Tracking Victoria's Energy Transition – 1990 to 2020

November 2022

Sustainability Victoria

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Sustainability Victoria acknowledges Aboriginal and Torres Strait Islander people as the Traditional Custodians of the land and acknowledges and pays respect to their Elders, past and present.

Foreword

Victoria's *Climate Change Act 2017* established a long-term greenhouse target of net zero emissions by 2050. Prior to this legislation the Victorian Government committed to reduce emissions by 15 to 20% below 2005 levels by 2020. Interim abatement targets have also been set under the *Act:* a 28 to 33% reduction by 2025; and a 45 to 50% reduction by 2030.

In 2004-05, Victoria's total net greenhouse gas emissions were 118.6 Mt CO_2-e, with 104.5 Mt CO_2-e, or 88.1%, of this resulting from energy production and use in Victorian homes, institutions and businesses, and for transport. These emissions will need to transition to net zero by 2050, requiring significant changes to the way in which energy is produced and used. Electricity and gas use will need to result in net zero emissions, either because they are produced from renewable sources, or because any emissions generated are captured and stored. Transport will need to result in net zero emissions, either because it is powered by renewable electricity or by zero emission fuels. Further, to manage the costs involved in this energy transition and to ensure the stability of the electricity supply system, it will be important to manage the amount of energy that is consumed *and* the timing of its use.

In this report we track the key elements of Victoria's energy transition from 1989-90 to 2019-20, with a focus on the period from 2004-05 to 2019-20, as 2005 is the benchmark year for our emission reduction targets. We look at how energy consumption has changed, in total and in the different economic sectors, how the electricity and natural gas production and distribution systems are changing, and how energy-related greenhouse gas emissions are changing in the wider context of our overall emissions.

This new report builds on a series of reports that Sustainability Victoria has prepared over the last five years for internal use. A key difference is that the data has been analysed from the perspective of the energy transition that is now well underway and the report has expanded to cover the transition of both the electricity and gas systems. In the main, this is a success story.

The energy production and consumption in Victoria today has been influenced by Victorian and Commonwealth government policies implemented over the last two decades, including policies to encourage both large- and small-scale renewable electricity generation, and policies to reduce energy consumption through: more efficient new buildings and equipment; replacing existing inefficient equipment with more efficient equipment, and; promoting energy saving behaviours. A key take out from the analysis is that Victoria is well on track to meet, and likely exceed, its current renewable energy and interim greenhouse targets. Policies have been particularly successful in increasing the share of renewable electricity in the overall generation mix, reducing the greenhouse intensity of Victoria's electricity supply. This is putting Victoria in a good position to reduce greenhouse emissions from gas appliances and equipment and from road transport, through policies and programs that facilitate electrification. The transformation of the gas and transport sectors to support Victoria's net zero target is still in the very early stages but is likely to gather pace during the 2020s.

One limitation of this report is that we have relied on the 2021 edition of the Australian Energy Statistics (AES) as the main source of energy consumption data, as it provides Australia's official energy statistics. It became evident during the preparation of the report that there are significant issues with the electricity and natural gas consumption data in the AES, and that better data is now available in information that electricity and gas distributors provide to the Australian Energy Regulator. These issues are discussed in Appendix 4 of the report. We have contacted the team at the Department of Industry, Science, Energy and Resources (DISER) responsible for preparing the 2021 edition of the AES used for this report and made them aware of these issues[1].

We intend to continue to track Victoria's energy transition using the available historical data, and update this report each year as new data becomes available.

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[1] The September 2022 release of the AES data includes some changes which have responded, in part, to the issues raised.

Executive summary

Victoria's *Climate Change Act 2017* established a long-term greenhouse target of net zero emissions by 2050. Prior to this legislation the Victorian Government committed to reduce emissions by 15 to 20% below 2005 levels by 2020. Interim abatement targets have also been set under the *Act:* a 28 to 33% reduction by 2025; and, a 45 to 50% reduction by 2030. In 2004-05, Victoria's total net greenhouse gas emissions were 118.6 Mt CO_2-e, with 104.5 Mt CO_2-e, or 88.1%, of this resulting from energy use in Victorian homes, institutions and businesses, and for transport. These emissions will need to transition to net zero by 2050, requiring significant changes to the way in which energy is produced and used. Electricity and gas use will need to result in net zero emissions, either because they are produced from renewable sources, or because any emissions generated during their production are captured and stored. Transport will need to result in net zero emissions, either because it is powered by renewable electricity or by zero emission fuels. Further, to manage the costs involved in this energy transition and to ensure the stability of the energy supply system, it will be important to manage the amount of electricity that is consumed *and* the timing of its use.

In this report we track the key elements of Victoria's energy transition from 1989-90 to 2019-20, with a focus on the period from 2004-05 to 2019-20, as 2005 is the benchmark year for our emission reduction targets. We look at how energy consumption has changed in the different economic sectors, how the electricity and natural gas production and distribution systems are changing, and how energy-related greenhouse gas emissions are changing in the wider context of our overall emissions. The analysis presented is based on historical data and so is backward looking. However, we also consider the implications of the recent historical trends for energy consumption and greenhouse gas emissions over the next decade, highlighting issues that will need to be addressed and likely future developments.

