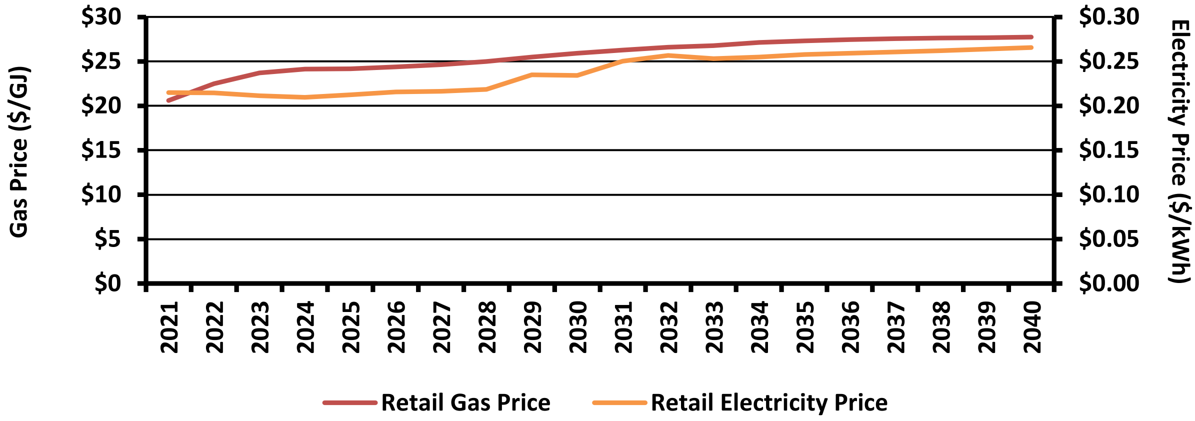
4.2.2.3 Retail Gas and Electricity Prices

Energeia used United Energy's time of use (ToU) default offer[32] to calculate annual electricity bills for electricity load profiles. Multinet retail block gas tariffs[33] were used to generate the annual bills for gas load profiles. The tariff rates were applied to the hourly end use profiles.

Energeia generated retail price forecasts for electricity and gas in Victoria using internally developed forecasts of wholesale and regulated network prices up to 2040, which are reported in Figure 37. The forecast increase in retail energy price is applied as a growth factor across ToU rates.

[32] Essential Services Commission (2021) 'Victorian Default Offer Price Review' https://www.esc.vic.gov.au/electricity-and-gas/prices-tariffs-and-benchmarks/victorian-default-offer/victorian-default-offer-price-review-2021
[33] Department of Environment, Land, Water and Planning (updated 2021) 'Victorian Energy Compare' https://compare.energy.vic.gov.au/

Figure 37 – Retail Electricity and Gas Price Forecasts



Source: UED, Multinet, Northmore Gordon, Energeia

Note that drivers of energy price changes over time are aligned across all segments (commercial, industrial, and residential) for this analysis.

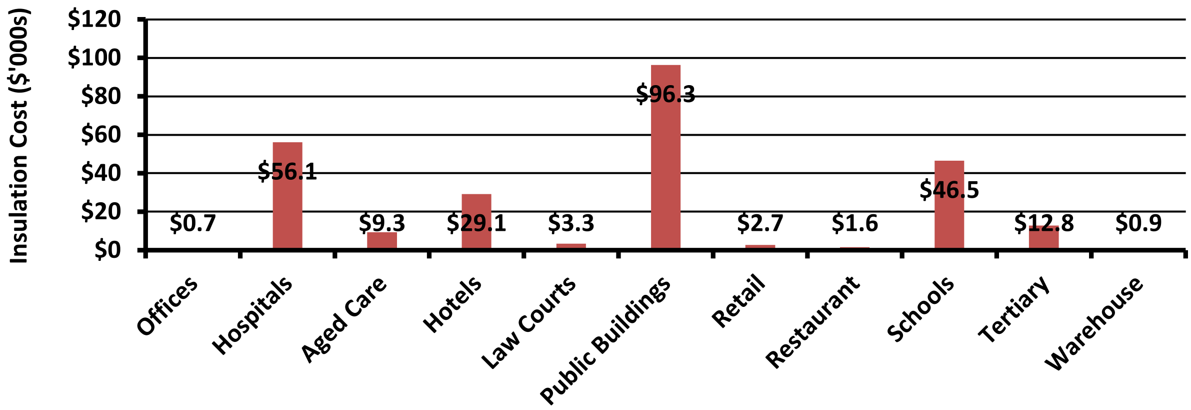
4.2.2.4 Energy Efficient Technology Costs

The total cost to install an appliance includes the capital cost of the appliance itself and the installation cost.

Equipment and installation cost information for commercial-grade appliances was difficult to obtain in the time allocated[34]. The assumed electrification technology costs were therefore developed by scaling the installed capital cost of residential appliances to account for each segment's average consumption. The assumed aggregated cost per appliance by fuel type is shown in the residential 5.2.2.2 Energy Efficient Technology Costs section.

Energeia's was able to infer the cost of draught sealing in the commercial segment from ClimateWorks (2010)[35] using the cost estimates provided to reach the quantified emissions abatement provided in the report. The estimated cost is shown by segment in Figure 38.

Figure 38 – Draught Sealing Insulation Cost



Source: ClimateWorks (2010), Energeia

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34 Future studies should consider a deeper-dive into the commercial appliance costs of each building segment addressed.

35 ClimateWorks (2010), 'Low Carbon Growth Plan for Australia'. pg 69. https://www.climateworksaustralia.org/resource/low-carbon-growth-plan-for-australia/

4.2.2.5 Carbon Emissions Costs

Emissions estimates by end use in the stock and turnover model were multiplied by a carbon cost assumption to estimate the cost of carbon in the CBA.

Energeia assumed a constant carbon cost of $25/t$CO_2$e, aligned with Northmore Gordon, which was based on current ACCU pricing[36]. Forecasting the cost of carbon emissions was out of scope for this project.

4.2.2.6 Appliance Lifetimes

Appliance lifetimes impact the annualised capex cost of installing a new appliance. Energeia's CBA model uses the same appliance lifetimes as assumed in the impact modelling in the Market Sizing section. Energeia's appliance lifetimes are a key assumption as dwellings are assumed to re-buy appliances at end of their lifetime. For example, if an appliance has a technical lifetime of 15 years, the customer would buy 1.25 appliances over the 20-year horizon. Annualized costs were used in the model to avoid cashflow timing issues.

4.2.2.7 Discount Rate

Aligned with Northmore Gordon, Energeia employed a 7% discount rate for the calculation of payback periods and internal rates of return, which is consistent with the Victorian Government Department of Treasury Guidelines[37].

4.2.3 Key Results

The following sections report on the results of our cost-benefit-assessment modelling in terms of estimated benefit-costs, net savings and payback periods by appliance type for each commercial sector.

4.2.3.1 Net Benefits by End Use and Segment

Calculated benefits reflect the energy bill savings as well as emissions reduction social benefits from the given activity and costs reflect the annuitized capital expenditure, with net savings calculated over a 20-year period.

The figures below break down the cost savings up to 2040 for each building sector by end use for each of the short-listed electrification and energy efficiency activities of space heating, water heating, cooking and draught sealing. The modelling results largely reflect the relative levels of gas consumption reported in the Gas Intensity section, with variation in net savings driven by differences in underlying end usage profiles.

The reduction of more expensive load profiles results in relatively greater net benefits. An outcomes by segment breakdown of the following results can be found in the commercial ranking results 4.3.2 and Appendix A.

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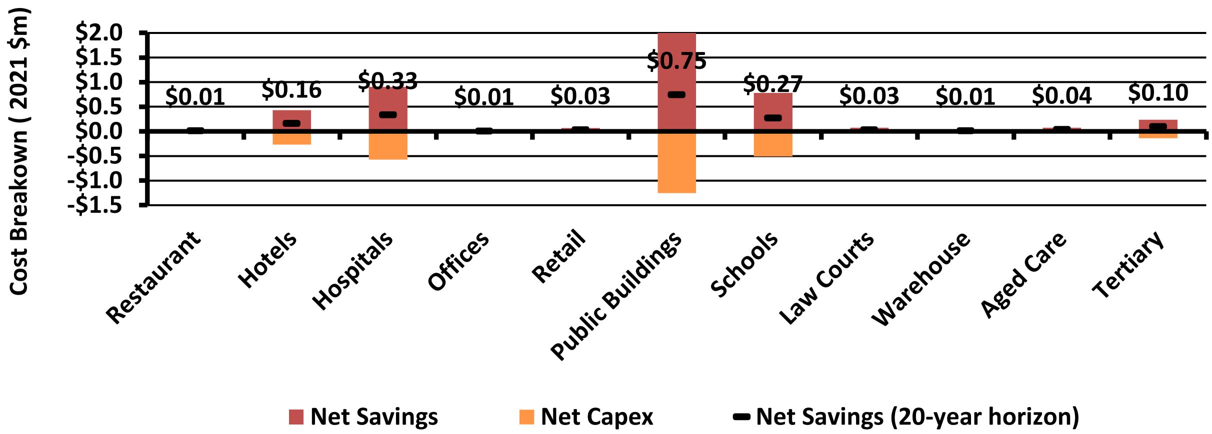
[36] High Voltage Brokers (2021)

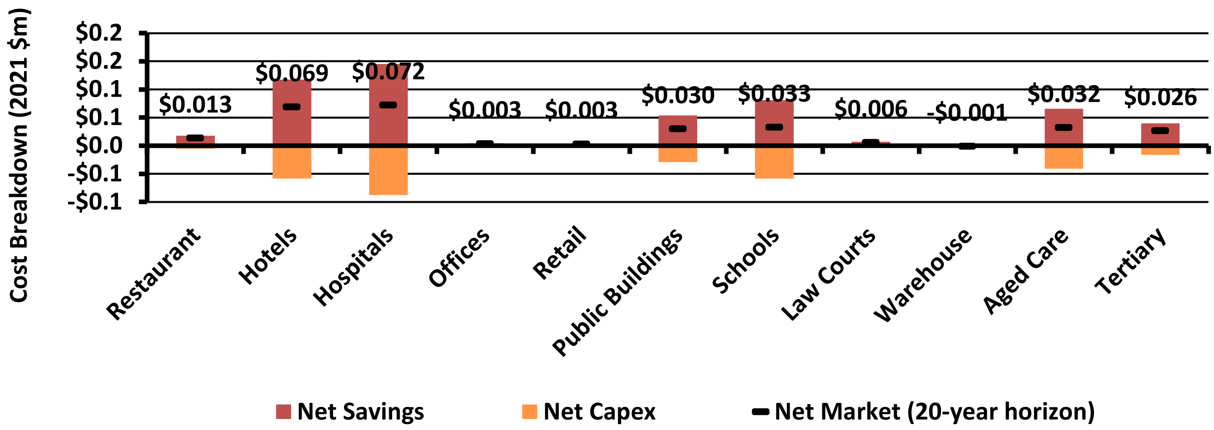
[37] Victorian Government Department of Treasury and Finance (2013), 'Economic Evaluation' https://www.dtf.vic.gov.au/investment-lifecycle-and-high-value-high-risk-guidelines/stage-1-business-case

Figure 39 – 20-Year Space Heating Electrification Net Benefits by Segment (Average Building)



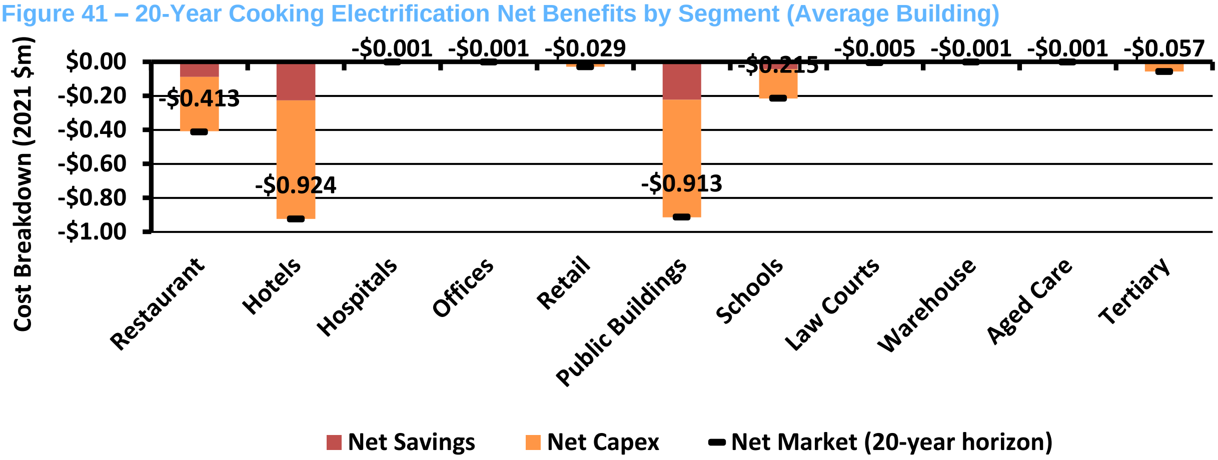
Source: Energeia, Note: Net savings includes customer energy bill and emissions savings

Figure 40 – 20-Year Water Heating Electrification Net Benefits by Segment (Average Building)



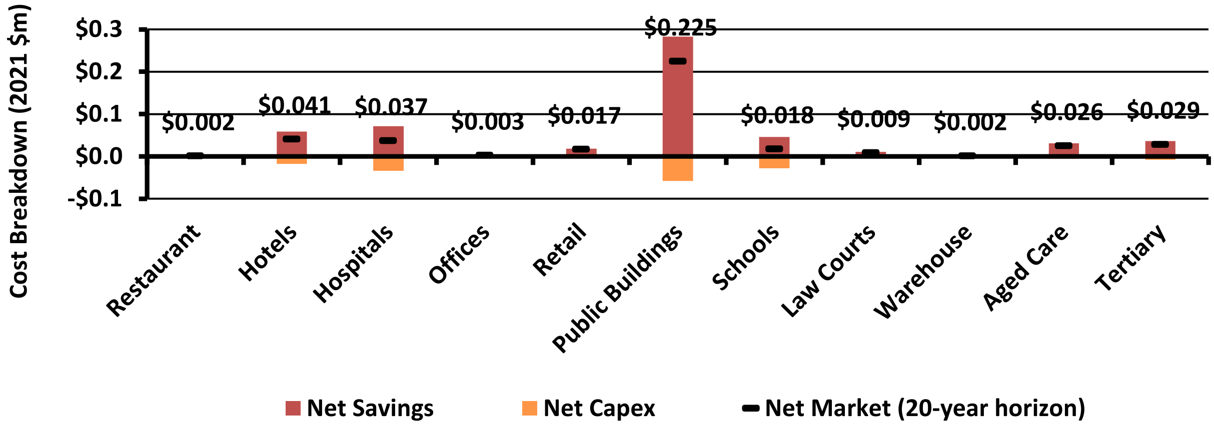
Source: Energeia, Note: Net savings includes customer energy bill and emissions savings

Figure 41 – 20-Year Cooking Electrification Net Benefits by Segment (Average Building)



Source: Energeia, Note: Net savings includes customer energy bill and emissions savings

Figure 42 – 20-Year Draught Sealing Costs and Net Benefits by Segment (Average Building)



Source: Energeia, Note: Net savings includes customer energy bill and emissions savings

It should be noted that the of cooking electrification with an induction cooktop result in negative net benefits to the average customer across all segments, as there are both higher costs to install and run induction appliances comparative to gas cooktops, based on Energeia's research into appliance efficiency, usage by segment and retail electricity and gas prices. Cooking electrification savings over a 20-year horizon are closest to positive for Retail, Tertiary and Schools segments.