The energy production and consumption in Victoria today has been influenced by Victorian and Commonwealth government policies implemented over the last two decades, including policies to encourage both large- and small-scale renewable electricity generation, and policies to reduce energy consumption through: more efficient new buildings and equipment; replacing existing inefficient equipment with more efficient equipment, and; promoting energy saving behaviours. A key take out from the analysis is that Victoria is well on track to meet, and likely exceed, its current renewable energy and interim greenhouse targets. Policies have been particularly successful in increasing the share of renewable electricity in the overall generation mix, reducing the greenhouse intensity of Victoria's electricity supply. This is putting Victoria in a good position to reduce greenhouse gas emissions from gas appliances and equipment and from road transport, through policies and programs that facilitate electrification. The transformation of the gas and transport sectors to support Victoria's net zero target is still in the very early stages but is likely to gather pace during the 2020s.

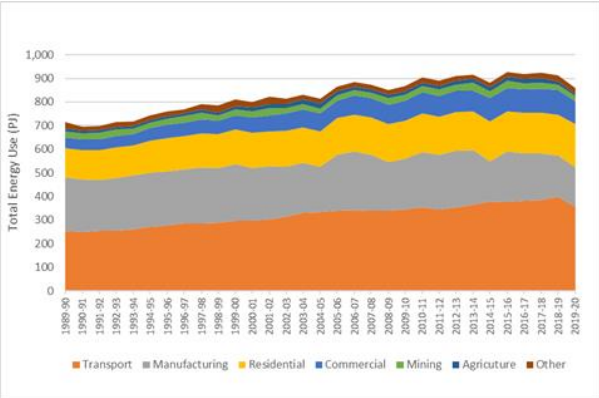
Another key observation is that the interdependence between the electricity and gas supply and transport systems is increasing, and that the interdependence between government policies that seek to influence energy supply and energy demand – long treated as largely separate domains – is also increasing. Historically, some electricity has been used in the production of natural gas and transport fuels, and natural gas has been used to power gas peaking plant to generate electricity at times of higher demand. In future, electricity will become a key transport 'fuel', and gas appliances and equipment will increasingly be replaced by electrical ones. This will increase the amount of renewable electricity that needs to be generated and increase electricity peak demand in both summer and winter. Some natural gas and transport fuels are likely to be replaced by hydrogen; renewable hydrogen can be produced from renewable electricity via electrolysis, ideally during the middle of the day to utilise excess solar electricity generation. The electricity supply system will become increasingly decentralised, with large, medium and small-scale renewable generators located around the state. A range of demand side activities will be necessary to help maintain the stability of this system, including storage, energy efficiency, load shifting and demand response. The role of energy efficiency will expand from a prime focus on saving energy to reduce energy bills *and* greenhouse gas emissions, to reducing energy bills, managing the growth in renewable electricity demand and helping to avoid network constraints. The location and timing of the energy savings will be just as important as the magnitude of the energy saving. Reducing electricity use at times of peak demand and shifting electricity use to the middle of the day to soak up excess PV generation will also become increasingly important.

The time period covered by this report includes the onset of restrictions introduced from March 2020 to manage the COVID-19 pandemic. These have had a noticeable impact on energy consumption in 2020 and disrupted the longer-term energy consumption trends. Residential energy consumption increased, while energy consumption in the Commercial sector (offices, retail, entertainment) and, especially, for Transport decreased. The influence of the

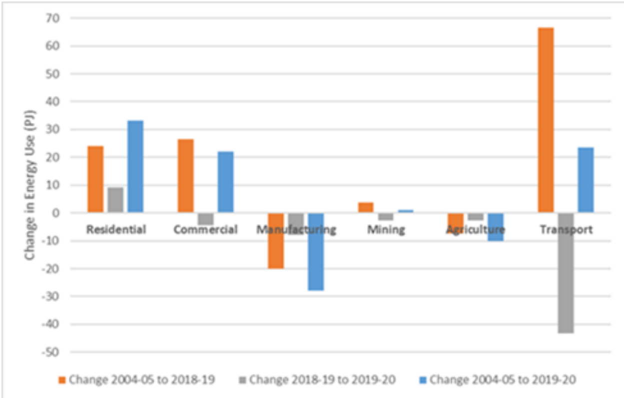
COVID-19 pandemic on energy consumption is likely to be present for several years and may have longer term implications for Victoria's energy consumption.

Victoria's overall energy consumption

The level and type of energy consumption has important implications for both the economy (energy costs, energy productivity) and the environment (greenhouse gas and other atmospheric emissions). In 2019-20, total energy *end-use* was 860.2 petajoules (PJ). It was dominated by the Transport (41.4%), Residential (21.3%), Manufacturing (19.3%) and Commercial (11.3%) sectors. Since 2004-05, total energy use has declined in the Manufacturing sector, but has increased in the other key sectors. The onset of COVID-19 restrictions in the last four months of 2019-20 disrupted the long-term energy consumption trends. From 2018-19 to 2019-20, energy consumption increased in the Residential sector by 5.3%, but declined in the Transport (10.8%) and Commercial (4.4%) sectors.

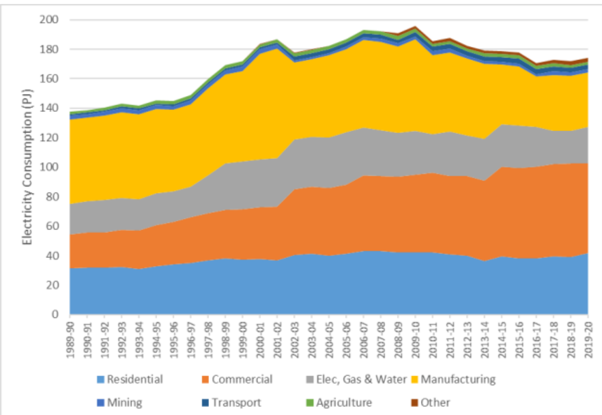


Victoria's total energy end-use, by sector

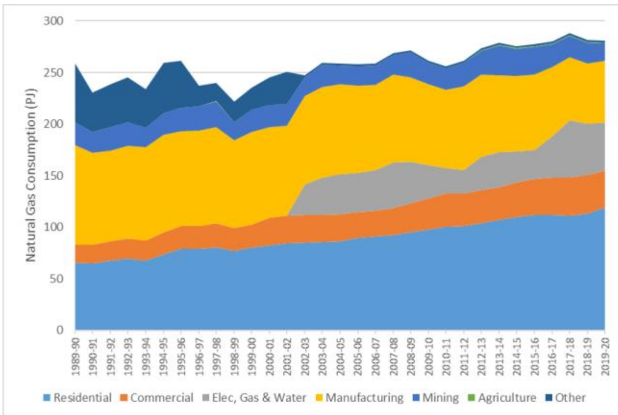


Impact of COVID-19 restrictions

Total Victorian electricity consumption in 2019-20 was 174.0 PJ. This was dominated by the Commercial sector (34.9%), followed by the Residential (24.1%), Manufacturing (21.1%), and Electricity, Gas and Water (14.2%) sectors. The Transport, Mining, Agriculture and Other sectors, played only a minor role. Since 2004-05, total electricity consumption has decreased by 8.3 PJ (4.6%). Consumption decreased in the Manufacturing (34.2%), Electricity, Gas and Water (28.6%) and Agriculture (13.1%) sectors, but increased in the Commercial (33.5%), Residential (4.4%), Mining (56.1%) and Transport (20.0%) sectors.



Victoria's total electricity consumption, by sector



Victoria's total natural gas consumption, by sector

Total Victorian natural gas consumption was 283.4 PJ in 2019-20. This was dominated by the Residential sector (42.0%), followed by the Manufacturing (21.0%), Electricity, Gas and Water (16.5%), Commercial (12.6%), and Mining (6.0%) sectors. Since 2004-05, total natural gas consumption has increased by 24.3 PJ (9.4%). This increase has been mainly in the Residential (38.3%), Commercial (34.9%), Electricity, Gas and Water (21.1%), and Transport (743%) sectors. Consumption decreased in the Manufacturing (31.9%) and Mining (6.2%) sectors.

Victoria's energy productivity remained below Australia's from 1989-90 until 2016-17, but from 2015-16 began increasing at a much faster rate so that, at $371.4 million/PJ, it now sits well above Australia's energy productivity of $323.8 million/PJ. Based on projected trends, Victoria's energy productivity may increase to around $575 million/PJ in 2029-30, an increase of 102% compared to 2015 and well above the Victorian Government's aspirational target of a 50% increase.

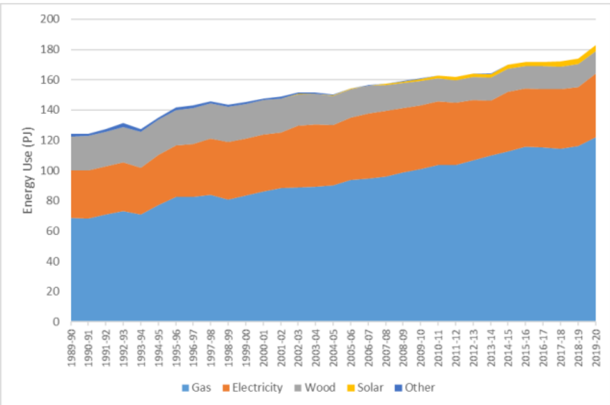
The Residential, Commercial and Road transport sectors are key drivers of increasing energy consumption and greenhouse emissions and are strongly influenced by population growth. Combined, they accounted for 59.1% of natural gas use, 54.7% of electricity use, 31.0% of other energy use, and 67.2% of Victoria's total net greenhouse gas emissions.

Transport energy consumption is dominated by Road (75.6%) and Air (18.8%) transport. Prior to the COVID-19 pandemic, energy use and emissions from Air transport were growing strongly, especially international air transport.

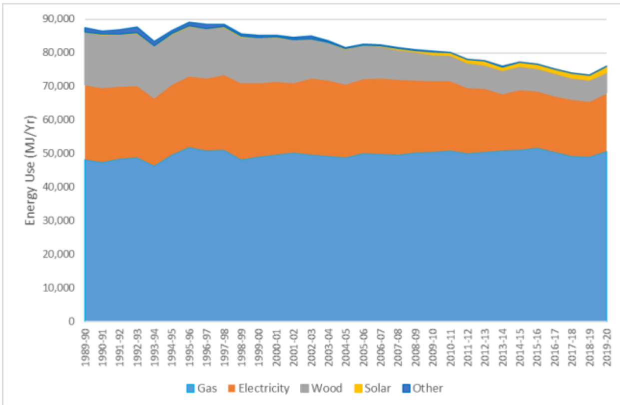
Victorian residential energy consumption

Residential energy consumption has a significant influence on Victoria's overall energy consumption and greenhouse gas emissions. It accounts for 24.1% of electricity use, 42.0% of natural gas use, and 22.2% of Victoria's net greenhouse gas emissions. Total Residential energy consumption in 2019-20 was 183.1 PJ, dominated by gas (66.7%), mains electricity (22.9%) and wood (8.2%). This consumption has shown a general increasing trend since 1989-90, driven mainly by increasing gas use, as well as increasing solar energy use since 2006-07. Since 2004-05, Residential energy consumption has increased by 33.1 PJ (22.1%), with gas use increasing by 32.1 PJ (35.6%) and electricity use increasing by 1.8 PJ (4.4%).