4.2.3.2 Payback Periods by End Use and Segment

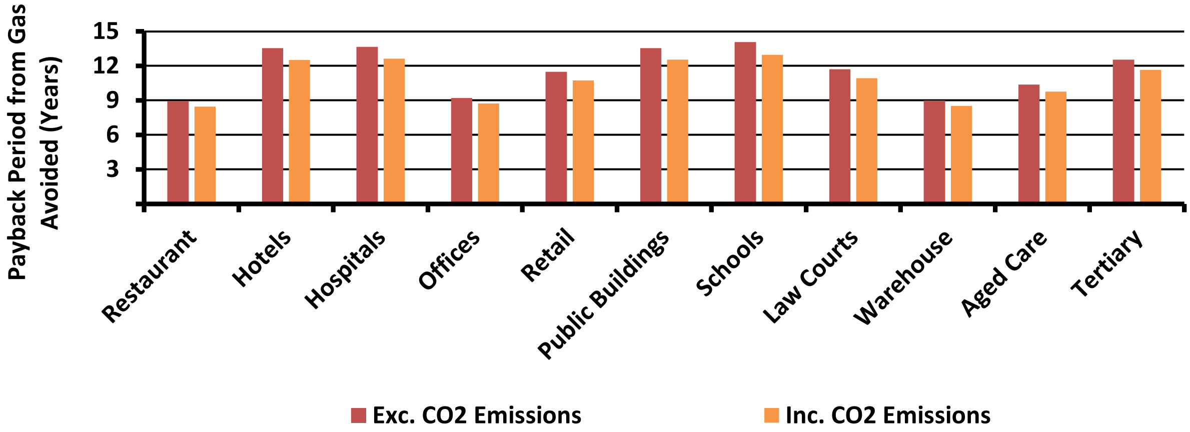
The results of Energeia's modelling of payback periods for each short-listed activity by end use and segment is shown in the figures below. The payback period was calculated as the time in years it would take for the more efficient electrification option to earn enough value through customer bill and emissions savings to justify its higher upfront cost.

Energeia's modelling shows the fastest paybacks for water heating electrification and draught sealing, with a weighted average[38] of 7.4 years and 5.5 years, respectively, including CO_2 emissions costs. The payback for space heating is almost as long as the lifetime of the equipment for some segments, with a weighted average of 10.6 years, indicating that it is a less attractive investment to commercial customers.

The modelling results largely reflect the appliance utilisation levels by segment based on the Gas Intensity and Gas End Use Splits by Segment inputs, with variation in net savings driven by differences in underlying end usage profiles.

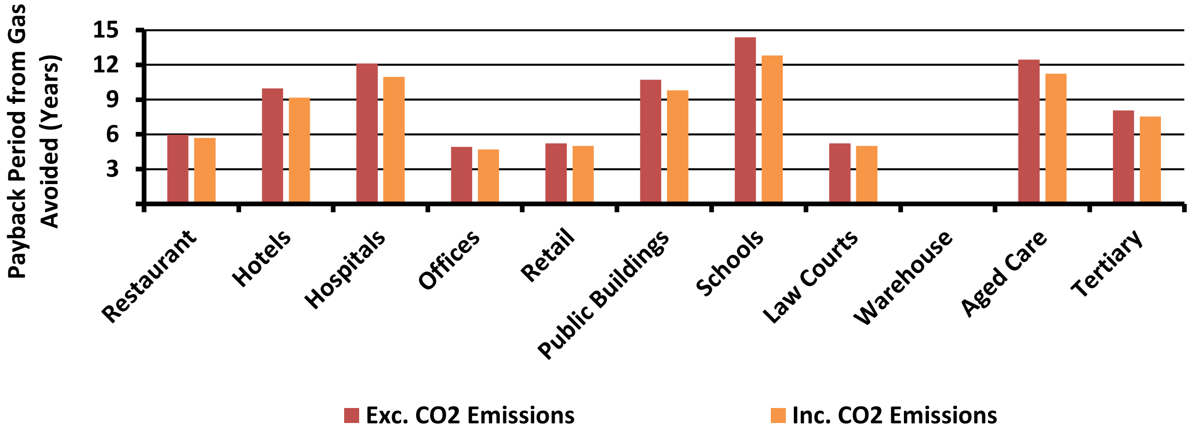
[38] Weighted averages are calculated per GFA for each segment for results

Figure 43 – Space Heating Electrification Payback Periods by Building Sector



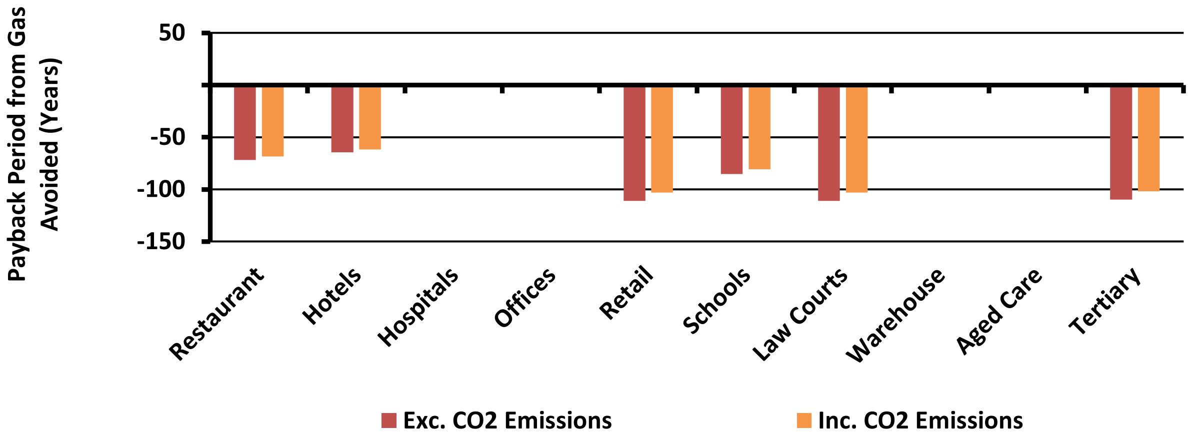
Source: Energeia

Figure 44 – Water Heating Electrification Payback Periods by Building Sector



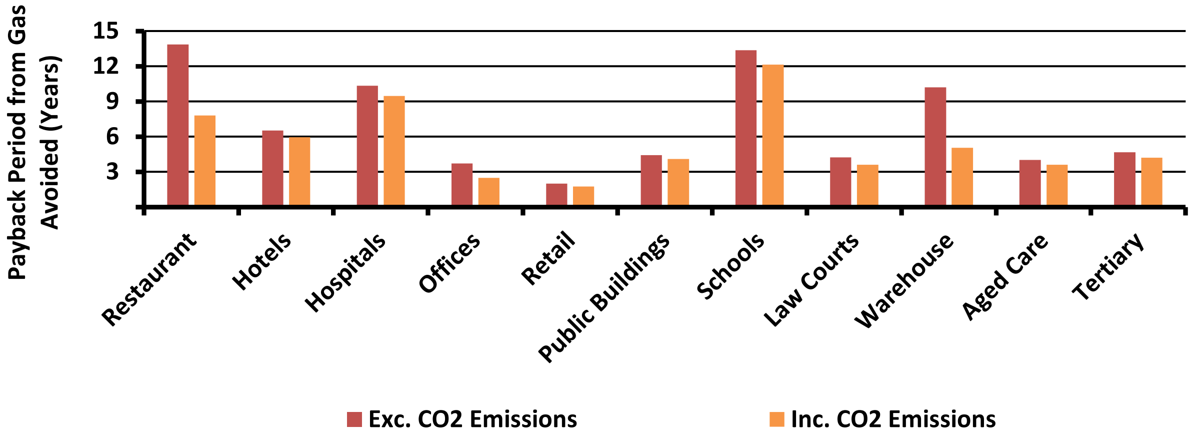
Source: Energeia, Note: Gaps in segments are due to lack of data availability

Figure 45 – Cooking Electrification Payback Periods by Building Sector



Source: Energeia. Note: negative payback periods indicate investment is higher cost to install and operate. Note: Gaps in segments are due to lack of data availability

Figure 46 – Draught Sealing Payback Periods by Building Sector



Source: Energeia

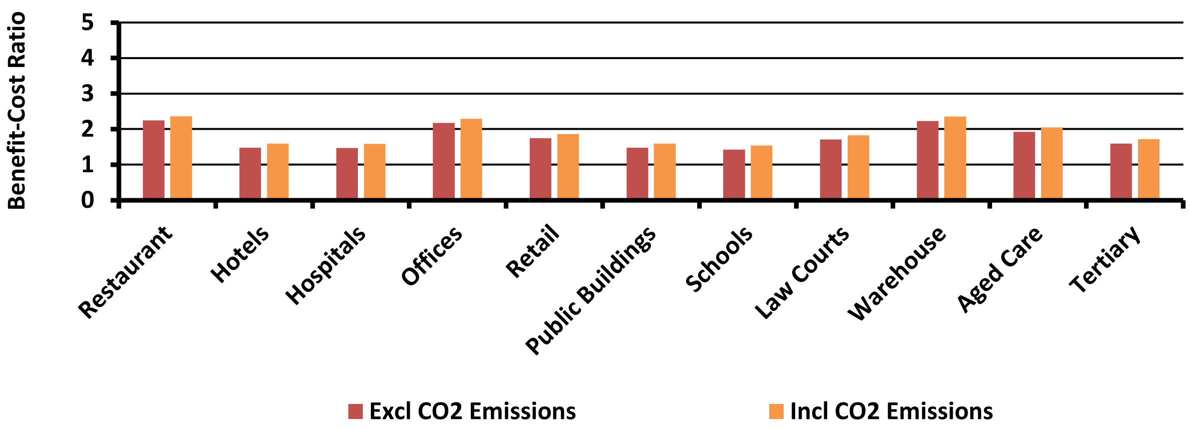
Energeia notes the negative payback periods reported for cooking electrification in Figure 45. This is a consequence of it being currently cheaper to install and run gas cooktops in comparison to induction cooking for commercial premises, based on assumed upfront costs, relative efficiency, and retail tariffs.

4.2.3.3 Benefit-Cost Ratio by End Use and Segment

Energeia's benefit-cost ratio modelling results show weighted average[39] ratios of 5.2, 2.6 and 2.0 for draught sealing and space and water heating electrification, respectively, including CO_2 emissions costs. Modelling of induction cooking costs found that they outweigh the benefits, i.e. they were less than 0.

The modelling results largely reflect the appliance utilisation levels by segment based on the Gas Intensity and Gas End Use Splits by Segment inputs, with variation in net savings driven by differences in underlying end usage profiles.

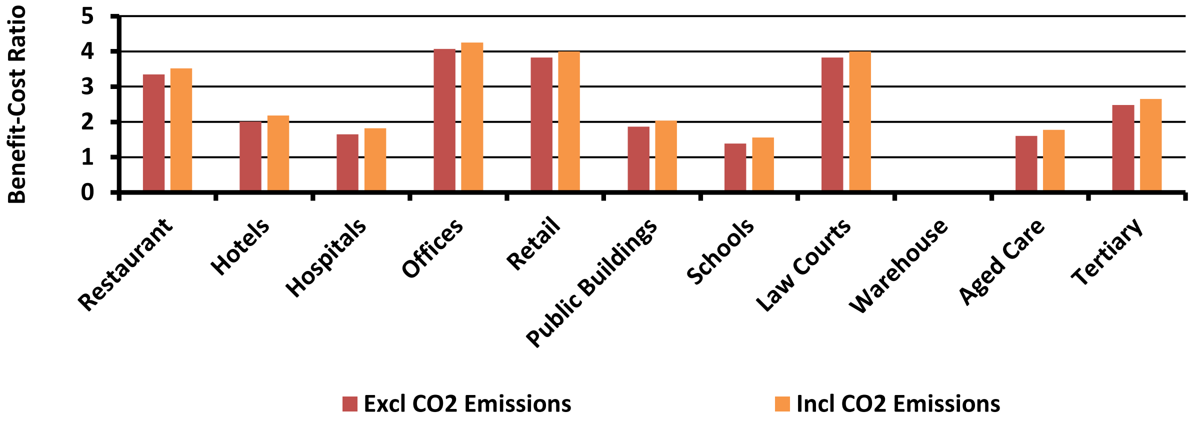
Figure 47 – Space Heating Electrification Benefit-Cost Ratio by Building Sector



Source: Energeia

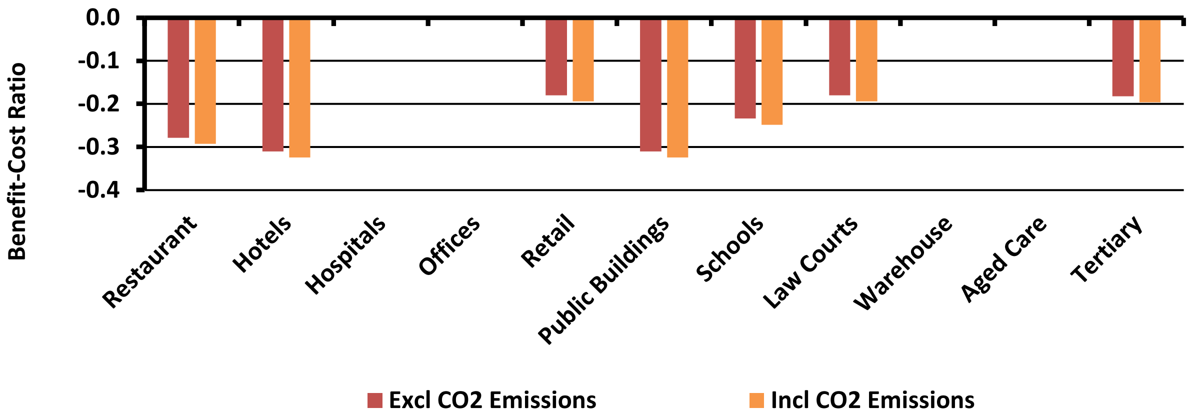
[39] Weighted averages are calculated per GFA for each segment for results

Figure 48 – Water Heating Electrification Benefit-Cost Ratio by Building Sector



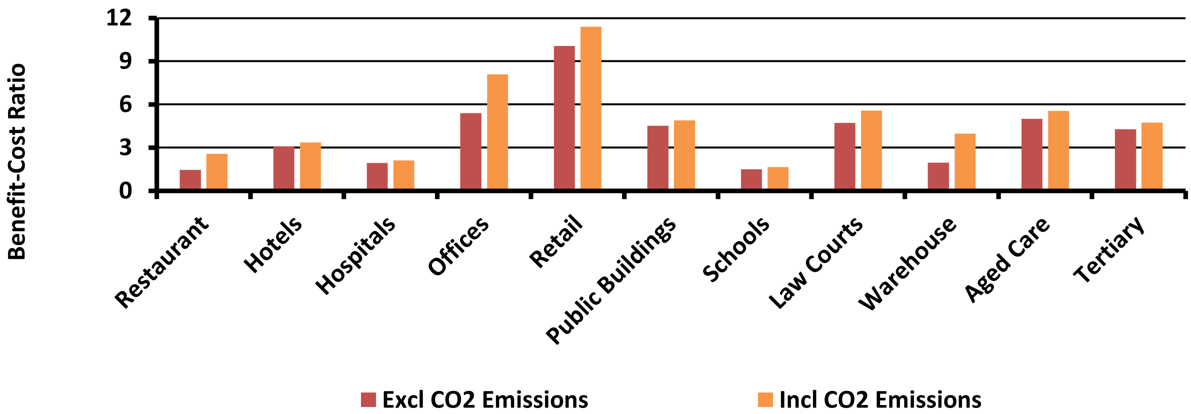
Source: Energeia. Note: Segments with gaps are low data availability in these segments

Figure 49 – Cooking Electrification Benefit-Cost Ratio by Building Sector



Source: Energeia. Note: Segments with gaps are low data availability in these segments

Figure 50 – Draught Sealing Benefit-Cost Ratio by Building Sector



Source: Energeia

Energeia again notes that cooking electrification results in a negative BCR. This is a consequence of it being currently cheaper to install and run gas cooktops in comparison to induction cooking for commercial premises, based on assumed upfront costs, relative efficiency and retail tariffs.