The commencement of COVID-19 restrictions in March 2020, combined with an unusually cold start to winter, had a significant impact on Residential energy consumption. Between 2004-05 and 2018-19, energy consumption increased by 23.9 PJ (15.9%), with gas use increasing by 26.1 PJ (29.0%) and electricity use falling by 1.1 PJ (2.7%). However, between 2018-19 and 2019-20, Residential energy consumption increased by 9.2 PJ (5.3%), with gas use increasing by 5.9 PJ (5.1%) and electricity use increasing by 2.9 PJ (7.3%).



Victoria's Residential energy consumption, by energy source



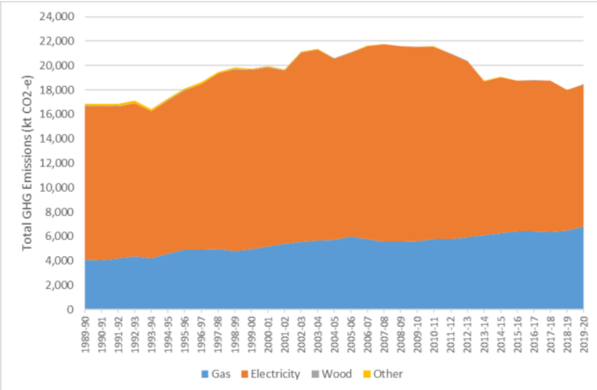
Energy consumption of the average household, by energy source

Since 2004-05, the energy consumption of the average Victorian household has declined by 5,511 MJ/yr (6.8%) to now be 75,944 MJ/yr. Between 2004-05 and 2018-19, it decreased by 8,026 MJ/yr (9.9%), but between 2018-19 and 2019-20 it increased by 2,524 MJ/yr (3.4%) due to the onset of the COVID-19 restrictions.

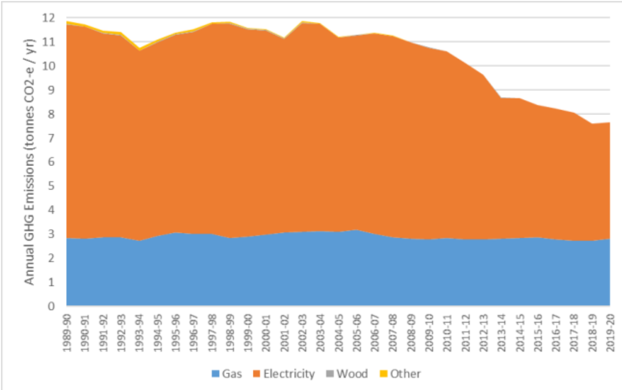
Average household electricity consumption decreased by 5,312 MJ/yr (24.3%), between 2004-05 and 2018-19, but increased by 895 MJ/yr (5.4%) between 2018-19 and 2019-20. The net change to 2019-20 was a decrease of 4,417 MJ/yr (20.2%). Average household gas consumption increased by 140 MJ/yr (0.3%) between 2004-05 and 2018-19 but increased by 1,607 MJ/yr (3.3%) in the year to 2019-20. The net change to 2019-20 was an increase of 1,747 MJ/yr (3.6%).

One of the most rapid changes in household energy consumption has been for solar energy. Between 2004-05 and 2019-20, the solar energy consumption of the average house increased by 1,597 MJ/yr (2,197%).

In 2019-20, we estimate that total Victorian greenhouse gas emissions from Residential *energy end-use* were 18.5 Mt CO_2-e, with electricity consumption responsible for 11.7 Mt CO_2-e (63.1%) and gas consumption responsible for 6.8 Mt CO_2-e (36.8%). Since 2004-05, total Residential greenhouse gas emissions from energy end-use have decreased from 20.6 Mt CO_2-e to 18.5 Mt CO_2-e, a reduction of 2.1 Mt CO_2-e (10.4%). The onset of the COVID-19 restrictions mean that the reduction is not as large as might have been expected, due to an increase in emissions from 2018-19 to 2019-20.



Victoria's Residential greenhouse emissions from energy end-use, by energy source



Greenhouse gas emissions from energy end-use in the average Victorian household, by energy source

From 2004-05 to 2018-19, we estimate that total emissions from Residential electricity consumption declined from 14.8 Mt CO_2-e to 11.5 Mt CO_2-e, a reduction of 3.3 Mt CO_2-e (22.5%), but between 2018-19 and 2019-20 the emissions increased by 0.14 Mt CO_2-e (1.2%) to 11.7 Mt CO_2-e. The declining greenhouse gas emissions from Residential electricity consumption reflects the reduction in the emissions intensity of mains electricity over this period, and reduced electricity use due to energy efficiency and rooftop PV systems.

From 2004-05 to 2018-19, we estimate that total emissions from Residential gas consumption increased from 5.7 Mt CO_2-e to 6.5 Mt CO_2-e, an increase of 0.8 Mt CO_2-e (13.1%), but between 2018-19 and 2019-20 the emissions increased by 0.34 Mt CO_2-e (5.3%) to 6.8 Mt CO_2-e. The net impact was that between 2004-05 and 2019-20, emissions from gas consumption increased by 1.1 Mt CO_2-e (19.0%).