4.3 Ranking

The purpose of this study is to identify the best energy efficiency opportunities for Infrastructure Victoria to recommend to the Victorian Government for implementation as part of their net zero carbon strategy. Energeia, in consultation with Northmore Gordon and Infrastructure Victoria, developed a fit-for-purpose ranking methodology to support the identification of the best energy efficiency opportunities. The following sections explain the methodology used and the results of the assessment.

4.3.1 Methodology

Energeia developed a ranking system to evaluate the short-listed energy efficiency opportunities in terms of their potential energy efficiency and economic impacts for commercial gas customers. The following ranking criteria were included in the assessment:

- **VEU Coverage** – Activities with a low VEU coverage were ranked highest, as being incremental to existing programs.
- **Total Energy Impact** – The net energy savings of each activity was calculated on a state-wide basis, with larger total savings ranked higher.
- **Total Gas Impact** – Gas savings from each measure was calculated, with larger total gas savings ranked higher.
- **Cost Effectiveness** – Benefit Cost Ratios (BCRs) were calculated for each activity, with higher BCRs ranked higher.

The market potential and CBA analysis were used to assess each energy efficiency opportunity against the above criteria.

4.3.2 Results

The results of Energeia's ranking process, with costs inclusive of carbon emissions costs, are reported in Table 12. Weighted averages are calculated by end use on the basis of GFA.

Table 12 – Commercial Ranking of Energy Efficiency Measures

Ranking	End Use	Indicator (/000' m2)	Average of Segments
1	Space Heating	Total Annual Gas Potential (GJ)	219.65
		Total Annual Energy Savings Potential (GJ)	190.76
		Total Annual CO_2 Potential (t CO_2)	9.08
		Annuitized Cost (/customer)	$9,516.08
		Customer BCR	2.0
		Customer Payback	10.6
		Customer IRR	12%
2	Water Heating	Total Annual Gas Potential (GJ)	82.2
		Total Annual Energy Savings Potential (GJ)	66.0
		Total Annual CO2 Potential (t CO_2)	2.9
		Annuitized Cost (/customer)	$1,274.97
		Customer BCR	2.3
		Customer Payback	6.9
		Customer IRR	17%
3	Cooking	Total Annual Gas Potential (GJ)	52.3
		Total Annual Energy Savings Potential (GJ)	27.9
		Total Annual CO_2 Potential (t CO_2)	-1.4
		Annuitized Cost (/customer)	$4,778.18
		Customer BCR	-0.1
		Customer Payback	-41.8
		Customer IRR	N/A
4	Draught Sealing	Total Annual Gas Potential (GJ)	13.1
		Total Annual Energy Savings Potential (GJ)	13.1
		Total Annual CO_2 Potential (t CO_2)	0.7
		Annuitized Cost (/customer)	$542.59
		Customer BCR	6.0
		Customer Payback	5.1
		Customer IRR	42%

Source: Energeia Analysis

Based on our assessment of total potential energy and gas savings, and associated cost-benefit outcomes, Energeia recommends that Infrastructure Victoria consider focusing on electrification of space and water heating and cooking, as the top three net zero activity opportunities in the Victorian commercial sector.

Energeia's inclusion of cooking despite its negative financials is due to its total potential energy efficiency, gas savings and decarbonization impact. It is the third largest gas end use in the commercial sector and full decarbonisation is not possible without addressing it. While it would not necessarily decrease emissions presently, Energeia's modelling shows that cooking electrification will decrease emissions by 2034, assuming no further improvements to induction cooktop efficiency.

In our view, induction's higher cost compared to gas cooktops represents an opportunity for government to provide a targeted incentive to meet its decarbonisation and gas savings goals. Complementary investments such as rooftop photovoltaics (PV) could be also made to offset the associated emissions before 2034.

Detailed market impact and CBA metric reporting by opportunity and segment is reported in Appendix B.

5 Residential Sector Analysis

Following initial desktop research of the most prospective gas energy efficiency opportunities, Victorian Energy Updates Program (VEU) measures and related activities, Energeia, in consultation with Infrastructure Victoria and Northmore Gordon, developed an initial list of potential gas energy efficiency activities to assess.

Energeia modelled the energy, gas, CO_2, cost and benefit impacts of the agreed top three electrification activities (space and water heating and cooking) and five retrofit insulation activities (ceiling, wall, floor, windows and draught sealing). The results of this analysis were used to rank the activities using agreed key criteria including gas and energy savings, CO_2 savings and financial savings, as well as non-energy savings including health benefits.

This section of the report outlines the market potential and cost-benefit-assessment modelling methodologies, key inputs and assumptions, and results of Energeia's residential sector analysis of short-listed gas energy efficiency opportunities for Infrastructure Victoria.

5.1 Market Sizing

Energeia's market potential modelling methodology, key inputs, assumptions, and results are reported below.

5.1.1 Methodology

The stock and turnover model used to assess residential market potential was similar to the model described in the commercial section. Key differences include the modelling of actual premises instead of GFA, and the inclusion of Class 1 and Class 2 segments, rather than commercial sector segments.

5.1.2 Key Inputs

Energeia configured its residential stock and turnover model with the same inputs as for the commercial model, but for the following classes as defined by the NCC[40]:

- Class 1: Detached houses and townhouses
- Class 2: Apartments[41]

Key differences in inputs or assumptions are detailed in the following sections.

5.1.2.1 Dwelling Stock

Energeia developed a forecast of dwellings by class and sub-class to 2035 using data from the Victorian Government, which is reported in Figure 51. Class 1 and Class 2 growth rates are based on Victoria in Future projections.

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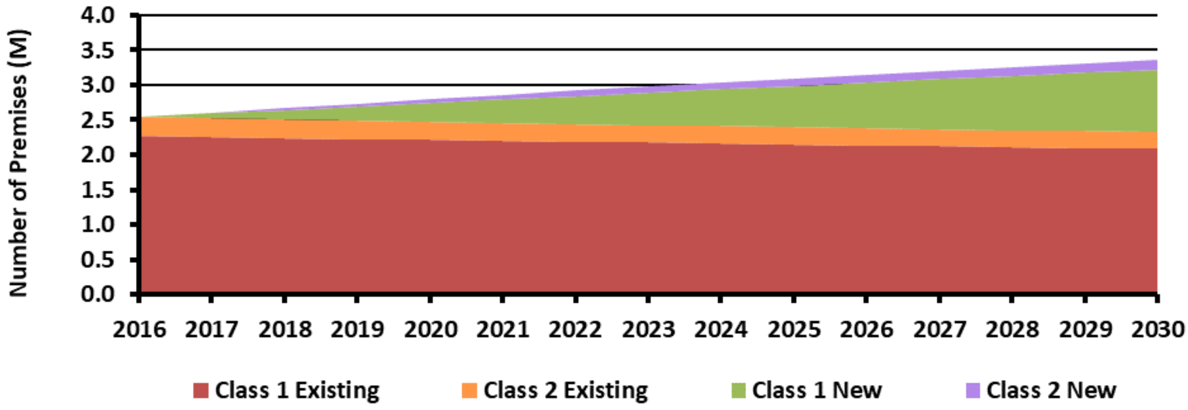
[40] NCC (2020), 'Building Classifications",
https://www.abcb.gov.au/sites/default/files/resources/2020//UTNCC_Building_classifications.PDF
[41] Class 2 premises are counted by number of dwellings

Figure 51 – Estimated Dwelling Forecasts for Victoria



Source: Energeia Analysis. Note: Pre-2021 indicates historic data

The net building stock remaining each year to target with potential energy savings activities are based on the estimated building stock in 2020, less the annual premise replacement activity.

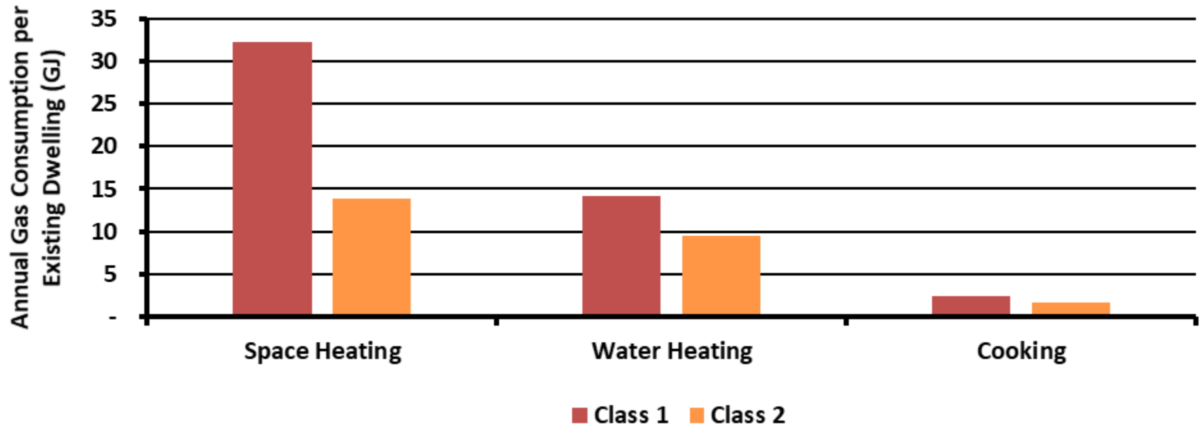
5.1.2.2 Replacement Rates

Residential premise replacement rates of 1% per annum were based on Energeia's analysis of Victorian permit data[42] and previously agreed with DELWP.

5.1.2.3 Gas Intensity

Annual gas consumption per premise was developed for each class using Sustainability Victoria's residential zero net carbon tool[43] for new residential dwellings. Energeia scaled these estimates based on desktop research to identify differences in energy efficiency between new and existing premises[44]. The results of our research and modelling of annual end use consumption by building class and end use is shown below in Figure 52.

Figure 52 – Average Annual Household Gas Consumption per Existing Dwelling by End Use



Source: Energeia, Sustainability Victoria ZNC Tool (undated)

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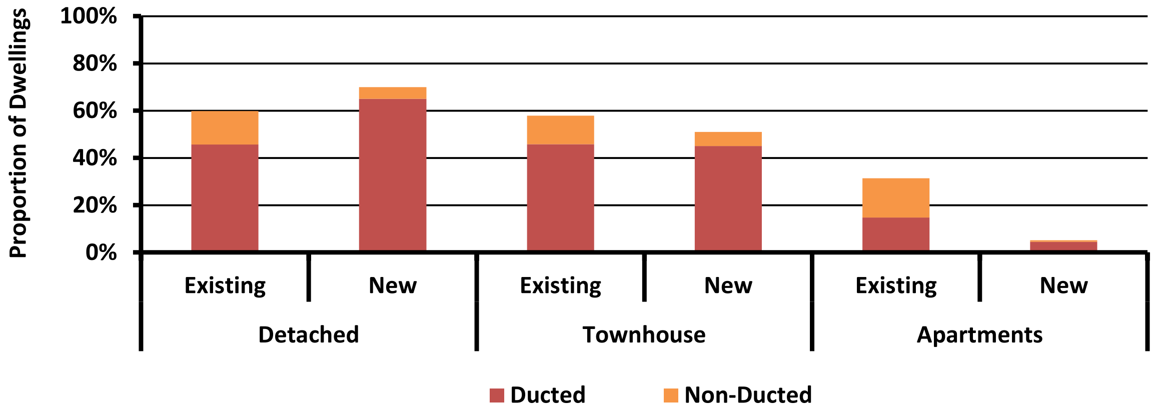
[42] Strategy Policy Research, (2017) https://www.vic.gov.au/sites/default/files/202002/Appendix_7_Electrification_Commercial.pdf
[43] Sustainability Victoria (undated). ZNC Tool
[44] Existing premise consumption data from AER (2020), https://www.aer.gov.au/system/files/Residential%20energy%20consumption%20benchmarks%20-%209%20December%202020_0.pdf

5.1.2.4 End Use Splits

Energeia estimated the end use fuel and technology mix for existing and new Victorian dwellings based on desktop research, proprietary reports provided by DELWP and stakeholder interviews with developers.

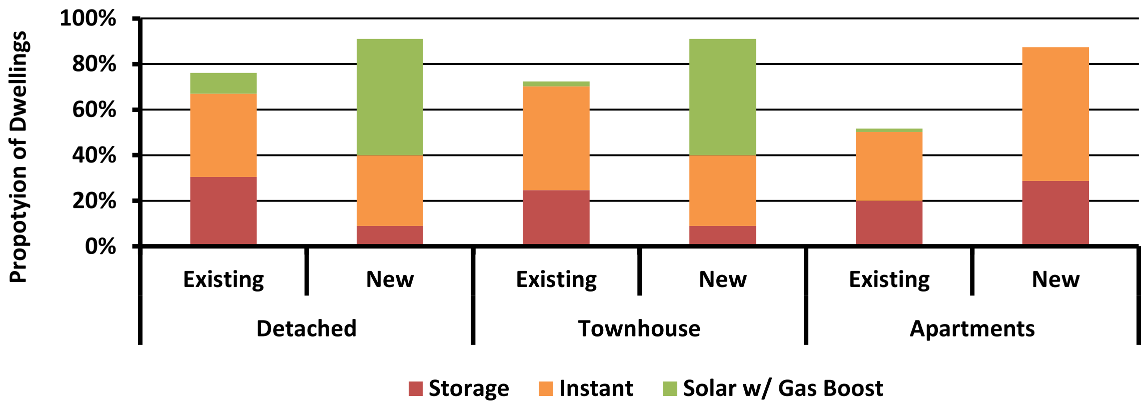
The results of our research and modelling are shown by dwelling and connection type in the figures below for space heating, space cooling, water heating and cooking appliances, respectively.