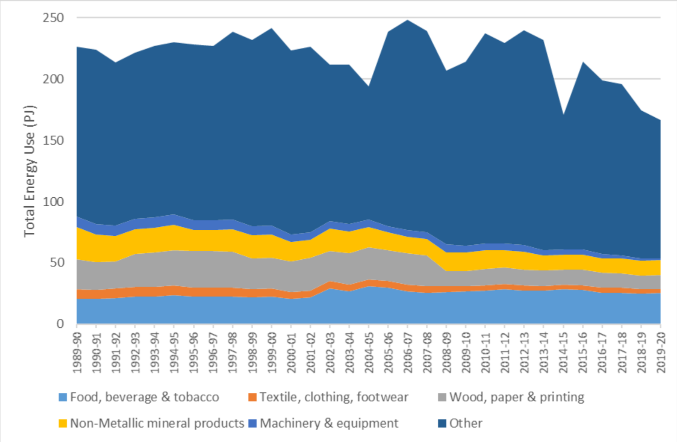
In 2019-20, the greenhouse gas emissions from energy end-use in the average Victorian household are estimated to be 7.7 tonnes CO_2-e. Average household emissions have reduced considerably (by 4.2 tonnes CO_2-e) since 1989-90, when they were 11.9 tonnes CO_2-e.

Between 2004-05 and 2018-19, the total average household emissions reduced by 3.6 tonnes CO_2-e (32.1%); average emissions from electricity decreased by 3.2 tonnes CO_2-e (39.7%) while average emissions from gas decreased by 0.38 tonnes CO_2-e (12.1%). However, in the year to 2019-20, average emissions from gas increased by 0.09 tonnes CO_2-e (3.4%) while average emissions from electricity decreased by 0.03 tonnes CO_2-e (0.5%). The net result was that between 2004-05 and 2019-20, total emissions reduced by 3.53 tonnes CO_2-e (31.5%).

Victorian manufacturing energy consumption

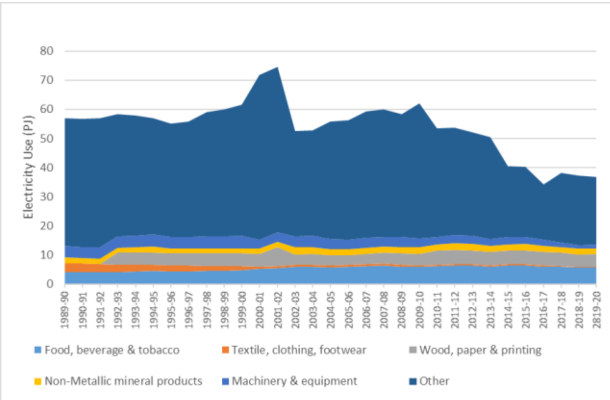
While Manufacturing energy consumption has declined considerably over the last few decades, it is still an important area of energy consumption. It accounts for 21.1% of electricity use and 21.0% of natural gas use. Total Manufacturing energy consumption in 2019-20 was 166.4 PJ, with consumption dominated by the "Other" sub-sector (112.6 PJ or 67.6% of the total). Other key sub-sectors were Food, Beverage and Tobacco (25.6 PJ, 15.4%), Non-Metallic Mineral Products (11.7 PJ, 7.0%), and Wood, Paper and Printing (11.6 PJ, 7.0%).

There was a reduction in total Manufacturing energy consumption between 1999-00 and 2004-05. Consumption then increased each year to 2006-07 and has trended down since then. Between 2004-05 and 2019-20, total Manufacturing energy consumption decreased by 27.8 PJ (14.3%). The largest reductions during this period occurred in the Wood, Paper and Printing (15.0 PJ, 56.3%), Food, Beverage and Tobacco (5.3 PJ, 17.2%), Machinery and Equipment (4.4 PJ, 72.4%), Non-Metallic Mineral Products (4.3 PJ, 26.9%) and Textile, Clothing and Footwear (2.3 PJ, 41.5%) sub-sectors. Energy consumption in the "Other" sub-sector increased by 3.5 PJ (3.2%).

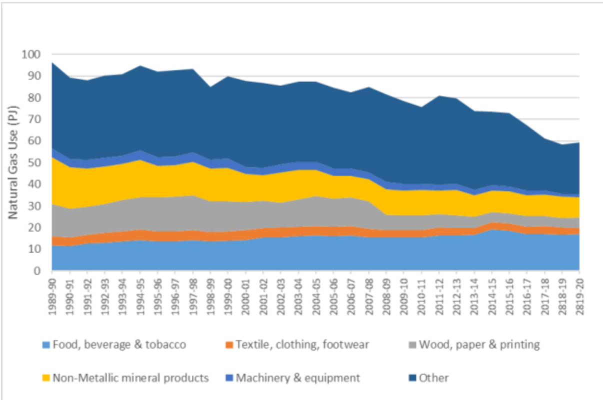


Total Manufacturing energy consumption, by sub-sector

Total electricity consumption in the Manufacturing sector in 2019-20 was 36.7 PJ. Consumption was highest in the "Other" manufacturing sector (23.2 PJ, 63.3%). Other key sub-sectors were Food, Beverage and Tobacco (5.8 PJ, 15.7%), Wood, Paper and Printing (4.4 PJ, 11.9%), and Non-Metallic Mineral Products (1.8 PJ, 5.0%). Since 2004-05, electricity consumption has declined in most Manufacturing sub-sectors. The largest reductions have occurred in the "Other" manufacturing (17.1 PJ, 42.4%), Machinery and Equipment (2.3 PJ, 63.9%), and Textile, Footwear and Clothing (0.6 PJ, 74.2%) sub-sectors. Electricity consumption has increased in the Wood, Paper and Printing (1.0 PJ, 28.3%), and Food, Beverage and Tobacco (0.1 PJ, 2.1%) sub-sectors.



Manufacturing electricity consumption, by sub-sector

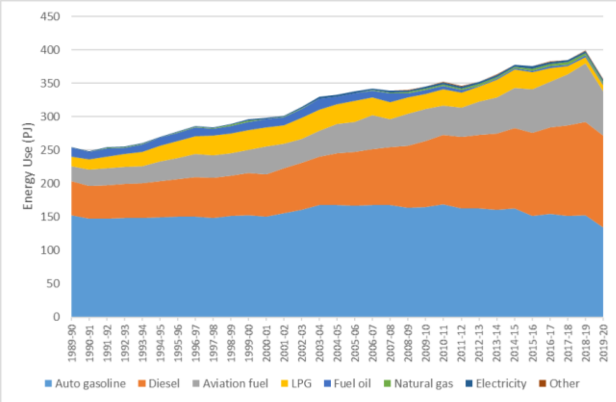


Manufacturing natural gas consumption, by sub-sector

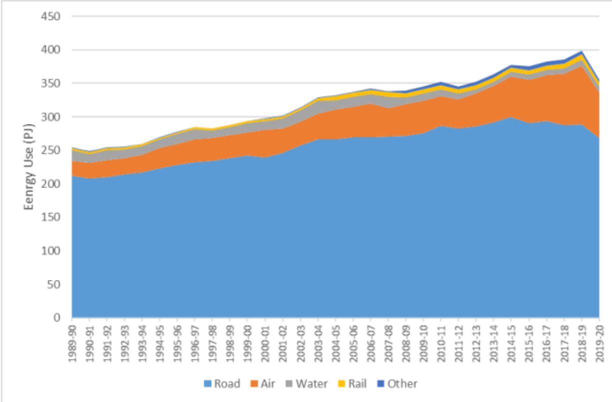
Total natural gas consumption in the Manufacturing sector in 2019-20 was 59.4 PJ. Consumption was largest in the "Other" sub-sector (24.0 PJ, 38.8%). Other key sub-sectors were Food, Beverage and Tobacco (17.0 PJ, 28.5%), Non-Metallic Mineral Products (9.5 PJ, 16.9%), Wood, Paper and Printing (4.7 PJ, 7.6%), and Textile, Footwear and Clothing (3.0 PJ, 5.8%). Since 2004-05, natural gas consumption has declined in all sub-sectors except Food, Beverage and Tobacco (0.5 PJ, 2.7% increase). The largest reductions have occurred in the "Other" manufacturing (16.0 PJ, 40.0%), Wood, Paper and Printing (9.0 PJ, 65.4%), Non-Metallic Mineral Products (2.7 PJ, 22.1%), Machinery and Equipment (2.3 PJ, 63.9%) and Textile, Footwear and Clothing (1.4 PJ, 31.6%) sub-sectors.

Victorian transport energy consumption

Transport is the largest area of energy use in Victoria, accounting for 41.4% of all energy end-use, and is a key area for increasing energy consumption and emissions. In 2019-20, the total energy consumption was 355.0 PJ, significantly lower than the total consumption of 399.9 PJ in 2018-19. This large reduction of 43.2 PJ (10.8%) reflects the impact of the initial COVID-19 lockdowns.



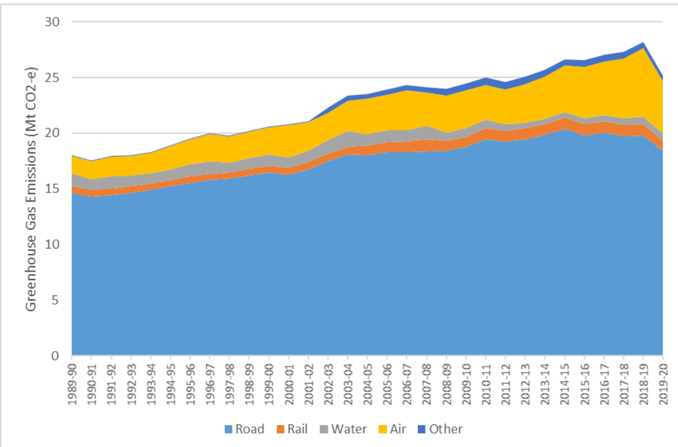
Victorian Transport energy consumption, by fuel



Victorian Transport consumption, by mode

In terms of fuels, in 2019-20 Transport energy consumption was dominated by diesel (38.6%), auto gasoline (37.6%), and aviation fuel (18.8%), together accounting for 95.0% of the total. Between 1989-90 and 2018-19, Transport energy consumption grew by 144.4 PJ (56.7%), with the key growth areas being diesel (increased by 88.7 PJ, 173.9%) and aviation fuel (66.1 PJ, 302.0%). However, the onset of the COVID-19 restrictions in late 2019-20 led to a significant reversal of this long-term growth trend.

In terms of modes, Victorian Transport energy consumption is dominated by Road transport. In 2019-20 this accounted for 269.1 PJ (75.6% of the total), compared to 66.9 PJ (18.8%) for Air transport; Water, Rail and Other modes of transport collectively accounting for only 19.9 PJ (5.6%) of the total. The impact of the COVID-19 restrictions is evident for both Road and Air transport. Between 1989-90 and 2018-19, Road transport energy consumption increased by 75.9 PJ (35.7%) while Air transport energy consumption increased by 66.1 PJ (302.0%). However, between 2018-19 and 2019-20, energy consumption for Road transport decreased by 19.5 PJ (6.8%) and for Air transport decreased by 21.1 PJ (24.0%), noting that restrictions were only in place for around four months of this year.