Figure 53 – Space Heating Gas Appliance Market Share



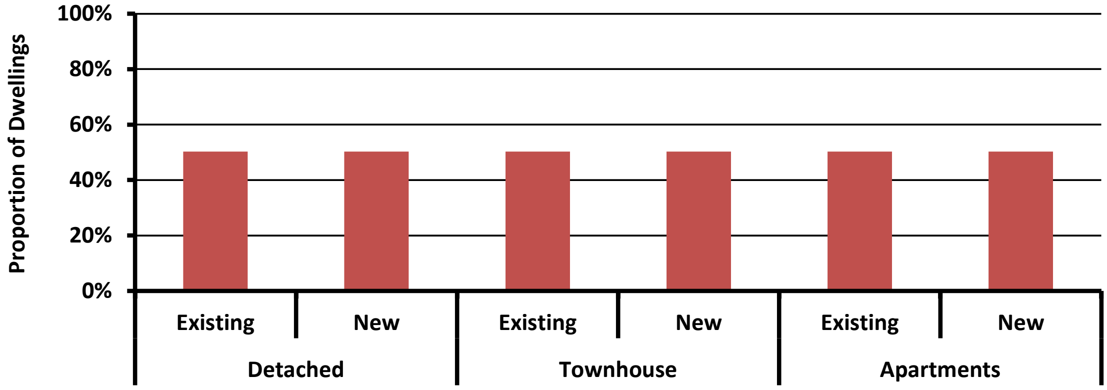
Source: Energeia Research and Analysis, DELWP, BIS Shrapnel (2020), CASBE BESS (2019)

Figure 54 – Water Heating Gas Appliance Market Share



Source: Energeia Research and Analysis, DELWP, BIS Shrapnel (2020), Ark Resources (2019), CASBE BESS (2019)

Figure 55 – Cooking Gas Appliance Market Share



Source: Energeia Research and Analysis, ABS (2011); Note: Includes both ovens and cooktops and only one type of gas cooking was considered, ABS's Other category was redistributed into the gas and electric proportion of dwellings

5.1.2.5 CO_2 Intensity

Aligning with the key inputs and assumptions in the Industrial and Large Commercial section (section 3.2.2.3), Energeia assumed the same electricity and gas CO_2 intensities for the residential sector as reported in the Commercial Average CO_2 Intensity section.

5.1.2.6 Appliance Lifetimes

Appliance lifetimes for residential properties were aligned with those used for the commercial segments and can be found in the Commercial Appliance Lifetimes section. This is simplifying assumption was made due to the low availability of quality data.

As this is a market potential study, Energeia applied a 100% energy efficient appliance uptake rate, with purchases smoothed over 10 years centred around existing appliance end of life.

5.1.2.7 Appliance Energy Efficiency

Relative residential appliance efficiencies are assumed to be the same as the commercial appliance efficiencies reported in the Commercial Appliance Energy Efficiency section.

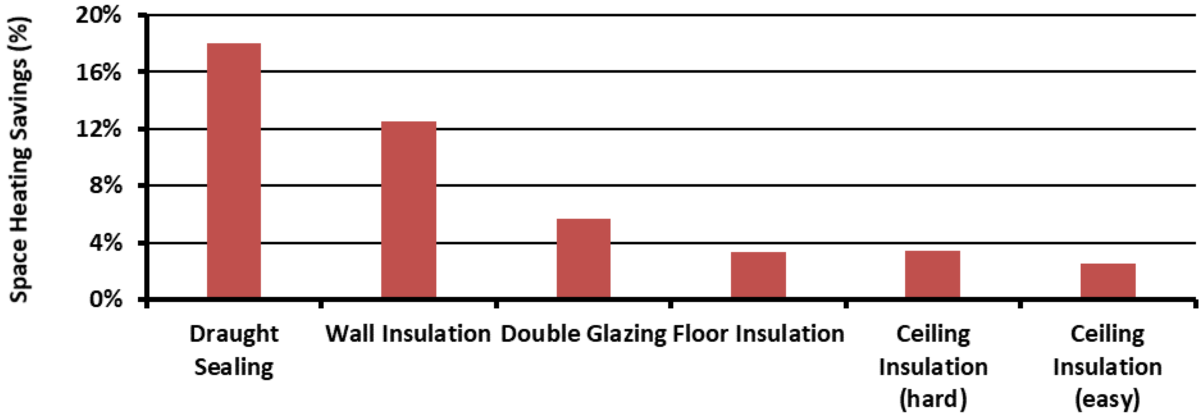
5.1.2.8 Draught Sealing Energy Efficiency

The insulation energy savings assumed per dwelling are based on Sustainability Victoria's On-Ground Assessment[45] and the following retrofit trials[46], which are reported in Figure 56 by type of insulation. Energeia assumed consistent savings across class 1 and class 2 dwellings in modelling insulation impacts, again due to data limitations.

[45] Sustainability Victoria (2015) 'Energy Efficiency Upgrade Potential of Existing Victorian Houses' https://assets.sustainability.vic.gov.au/susvic/Report-Energy-Energy-Efficiency-Upgrade-Potential-of-Existing-Victorian-Houses-Sep-2016.pdf

[46] Sustainability Victoria (2016) 'Cavity Wall Insulation Retrofit Trial' https://assets.sustainability.vic.gov.au/susvic/Report-Energy-Cavity-Wall-Insulation-Retrofit-Trial-Sep-2016.pdf

Figure 56 – Insulation Savings by Type



Source: Sustainability Victoria (2016)

As it has the highest potential impact overall, Energeia focused on draught sealing for residential building thermal improvements. The above draught sealing impacts were applied to space heating[47] driven energy consumption to determine market potential impacts, costs, and benefits.

5.1.3 Key Results

The following sections report on the outcomes of our modelling of current gas and energy consumption and CO_2 emissions by dwelling class and end use, as well as our modelling of the impact of short-listed energy efficiency technologies on annual gas and energy consumption and CO_2 emissions.

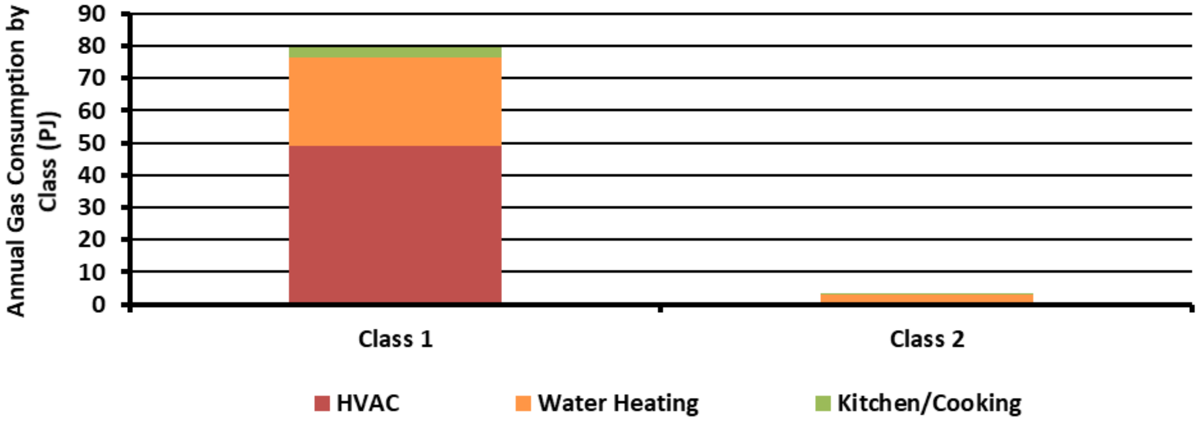
5.1.3.1 Gas Consumption by Class and End Use

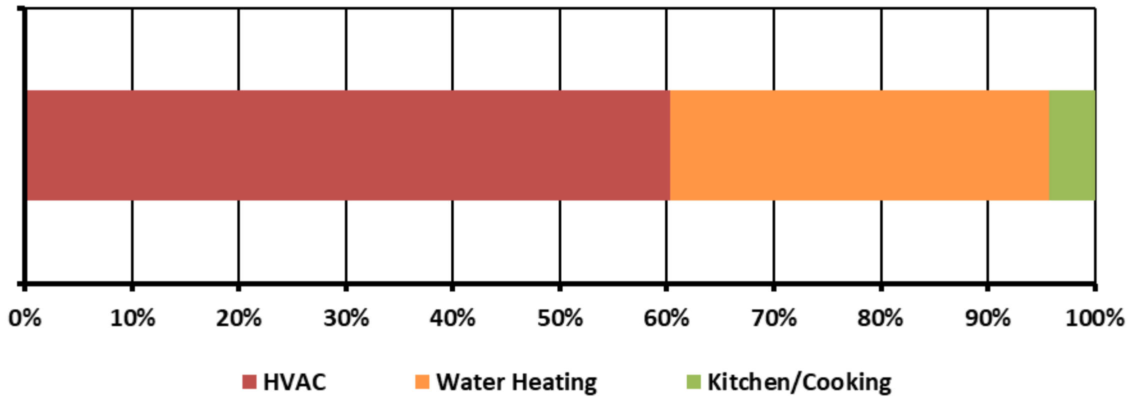
The results of Energeia's modelling of current gas consumption by end use and dwelling class are reported in Figure 57, which shows total gas consumption of 82.8 PJ per annum across existing Class 1 and Class 2[48] by end use.

Other residential gas end uses such as pool and spa pumps and dryers were excluded from the analysis due to lack of data availability. However, they are relatively minor in aggregate consumption compared to space heating, water heating and cooking.

[47] Energeia notes that insulation will also reduce the energy consumption for space cooling, however, this does not involve natural gas, and is expected to be relatively negligible in terms of total annual consumption and therefore cost savings.
[48] The 2021 AEMO GSOO states that Victoria's residential and commercial gas consumption totals 124 PJ in 2021. Our modelling has accounted for 103.5 PJ (82.8 PJ commercial plus 20.7 PJ residential gas consumption), with the discrepancy driven by the overlap between the commercial and industrial segments in building stock data.

Figure 57 – Existing Dwelling Residential Gas Consumption by End Use and Class (2020)





Source: Energeia Modelling

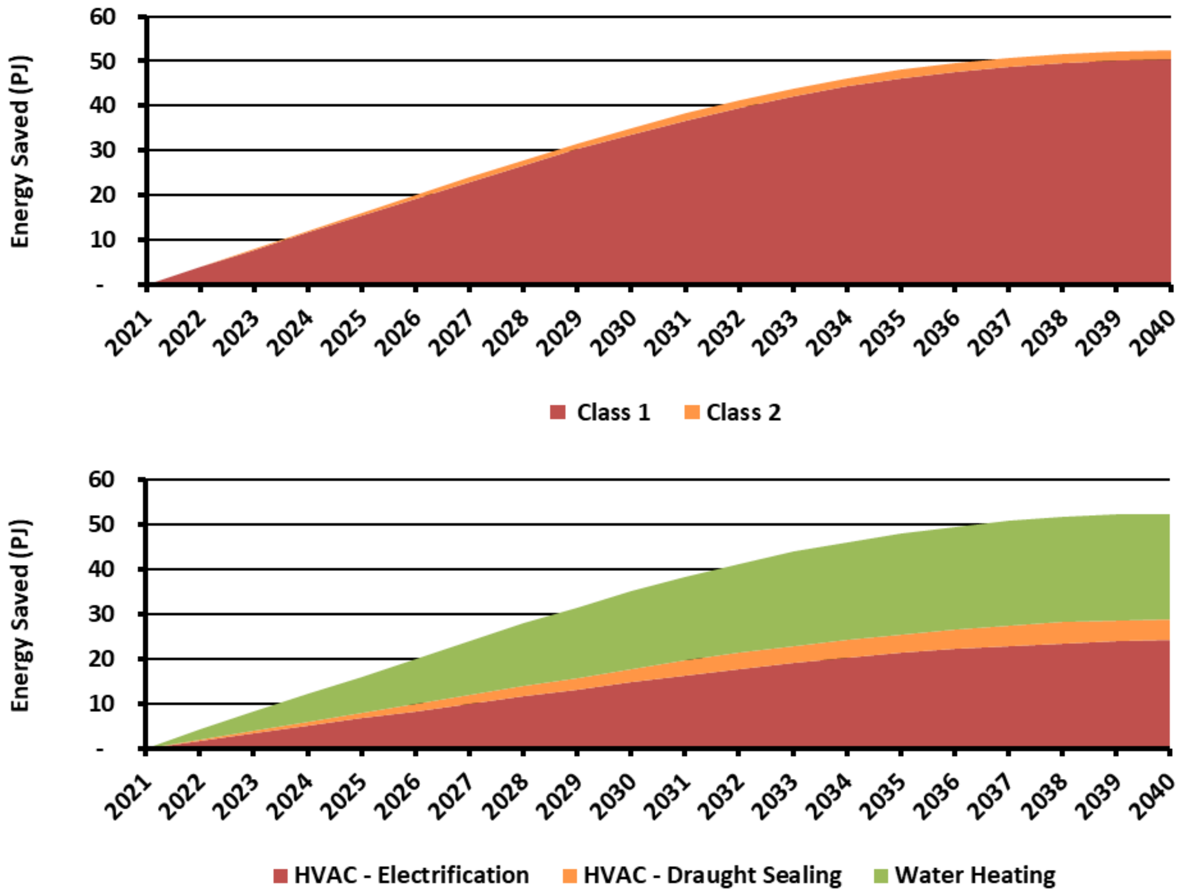
Similar to the commercial results, HVAC is the highest consumer of gas in the residential sector.

5.1.3.2 Energy Savings by Class and End Use

The results of Energeia's modelling of the impact of energy efficiency activities are reported in Figure 58 by class and end use, which shows total annual energy savings reaching 35.1 PJ by 2030 and 52.5 PJ by 2040. As both HVAC electrification and draught sealing impact on HVAC consumption, we have assumed a 50/50 adoption to avoid double counting the potential benefit.

The modelling shows HVAC and water heating electrification to be the two largest contributors to energy savings by far, with draught sealing a distant third. The modelling also shows that savings are predominantly in class 1 dwellings, reflecting their significantly larger share of the housing stock and energy intensity. Relative contributions of HVAC and water heating electrification and draught sealing to energy savings is equal to 42%, 49% and 8%, respectively, by in 2030 and 46%, 45%, 9% by 2040.