Victorian Transport sector emissions, by mode

In 2019-20, we estimate that energy consumption in *all modes* of transport in Victoria was responsible for 25.0 Mt CO_2-e of greenhouse gas emissions. If International air transport and International shipping are omitted (they are not included in the official greenhouse gas inventory) as well as electricity use (included under Electricity generation in the inventory), the total is reduced to 20.8 Mt CO_2-e, or 25.0% of Victoria's 2019-20 net emissions. Estimated total emissions from *all modes* of transport increased by 10.3 Mt CO_2-e (58.2%) between 1989-90 and 2018-19. This growth was dominated by Road (5.4 Mt CO_2-e, 37.4%) and Air (4.6 Mt CO_2-e, 335%) transport. However, due to the introduction of the COVID-19 restrictions in late 2019-20, these emissions decreased by 3.0 Mt CO_2-e (10.8%) between 2018-19 to 2019-20. The largest emission reductions occurred for Air (1.4 Mt CO_2-e, or 23.8%) and Road (1.3 Mt CO_2-e, or 6.6%) transport.

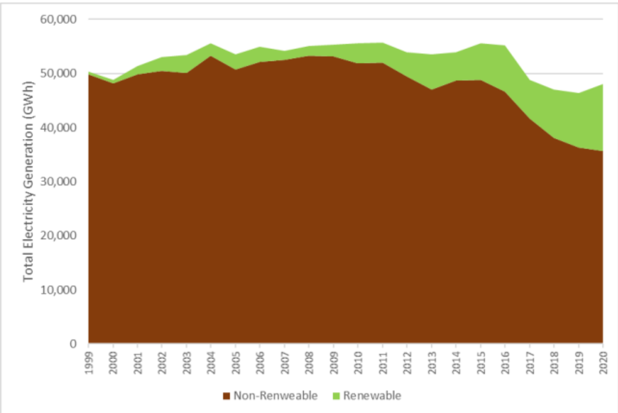
For the transport modes that are included in Victoria's greenhouse gas inventory, the total greenhouse gas emissions were 20.2 Mt CO_2-e in 2004-05. Between 2004-05 and 2019-20, these emissions increased by 0.6 Mt CO_2-e (2.9%). However, this increase would have been much higher if they hadn't reduced by 1.9 Mt CO_2-e between 2018-19 and 2019-20 due to the onset of the COVID-19 restrictions.

A key reason for Victoria's increasing emissions from Transport energy use has been Air transport. Between 1989-90 and 2018-19 total Air transport emissions increased by 4.6 Mt CO_2-e (335%). Domestic Air transport emissions increased by 1.3 Mt CO_2-e (255%) and International Air transport emissions by 3.4 Mt CO_2-e (379%). Between 2018-19 and 2019-20, total Air transport emissions decreased by 1.4 Mt CO_2-e (23.8%), with Domestic Air transport decreasing by 0.4 Mt CO_2-e (23.7%) and International Air transport decreasing by 1.0 Mt CO_2-e (23.8%).

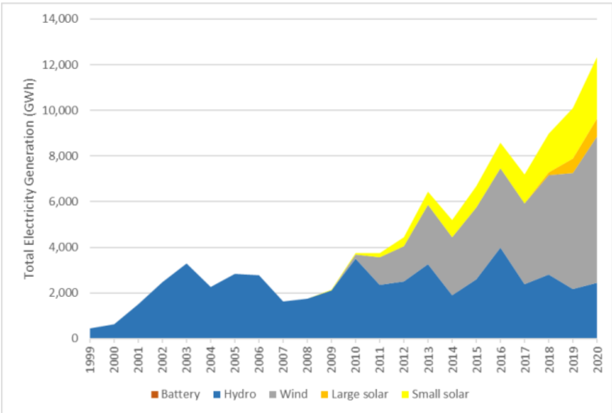
Victoria's electricity system transition

In the early 2000s, Victoria had a conventional one-way electricity supply system, characterised by large brown-coal fired power stations to generate "baseload" electricity, and gas peaking plant and hydroelectricity to generate electricity at times of higher demand. The only renewable electricity was from hydro. Use of simple "dumb" electricity meters meant consumers received bills only every few months, and largely played a passive role in the system. The electricity system is now undergoing a major transformation to support Victoria's transition to net zero emissions. Renewable electricity generation is increasing, large numbers of households and businesses generate electricity on-site using rooftop PV systems, storage batteries are starting to be installed, and most households and businesses have smart meters to provide detailed information on electricity consumption.

The transition to a fully renewable electricity supply is well under way to meet, and likely exceed, Victoria's renewable electricity targets – 25% by 2020, 40% by 2025 and 50% by 2030. Renewable electricity accounted for 25.7% of total generation in 2020 (31.7% in 2021) and is well on track to exceed the 50% target in 2030. This is driven by a rapid increase in wind and rooftop PV generation and, more recently, in large-scale PV generation.