Figure 58 – Total Annual Potential Residential Energy Savings by Class and End Use



Source: Energeia Modelling

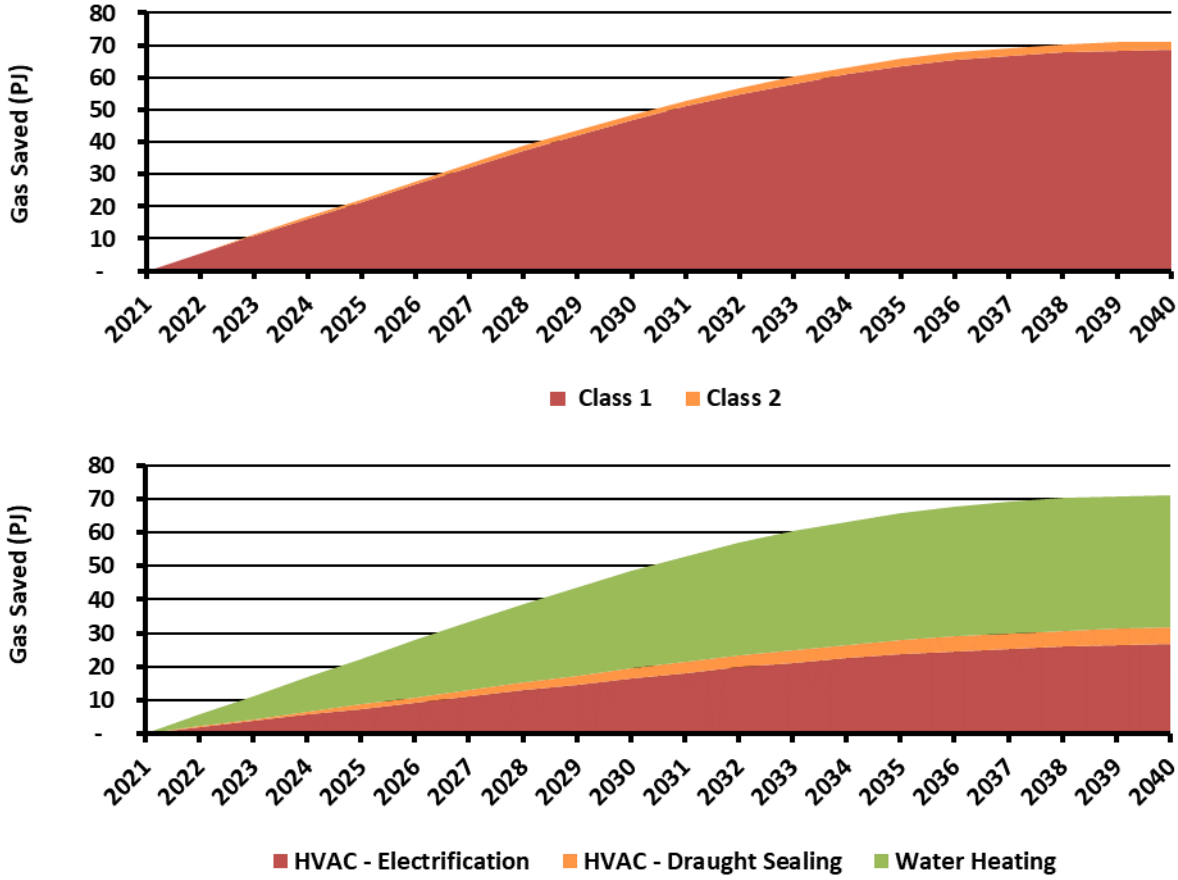
5.1.3.3 Gas Savings by Class and End Use

Energeia's modelling results, shown in Figure 59, show total annual energy savings from the top three ranked energy efficiency activities in Section 5.3, reaching 48.5 PJ by 2030 and 71.1 PJ by 2040.

The assumed 50/50 split of draught sealing and HVAC electrification results in water heating electrification contributing the most gas savings. If draught sealing was removed as an activity, and all HVAC savings were due to electrification, it would generate greater savings than water heating. However, draught sealing has been included in the top three ranking due to its relatively high BCR.

In total, HVAC electrification, water heating and draught sealing's share of total gas savings is equal to 34%, 64% and 5%, respectively, by 2030, and reach 38%, 60%, 5% by 2040.

Figure 59 – Total Annual Potential Residential Gas Savings by Class and End Use



Source: Energeia Modelling

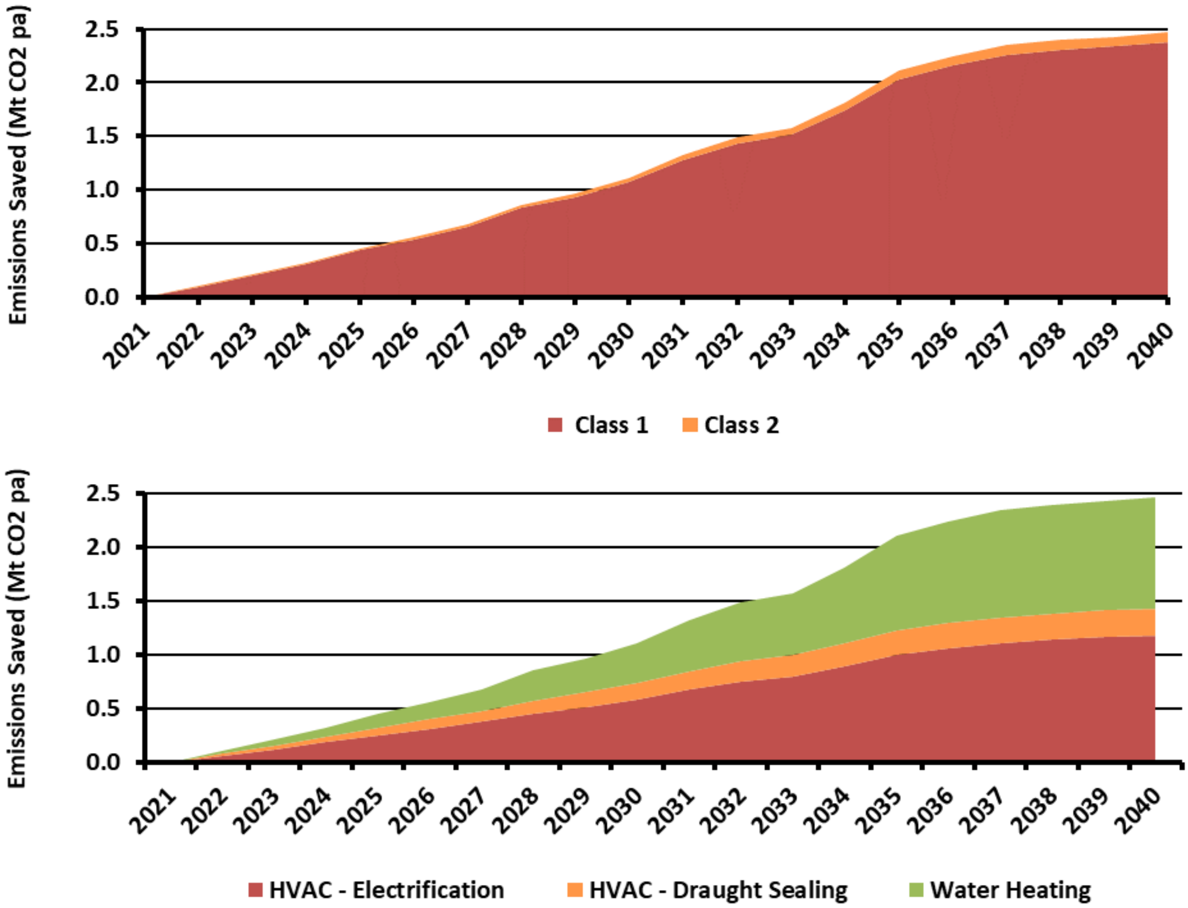
5.1.3.4 CO_2 Savings by Class and End Use

Energeia's modelling of CO_2 impacts of the top three ranked energy efficiency activities applied the CO_2 intensity assumption to the savings in gas, and the wholesale electricity CO_2 intensity assumption to any increases in electricity assumption.

The results of our modelling by dwelling class and end use over the period to 2040 is reported in Figure 60, which shows total annual CO_2 savings reaching 1.1 Mt per annum by 2030 and 2.4 MT by 2040.

As has been the case with energy and gas savings, HVAC electrification contributes the largest overall CO2 emissions savings, followed by electrification of water heating. The relative contribution of HVAC electrification, water heating and draught sealing to CO_2 emissions reductions is 53%, 33% and 14%, respectively, by 2030 and 48%, 42% and 10% by 2040.

Figure 60 – Total Annual Potential Residential CO_2 Savings by Class



Source: Energeia Modelling

5.2 Cost-Benefit Assessment

This section outlines Energeia's modelling methodology for assessing a customer's financial impacts from implementing each of the energy efficiency activities by dwelling class, including the key inputs and modelling results.

5.2.1 Methodology

Energeia used the same cost-benefit-assessment modelling methodology as described in the Commercial Methodology section.

5.2.2 Key Inputs

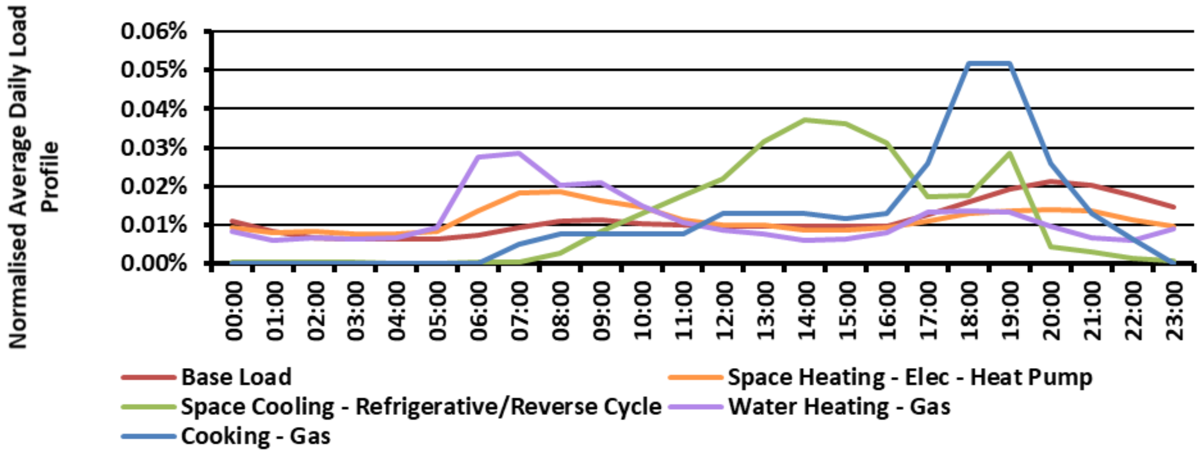
The key inputs were collected by dwelling class and end use where available and are detailed below.

5.2.2.1 End Use Load Profiles

Energeia developed residential end use load profiles for Class 1 dwellings based on outputs from Sustainability Victoria's Zero Net Carbon Tool. Unitised load profiles were calculated by dividing each hour by total annual consumption and they were scaled to annual energy consumption by end use and fuel type.

Class 2 dwellings were assumed to have the same load shape but a different annual energy consumption, mainly due to less dwelling area and occupants on average. The average daily load shape by end use is shown in Figure 61.

Figure 61 – Average Day Load Profile by End Use

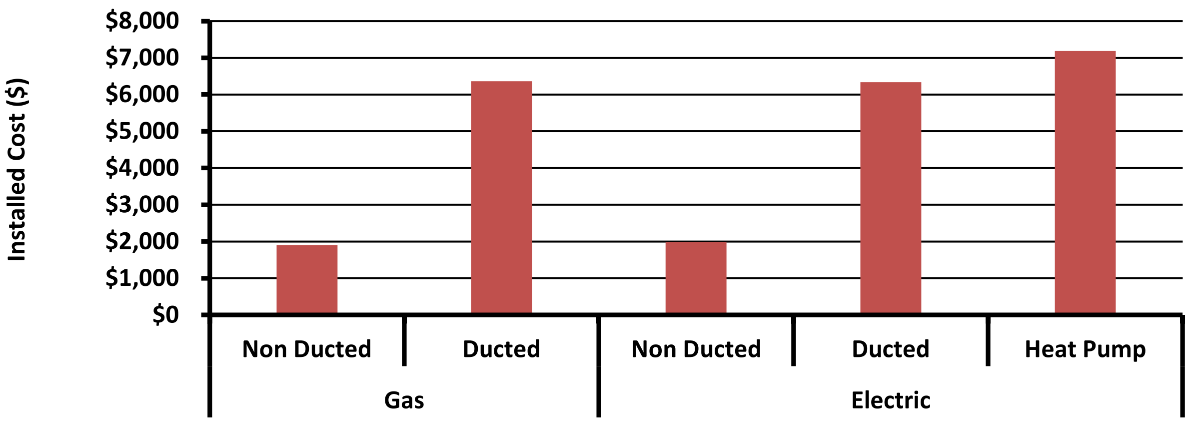


Source: Energeia, DELWP, Sustainability Victoria

5.2.2.2 Energy Efficient Technology Costs

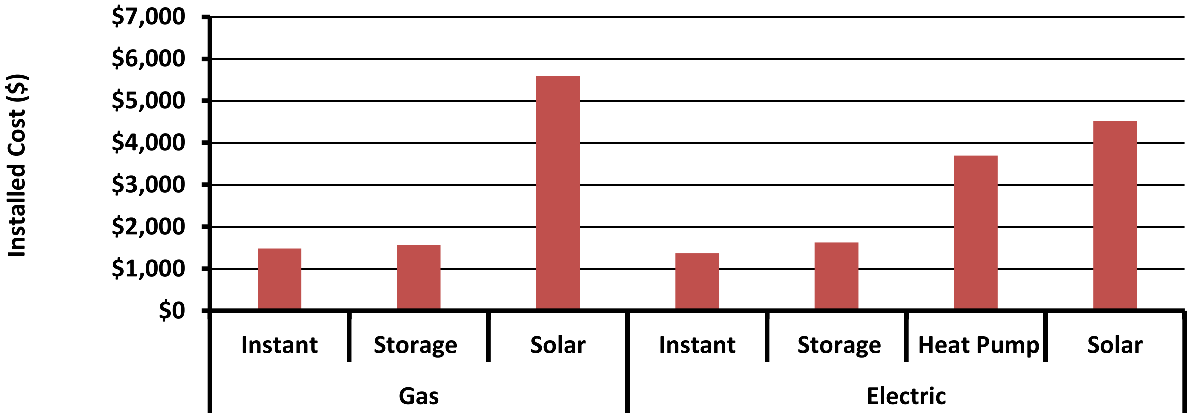
Energeia's installed cost assumptions for each appliance was developed based on desktop research and comparison with other published public domain and proprietary figures. The figures below show Energeia's estimates for space heating, water heating and cooking appliances for Class 1 dwellings. The modelling assumes similar equipment costs for a Class 1 and Class 2 dwelling due to data limitations. Furthermore, our analysis only considers class 2 dwellings with individual water heating and space heating, centralised options were not considered in the CBA.

Figure 62 – Space Heating Appliance Cost Comparison



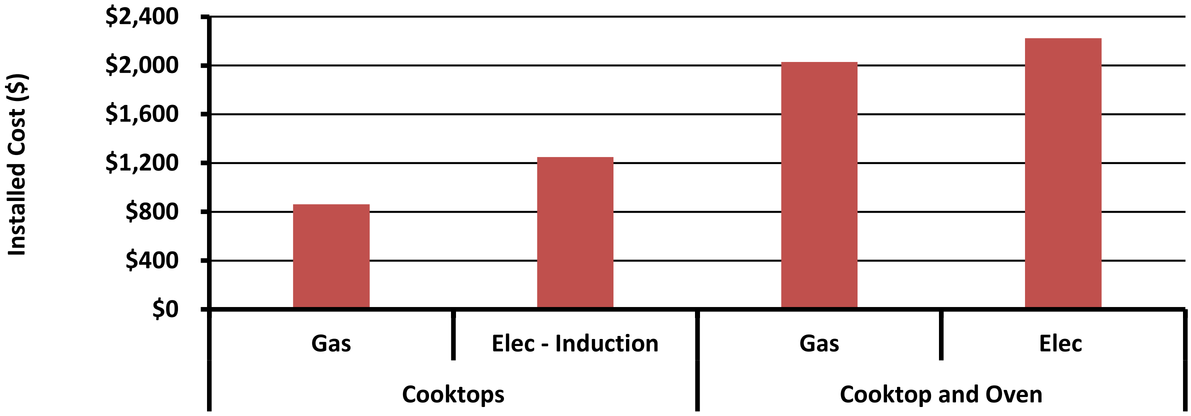
Source: Energeia Research, Renew (2018) and (2019) and ZNC tool, DELWP (2018)

Figure 63 – Water Heating Appliance Cost Comparison



Source: Energeia Research

Figure 64 – Cooking Appliance Cost Comparison



Source: Energeia

5.2.2.3 Appliance Lifetimes

As a simplifying assumption, appliance lifetimes for residential properties were aligned with those used for the commercial segments and can be found in the Commercial Appliance Lifetimes section. Dwellings are assumed to replace their appliances at the end of their lifetime. For example, if an appliance has a technical lifetime of 15 years, the customer is assumed to buy 1.25 appliances over the 20-year horizon, with the total cost annualized over the appliance's assumed lifetime.

5.2.2.4 Appliance Energy Efficiency

Relative residential appliance efficiencies are assumed to be the same as commercial appliance efficiencies reported in the Commercial Appliance Energy Efficiency section.

5.2.2.5 Insulation Energy Efficiency

Energeia's assumptions for insulation energy efficiency are the same as reported in the Market Sizing Key Inputs section. Only draught sealing was considered for the CBA analysis as being the highest ranked building thermal improvement option.

5.2.2.6 Retail Gas and Electricity Prices

Standing offer residential retail tariffs[49] from Multinet Gas and United Energy Distribution (UED) electricity distribution network areas were used to in the CBA model, with identical price forecasts applied as for the commercial analysis, which are reported in the Commercial Retail Gas and Electricity Prices section.

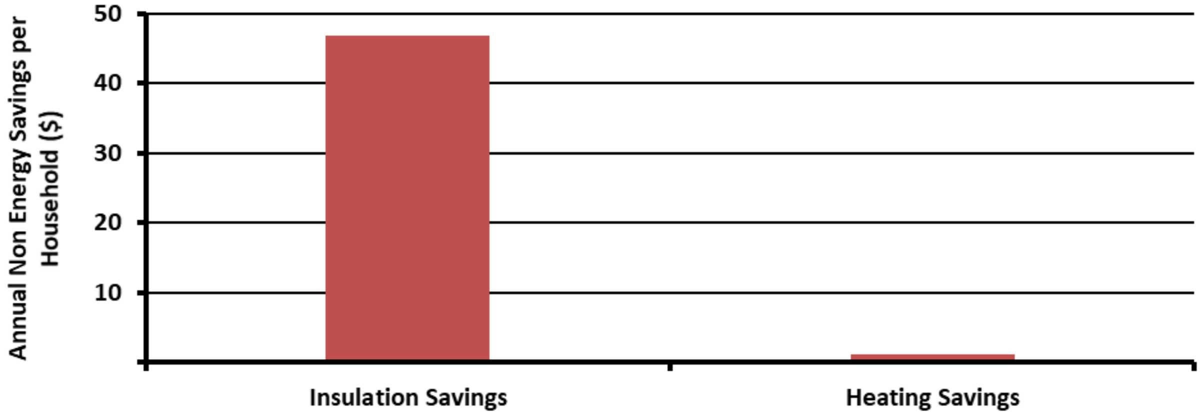
5.2.2.7 Carbon Emissions Costs

The residential CBA used the same carbon price and CO_2 intensity assumptions as reported in the Commercial Carbon Emissions Costs section.

5.2.2.8 Health Benefits

Indirect savings from reduced negative health impacts are taken from a study of the economic impact of implementing energy efficiency changes[50] that moderate indoor temperature and relative humidity to more optimal levels. The financial benefits are driven by reduced hospitalisations and household pharmaceutical spending, fewer days off school and reduced medical visits. The annuitised savings due to retrofit insulation and clean heating solutions can be seen in Figure 65 below. Energeia has included these health savings assumptions in our draught sealing[51] and efficient space heating CBAs.

Figure 65 – Annual Health Savings from Insulation and Clean Heating per Household



Source: University of Otago (2011)

Note that it was assumed that the health benefits only counted towards residential dwellings and were not counted for the commercial analysis.

5.2.2.9 Discount Rate

The residential CBA used the same discount rate as reported in the Commercial Discount section.

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[49] UED's ToU tariff was assumed, however, it is noted that most UED customers are on a flat tariff.
[50] University of Otago Wellington (2011), "The Impact of Retrofitted Insulation and New Heaters on Health Services Utilisation and Cost, Pharmaceutical Costs and Mortality" https://www.motu.nz/assets/Documents/our-work/urban-and-regional/housing/The-Impact-of-Retrofitted-Insulation-and-New-Heaters-on-Health-Services-Utilisation-and-Costs-Pharmaceutical-Costs-and-Mortality-Evaluation-of-Warm-Up-New-Zealand-Heat-Smart.pdf
[51] While the study looked at wall and ceiling insulation, the drivers of the health benefits quantified can be applied to draught sealing, which serves the same purpose as wall and ceiling insulation

5.2.3 Key Results

The following sections report on the results of our CBA modelling in terms of estimated benefit-costs, net savings, payback periods and BCR by appliance type for each dwelling class. No subsidies or rebates are included in our estimated investment costs.

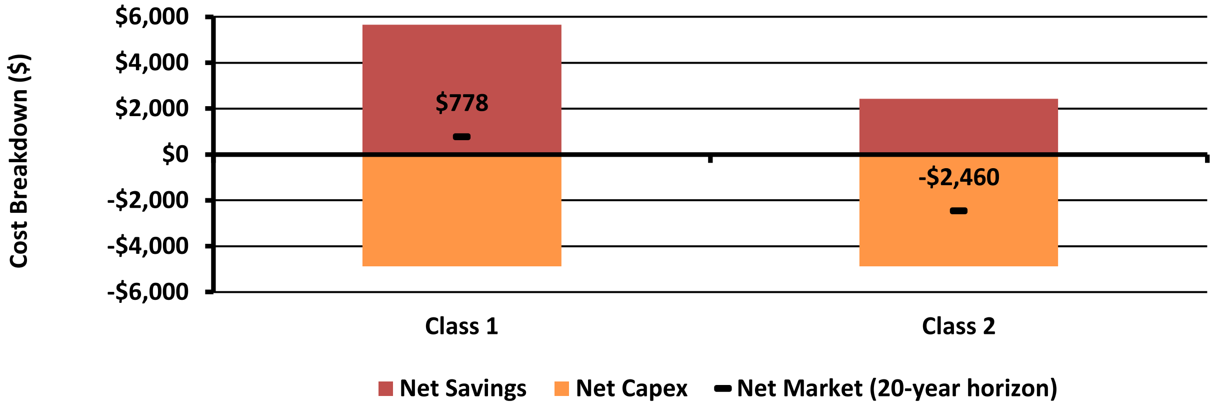
5.2.3.1 Net Benefits by End Use and Segment

Energeia's calculated benefits reflect the energy bill savings as well as emissions reduction social benefits and health benefits from the given activity, and costs reflect the annuitised capital expenditure, with net savings calculated over a 20-year period.

The modelling results show that draught sealing delivers the highest net savings of $2,480 and $1,836 for Class 1 and Class 2, respectively. Water heating delivers the next highest net savings of $1,153 for Class 1 and $167 for Class 2 dwellings. HVAC electrification provides the lowest net savings for Class 1 of $778 and a net loss of $2,460 for Class 2 dwellings.

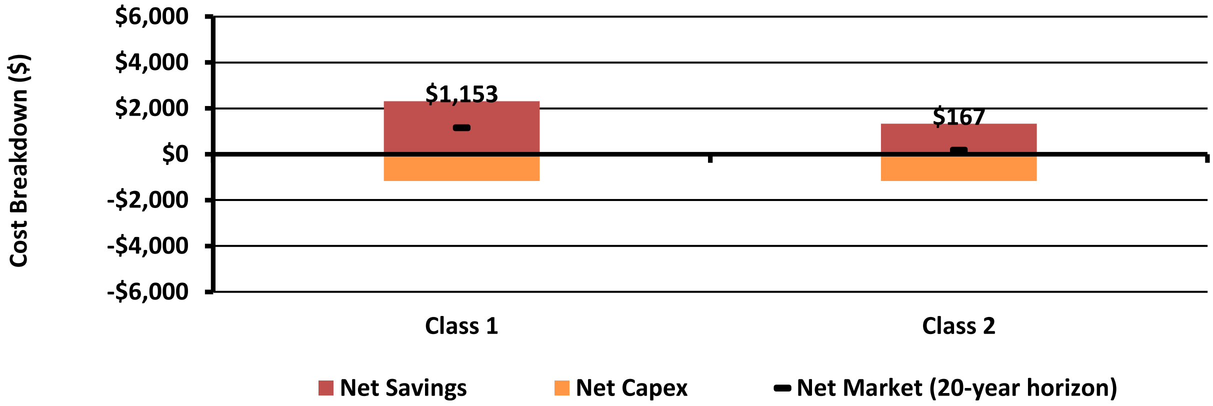
The reason for the negative Class 2 net benefit is due to our estimate of space heating energy consumption per dwelling, which is lower than Class 1 dwellings but comparable in investment costs terms. A detailed breakdown of the results can be found in Table 12 of Appendix B.

Figure 66 – 20-Year Space Heating Cost Breakdown by Dwelling Type (Average Customer)



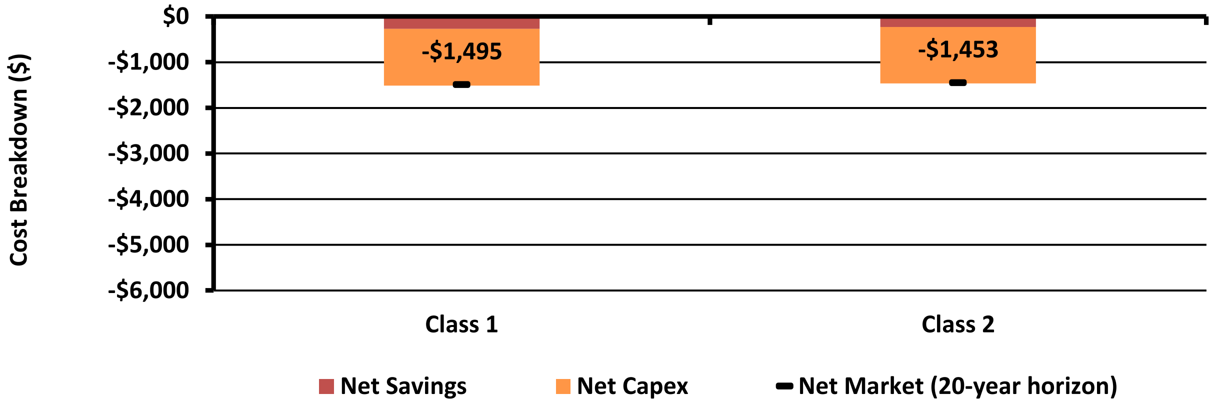
Source: Energeia, Note: Net savings includes customer energy bill, health and emissions savings

Figure 67 – 20-Year Water Heating Cost Breakdown by Dwelling Type (Average Customer)



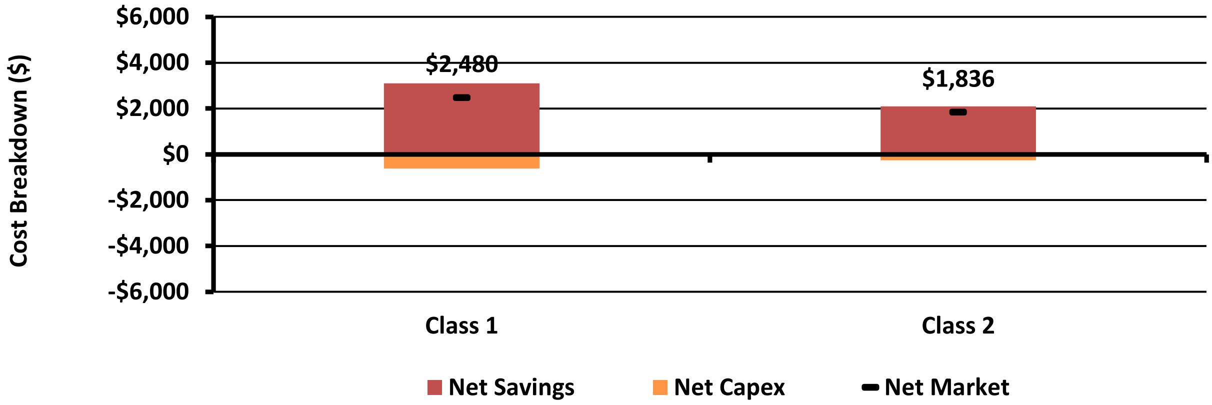
Source: Energeia, Note: Net savings includes customer energy bill, health and emissions savings

Figure 68 – 20-Year Cooking Cost Breakdown by Dwelling Type (Average Customer)



Source: Energeia, Note: Net savings includes customer energy bill, health and emissions savings

Figure 69 – 20-Year Draught Sealing Cost Breakdown by Dwelling Type (Average Customer)



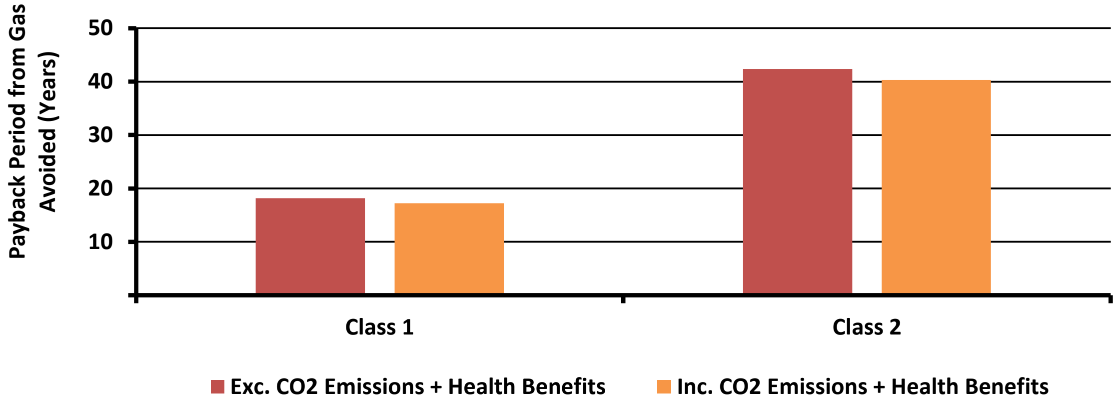
Source: Energeia, Note: Net savings includes customer energy bill, health and emissions savings

5.2.3.2 Payback Periods by End Use and Segment

The results of Energeia's modelling of simple payback periods by energy efficiency activity and dwelling class are reported in the figures below with and without CO_2 emissions costs and health benefits. Note that any subsidies and rebates are not included this analysis.

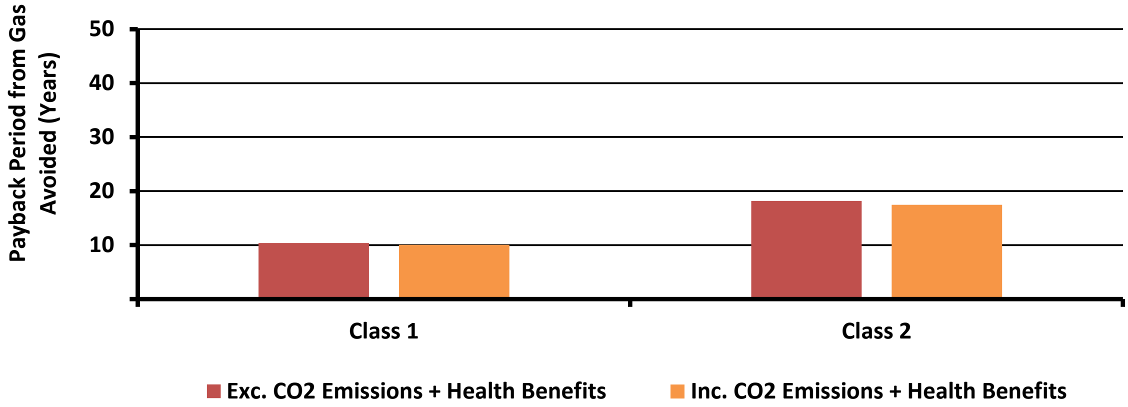
The modelling results show payback periods as low as 2 years in the case of Class 2 draught sealing, and over 40 years in the case of Class 2 HVAC electrification. They are generally less than the lifetime of the appliance, except in the case of Class 2 HVAC electrification, however, draught sealing is the only activity with a financially attractive payback period of 4 and 2.5 years for Class 1 and Class 2, respectively (including CO2 emissions costs).

Figure 70 – Space Heating Electrification Payback Period by Dwelling Type



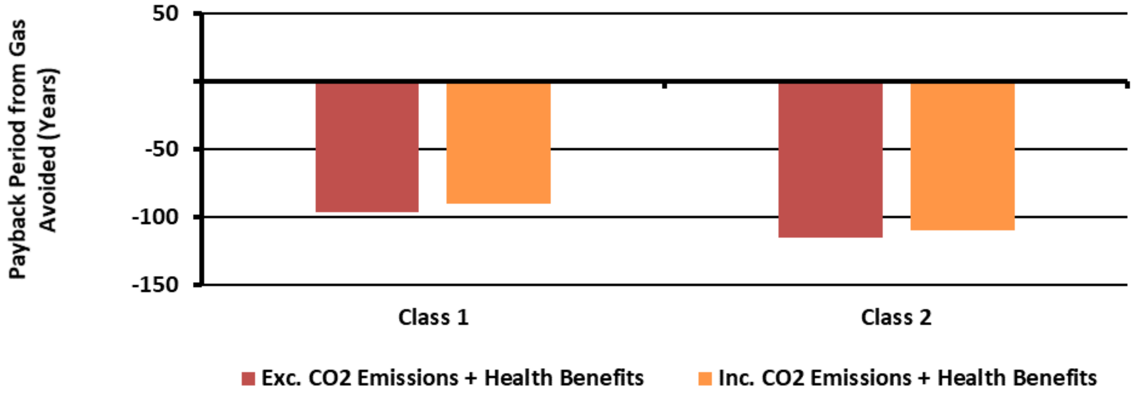
Source: Energeia

Figure 71 – Water Heating Electrification Payback Period by Dwelling Type



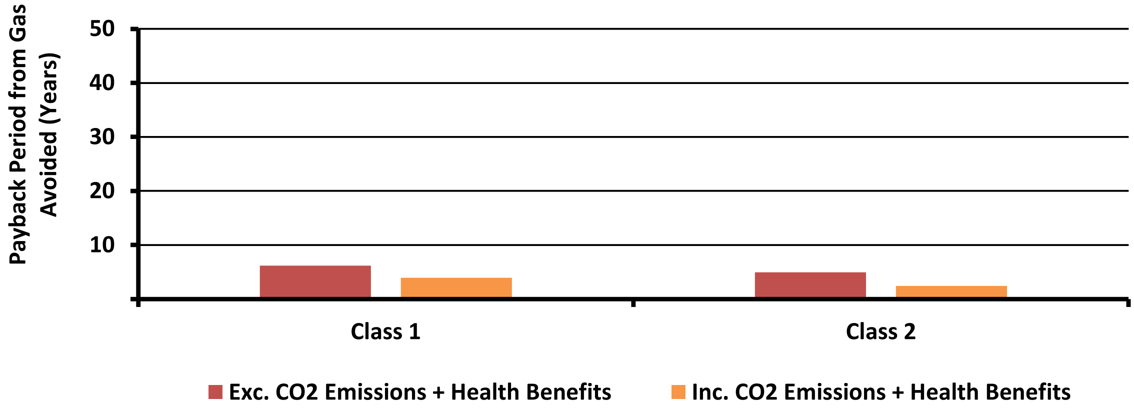
Source: Energeia

Figure 72 – Cooking Electrification Payback Period by Dwelling Type



Source: Energeia

Figure 73 – Draught Sealing Payback Period by Dwelling Type



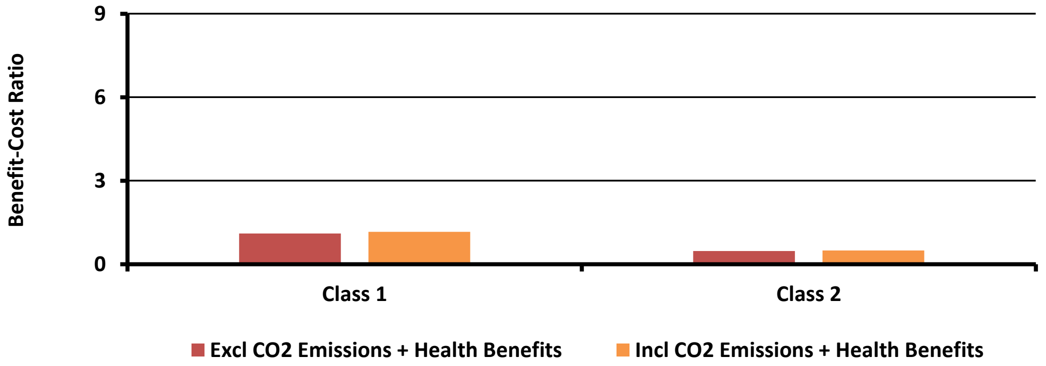
Source: Energeia

Energeia notes cooking electrification's negative payback period. This is a consequence of it being currently cheaper to install and run gas cooktops in comparison to induction cooking for residential premises, based on assumed upfront costs, relative efficiency, and retail tariffs, which was also the case for commercial cooking electrification.

5.2.3.3 Benefit-Cost Ratio

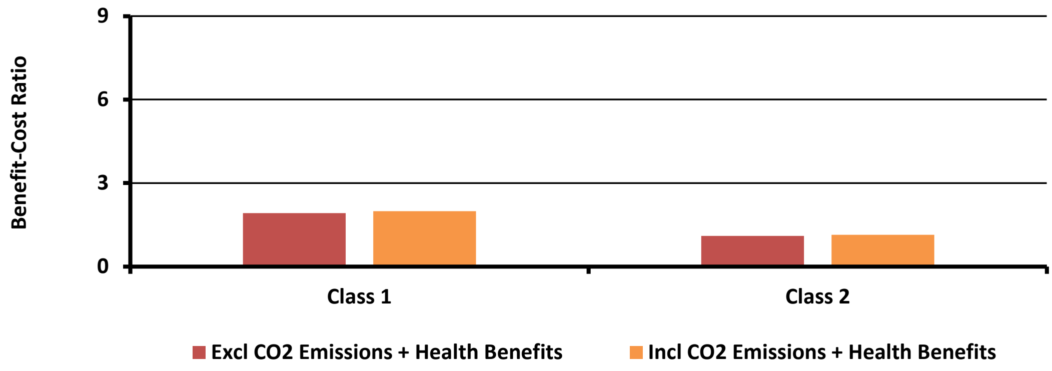
The results of Energeia's benefit-cost modelling are reported in the figures below by residential dwelling class and end use, with and without health benefits. The modelled BCRs reflect the net benefit and payback results, with less than 1 BCRs for Class 2 HVAC electrification, and over 8 BCRs for Class 2 insulation including CO_2 and health benefits.

Figure 74 – Space Heating Electrification Benefit-Cost Ratio by Dwelling Type



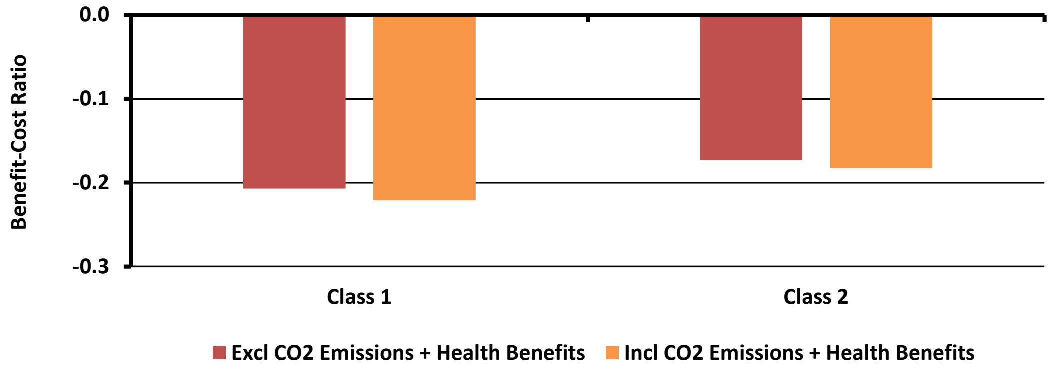
Source: Energeia

Figure 75 – Water Heating Electrification Benefit-Cost Ratio by Dwelling Type



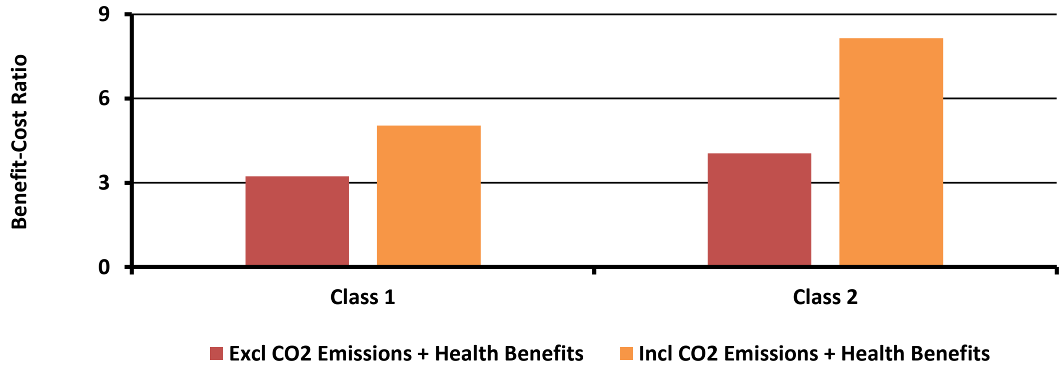
Source: Energeia

Figure 76 - Cooking Electrification Benefit-Cost Ratio by Dwelling Type



Source: Energeia

Figure 77 – Draught Sealing Benefit-Cost Ratio by Dwelling Type



Source: Energeia

Cooking electrification also results in negative BCR, which is again the consequence of it being currently cheaper to install and run gas cooktops in comparison to induction cooking for residential premises, based on assumed upfront costs, relative efficiency, and retail tariffs.

5.3 Ranking

The purpose of this study is to identify the best energy efficiency opportunities for Infrastructure Victoria to recommend to the Victorian Government for implementation as part of their net zero carbon strategy. Energeia, in consultation with Northmore Gordon and Infrastructure Victoria, applied the same fit-for-purpose ranking methodology detailed in the commercial section to identify the best residential energy efficiency opportunities.

5.3.1 Results

The result of Energeia's ranking process, with financial results inclusive of carbon costs and health benefits, is reported in Table 13 below.

Table 13 – Residential Ranking of Energy Efficiency Measures

Ranking	End Use	Indicator (/customer)	Class 1	Class 2
1	Space Heating	Total Annual Gas Potential (GJ)	33.2	13.9
		Total Annual Energy Savings Potential (GJ)	29.9	12.5
		Total Annual CO_2 Potential (t CO_2)	5.8	2.4
		Annuitized Cost	$4,882.74	$4,882.74
		Customer BCR	1.2	0.5
		Customer Payback	17.3	40.3
		Customer IRR	1%	-12%
2	Water Heating	Total Annual Gas Potential (GJ)	19.1	9.4
		Total Annual Energy Savings Potential (GJ)	11.1	7.4
		Total Annual CO_2 Potential (t CO_2)	1.0	0.7
		Annuitized Cost	$1,164.50	$1,164.50
		Customer BCR	2.0	1.1
		Customer Payback	10.1	17.5
		Customer IRR	12%	1%
3	Draught Sealing	Total Annual Gas Potential (GJ)	6.0	2.5
		Total Annual Energy Savings Potential (GJ)	6.0	2.5
		Total Annual CO2 Potential (t CO_2)	1.6	0.7
		Annuitized Cost	$613.74	$257.04
		Customer BCR	5.0	8.1
		Customer Payback	4.0	2.5
		Customer IRR	44%	72%
4	Cooking	Total Annual Gas Potential (GJ)	2.5	1.6
		Total Annual Energy Savings Potential (GJ)	0.9	0.6
		Total Annual CO_2 Potential (t CO_2)	-0.8	-0.5
		Annuitized Cost	$1,238.42	$1,238.42
		Customer BCR	-0.2	-0.2
		Customer Payback	-90.5	-109.4
		Customer IRR	N/A	N/A

Source: Energeia Analysis

Based on our assessment of energy and gas savings, and associated cost-benefit outcomes including carbon emissions and health benefits, Energeia recommends that Infrastructure Victoria consider focusing on electrification of space and water heating and on draught sealing as the top three energy efficiency activity opportunities in the Victorian residential sector.

All three opportunities present significant reductions in both gas consumption and emissions, as well as being financially beneficial to the residential customer. The exception to this is Class 2 space heating electrification, which has a high payback period of 40 years. Incentives could be considered in order to increase the energy efficiency of this dwelling type.

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Appendix A. Individual CBA Outputs for Industrial and Large Commercial

The following tables set out the Individual CBA outputs for each of the industrial and large commercial sub-sectors. Note that GHG emissions and energy cost savings are based on 2021 emissions factors and energy tariffs.

Table 14: Burner and Boiler Upgrades for Industrial and Large Commercial sub-sectors

Sub-sector	Number of facilities applicable	Ave Gas consumption GJ	Actual changes	Gas savings	Electricity savings/cost (MWh)	Average CAPEX	Energy cost savings	Payback	GHG Emissions Saving
Division B - Mining	38	2,130	Reducing excess air, burner controls	10%	12.60	$20,000	$3,576	5.6	20.9
Food, beverage and tobacco product manufacturing	242	67,060	Oxygen trim, high efficiency burners, high efficiency boilers, condensing boilers (for hot water), insulation of boiler itself	10-15%	8.40	$250,000	$101,898	2.5	524.9
Textile, leather, clothing and footwear manufacturing	52	61,987	High efficiency boilers (hot water), condensing boilers (hot water)	10-15%	0.00	$150,000	$77,754	1.9	399.3
Wood product manufacturing	60	12,154	Oxygen trim, high efficiency boilers, condensing boilers (hot water)	10-15%	0.00	$50,000	$15,245	3.3	78.3
Pulp, paper and converted paper product manufacturing	32	285,833	Economisers, high efficiency burners	5%	0.00	$100,000	$143,413	0.7	736.4
Printing (including the reproduction of recorded media)	46	2,413	Oxygen trim, high efficiency burners, high efficiency boilers, economisers	10%	0.00	$20,000	$2,421	8.3	12.4
Petroleum and coal product manufacturing	18	391,612	High efficiency burners, reduce excess air, high efficiency boilers	15-20%	16.80	$400,000	$689,620	0.6	3544.6

Sub-sector	Number of facilities applicable	Ave Gas consumption GJ	Actual changes	Gas savings	Electricity savings/cost (MWh)	Average CAPEX	Energy cost savings	Payback	GHG Emissions Saving
Basic chemical and chemical product manufacturing	95	67,148	Reducing excess air, burner controls, high efficiency burners, oxy burners (high temp applications)	5%	16.80	$100,000	$35,608	2.8	186.2
Polymer product and rubber product manufacturing	95	1,596	Not applicable						
Non-metallic mineral product manufacturing	68	102,395	Oxy burners, economisers, reduce excess air, improved burner controls	5%-10%	8.40	$100,000	$78,022	1.3	402.3
Primary metal and fabricated metal product manufacturing	204	20,532	Pulse firing burners, reduce excess air, burner controls	5% to 20%	0.00	$100,000	$25,754	3.9	132.2
Transport equipment & machinery and equipment manufacturing	313	224	Not applicable						
Commercial office	110	10,227	Condensing boilers	10%	0.00	$50,000	$12,828	3.9	65.9
Large retail	70	12,857	Not applicable						
Aquatic Centre/other Public	480	7,500	Condensing boilers	10%	0.00	$35,000	$18,815	1.9	96.6
Health care and social services	91	22,379	High efficiency boilers (hot water), condensing boilers (hot water)	15%	0.00	$100,000	$33,685	3.0	173.0
Large Education	33	61,711	Not applicable						
Other Commercial	112	18,183	Not applicable/Not modelled						

Table 15: Low Temperature Heat Pumps for Industrial and Large Commercial sub-sectors

Sub-sector	Number of facilities applicable	Ave Gas consumption GJ	Actual changes	Gas savings	Electricity savings/cost (MWh)	Average CAPEX	Energy cost savings	Payback	GHG Emissions Savings
Division B - Mining	38	2,130	Not applicable						0.0
Food, beverage and tobacco product manufacturing	242	67,060	Replace hot water boilers with heat pump, replace steam HEX water with heat pump	20-40%	-1490.22	$600,000	$99,108	6.05	214.4
Textile, leather, clothing and footwear manufacturing	52	61,987	Replace hot water boilers with heat pump	30-60%	-1721.87	$500,000	$114,514	4.37	247.7
Wood product manufacturing	60	12,154	Air to air heat pump dehumidification of sawmill kilns	35%	-236.32	$50,000	$15,717	3.18	34.0
Pulp, paper and converted paper product manufacturing	32	285,833	Not applicable						
Printing (including the reproduction of recorded media)	46	2,413	Not applicable						
Petroleum and coal product manufacturing	18	391,612	Not applicable						
Basic chemical and chemical product manufacturing	95	67,148	Replace hot water boilers with heat pump	10-20%	-559.57	$300,000	$37,214	8.06	80.5
Polymer product and rubber product manufacturing	95	1,596	Not applicable						
Non-metallic mineral product manufacturing	68	102,395	Not applicable						
Primary metal and fabricated metal product manufacturing	204	20,532	Not applicable						

Sub-sector	Number of facilities applicable	Ave Gas consumption GJ	Actual changes	Gas savings	Electricity savings/cost (MWh)	Average CAPEX	Energy cost savings	Payback	GHG Emissions Savings
Transport equipment & machinery and equipment manufacturing	313	224	Not applicable						
Commercial office	110	10,227	Replace DHW with heat pump + replace hot water loops in HVAC with reverse cycle chiller	10-20%	-340.90	$240,000	$22,671	10.6	49.0
Large retail	70	12,857	Replace DHW with heat pump + Reverse cycle packaged units		-428.57	$240,000	$28,502	8.4	61.6
Aquatic Centre/other Public	480	7,500	Replace boilers with heat pump	70-100%	-666.67	$400,000	$44,337	9.0	95.9
Health care and social services	91	22,379	Heat pump hot water + replace hot water loops in HVAC with reverse cycle chiller	15%	-621.63	$400,000	$41,342	9.7	89.4
Education	33	61,711	Replace DHW with heat pump + replace gas heating with reverse cycle chillers	15%	-2057.02	$1,000,000	$136,804	7.3	295.9
Other Commercial	112	18,183	Not applicable						

Table 16: Heat Recovery for Industrial[52]

Sub-sector	Number of facilities applicable (ABS)	Ave Gas consumption GJ	Actual changes	Gas savings	Electricity savings/cost (MWh)	Average CAPEX	Energy cost savings	Payback	GHG Emissions Savings
Division B - Mining	38	2,130	Not applicable		0				

[52] Activity not considered for Large Commercial sectors

Food, beverage and tobacco product manufacturing	242	67,060	Heat recovery from compressors, process heat integration, optimising heat exchangers	10%	0	$250,000	$67,292.74	3.72	345.6
Textile, leather, clothing and footwear manufacturing	52	61,987	Heat recovery from compressors, optimising heat exchangers	10%	0	$150,000	$62,202.82	2.41	319.4
Wood product manufacturing	60	12,154	Kiln heat recovery, preheat combustion air	10%	0	$50,000	$12,195.81	4.10	62.6
Pulp, paper and converted paper product manufacturing	32	285,833	Pre-heat combustion air, process heat integration, flash steam recovery for low pressure steam, blowdown heat recovery	10-20%	0	$500,000	$430,239.97	1.16	2209.3
Printing (including the reproduction of recorded media)	46	2,413	Not applicable						
Petroleum and coal product manufacturing	18	391,612	Preheat combustion air, process heat integration, flash steam recovery for low pressure steam, blowdown heat recovery	5% - 15%	0%	$500,000	$294,729.75	1.70	1513.5
Basic chemical and chemical product manufacturing	95	67,148	Preheat combustion air, process heat integration, flash steam recovery for low pressure steam, blowdown heat recovery	5% - 10%	0%	$200,000	$50,536.05	3.96	259.5
Polymer product and rubber product manufacturing	95	1,596	Not applicable						
Non-metallic mineral product manufacturing	68	102,395	Preheat combustion air, furnace/kiln heat recuperator, heat recovery from compressors, flash steam heat recovery	~10%	0%	$400,000	$102,751.14	3.89	527.6
Primary metal and fabricated metal product manufacturing	204	20,532	Furnace recuperators, combustion air preheating	10%	0%	$400,000	$30,904.50	12.94	158.7
Transport equipment & machinery and equipment manufacturing	313	224	Not applicable						

Appendix B. Detailed CBA Reporting for Small Commercial Opportunities

The following section outlines the key outcomes of Energeia analysis.

Commercial CBA Reporting Outcomes

The following section contains the ranking tables of Energeia commercial analysis by end use, in order of the final ranking developed. The breakdown of rankings by segment and end use against Energeia's benchmarking metrics can be seen in the table below.

Table 17 – Commercial Ranking by End Use and Segment

End Use	Indicator (000' m2)	Restaurant	Hotels	Hospitals	Offices	Retail	Public Buildings	Schools	Law Courts	Warehouse	Aged Care	Tertiary	Weighted Average
Space Heating	Total Annual Gas Potential (GJ)	285.1	249.1	364.8	202.9	215.1	386.7	273.7	118.3	32.4	137.4	477.3	219.7
	Total Annual Energy Savings Potential (GJ)	247.6	216.6	316.9	176.1	186.8	335.9	237.7	102.8	28.1	119.3	414.9	190.8
	Total Annual CO_2 Potential (t CO_2)	11.8	10.3	15.1	8.4	8.9	16.0	11.3	4.9	1.3	5.7	19.7	9.1
	Annuitized Cost	$509.36	$13,433.45	$28,587.72	$362.01	$1,744.34	$62,642.00	$25,328.71	$2,061.35	$550.88	$1,846.95	$6,959.24	$9,516.08
	Customer Payback	8.5	12.5	12.6	8.7	10.7	12.5	13.0	10.9	8.5	9.8	11.7	10.6
	Customer BCR	2.4	1.6	1.6	2.3	1.9	1.6	1.5	1.8	2.4	2.0	1.7	2.0
	Customer IRR	16.4%	7.4%	7.2%	15.6%	10.7%	7.3%	6.6%	10.2%	16.2%	12.9%	8.8%	12%
Water Heating	Total Annual Gas Potential (GJ)	325.8	120.3	124.3	65.6	13.7	19.7	69.5	11.8	3.0	341.9	121.7	82.2
	Total Annual Energy Savings Potential (GJ)	261.6	96.6	99.8	52.6	11.0	15.8	55.8	9.5	2.4	274.4	97.7	66.0
	Total Annual CO_2 Potential (t CO_2)	11.7	4.3	4.4	2.3	0.5	0.7	2.5	0.4	0.1	12.2	4.4	2.9

	Annuitized Cost	$262.93	$2,923.02	$4,394.83	$52.97	$50.02	$1,438.67	$2,914.05	$93.10	$58.22	$2,049.29	$800.66	$1,274.97
	Customer Payback	5.7	9.2	11.0	4.7	5.0	9.8	12.8	5.0	0.0	11.2	7.5	6.9
	Customer BCR	3.5	2.2	1.8	4.2	4.0	2.0	1.6	4.0	0.0	1.8	2.7	2.3
	Customer IRR	28%	14%	10%	34%	32%	13%	7%	32%	0%	10%	19%	17%
Cooking	Total Annual Gas Potential (GJ)	1238.1	91.6	0.0	0.0	20.5	29.5	12.9	1.7	0.0	0.0	22.7	52.3
	Total Annual Energy Savings Potential (GJ)	660.6	48.4	0.0	0.0	10.9	15.7	6.9	0.9	0.0	0.0	12.1	27.9
	Total Annual CO_2 Potential (t CO_2)	-32.8	-2.4	0.0	0.0	-0.5	-0.8	-0.3	0.0	0.0	0.0	-0.6	-1.4
	Annuitized Cost	$15,967.86	$34,862.22	$61.92	$61.92	$1,199.18	$34,488.09	$8,624.23	$221.83	$61.92	$61.92	$2,369.57	$4,778.18
	Customer Payback	-68.3	-61.6	0.0	0.0	-102.9	-61.7	-80.6	-102.9	0.0	0.0	-101.8	-41.8
	Customer BCR	-0.3	-0.3	0.0	0.0	-0.2	-0.3	-0.2	-0.2	0.0	0.0	-0.2	-0.1
	Customer IRR	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Draught Sealing	Total Annual Gas Potential (GJ)	5.8	12.9	11.7	15.2	35.0	24.2	6.8	7.5	1.1	12.2	30.5	13.1
	Total Annual Energy Savings Potential (GJ)	5.8	12.9	11.7	15.2	35.0	24.2	6.8	7.5	1.1	12.2	30.5	13.1
	Total Annual CO_2 Potential (t CO_2)	0.3	0.7	0.6	0.8	1.8	1.3	0.4	0.4	0.1	0.6	1.6	0.7
	Annuitized Cost	$48.05	$876.30	$1,686.92	$21.10	$81.67	$2,898.00	$1,399.11	$99.82	$26.48	$281.05	$384.42	$542.59
	Customer Payback	7.8	5.9	9.5	2.5	1.8	4.1	12.1	3.6	5.0	3.6	4.2	6.0
	Customer BCR	2.6	3.4	2.1	8.1	11.4	4.9	1.6	5.6	4.0	5.6	4.7	5.1
	Customer IRR	19%	27%	14%	70%	96%	41%	8%	47%	34%	47%	40%	42%

Appendix C. Commercial Sector Stock Inclusions

The Commercial Baseline Study formed the foundations of the segments used in the Commercial Sector Analysis. The following table outlines inclusions and exclusions defined by the datasets utilised and defined in the report body.

Table 18 Inclusions and Exclusions by Segment

Segment	Inclusions	Exclusions
Offices	Standalone offices, with a Net Lettable Area of greater than 1000m^2	Non-standalone offices such as home offices, offices within industrial buildings or office building less than 1000m^2
Hospitals	Public and private hospitals	Health clinics and doctors' surgeries
Aged Care	Aged Care	
Hotels	Hotels, including related office, conference, and dining facilities	Hotels and motels with fewer than 5 beds
Law Courts	Court Houses	
Public Buildings	Galleries, museums, libraries	Aquatic centres, religious buildings, kindergartens, childcare, and other public buildings
Retail	Shopping centres and supermarkets	Food service
Restaurants	Restaurants, cafes, coffee shops, bars, and fast-food outlets	
Schools	Public and private schools	
Tertiary	University and TAFE buildings	
Warehouses	Warehouses	

Source: Council of Australian Governments (2012) 'Baseline Energy Consumption and Greenhouse Gas Emissions in Australia

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