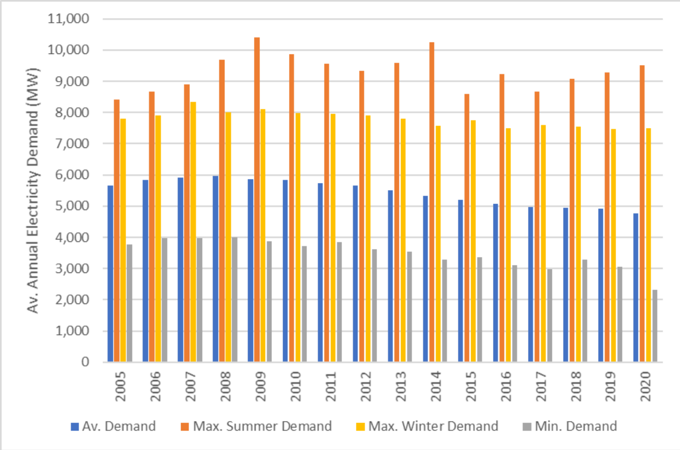


Victorian electricity generation, by type



Victorian renewable electricity generation, by type

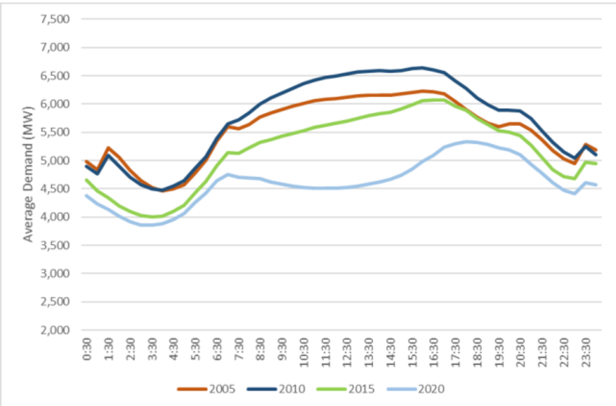
Victoria's electricity system needs to provide enough electricity to meet the electricity demand, both the total annual and daily demand, and the demand peaks during the day. Average total electricity system demand peaked in 2008 and has been decreasing since then. Since 2005, it has decreased by 905 MW (16%). In contrast, summer peak electricity demand has shown a general upward trend and has increased by 1,094 MW (13%) since 2005. Increasing population, increasing numbers of electric vehicles, electrification of residential gas appliances, and hotter summers have the potential to further increase summer peak demand.



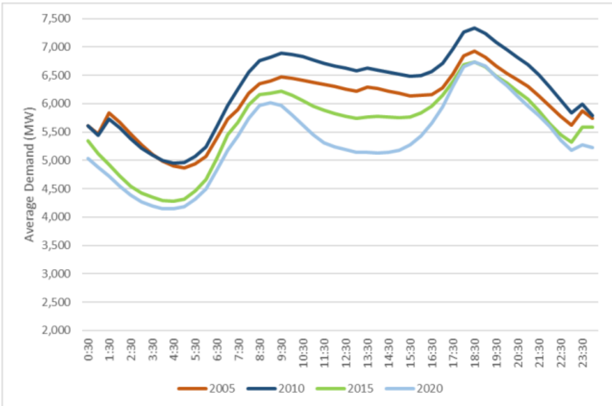
Characteristics of Victorian electricity system demand

Winter maximum demand peaked at 8,349 MW in 2007 and has shown a slow decline since, with some variation due to the severity of winters. From 2005 to 2020 it declined by 3.8%. A trend to electrification of residential gas appliances and uptake of electric vehicles will drive increases in total electricity consumption and peak demand, offset to some extent by rooftop PV generation. Residential electrification has the potential to significantly increase winter peak demand, although increased building and equipment efficiency could mitigate this impact.

The rapid increase in rooftop PV systems is hollowing out the daily electricity demand profile at all times of the year and has shifted the timing of minimum system demand from the early morning to the middle of the day and driven it to very low levels. Minimum demand was only 2,037 MW in 2020, and Victoria's system requires a minimum demand of 800 to 1,600 MW to guarantee stability.



Average daily demand profile - summer



Average daily demand profile - winter

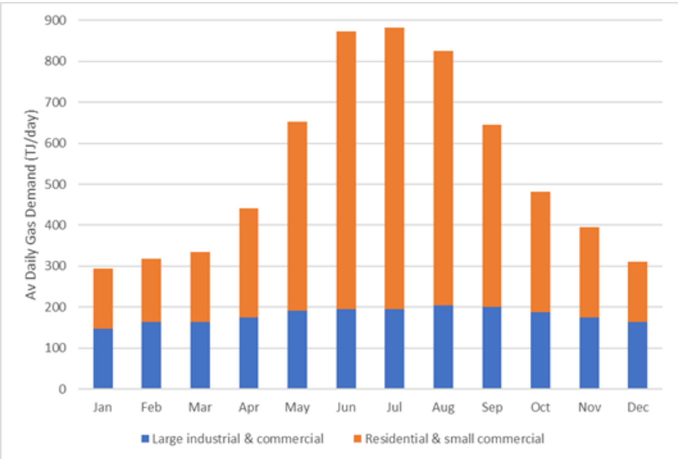
While average electricity demand is higher in winter than in summer, the maximum electricity demand on the peak day in summer is currently much higher than the maximum demand on the peak day in winter. Victoria is still very much a 'summer peaking' state. Very high electricity demand can be experienced during the afternoon on hot summer days during the working week when businesses are also operating. Electricity demand for residential air conditioning is a key contributor to this demand peak.

Battery storage, shifting electricity use to the middle of the day, and smart controls for rooftop PV systems will be increasingly necessary to manage issues with excess PV generation. Battery storage and demand response will be increasingly necessary to manage summer, and looming winter, peak demand issues.

Victoria's natural gas system transition

Natural gas has been a major energy source in Victoria for over four decades. It is used widely for residential heating, water heating and cooking, is an important energy source for business, especially manufacturing, and is used to power gas peaking plants that generate electricity at times of high demand. To achieve Victoria's target of net zero emissions by 2050, the greenhouse gas emissions from the energy end-uses that consume natural gas today will need to transition to net zero by this time. There are several ways in which this could be achieved: gas appliances and equipment could be replaced with high efficiency electrical equivalents powered by fully renewable electricity – this is known as “electrification”; replacing natural gas with hydrogen produced from a renewable or net zero emission process; or replacing natural gas with biogas. The policies and programs to put Victoria on this trajectory are set out in the *Gas Substitution Roadmap* released in July 2022.

Most natural gas (61%) is used in gas appliances and equipment in homes and small businesses. Residential gas use is particularly important and drives increased gas consumption during the winter months, both the daily gas demand and the demand peaks in the morning and evening.



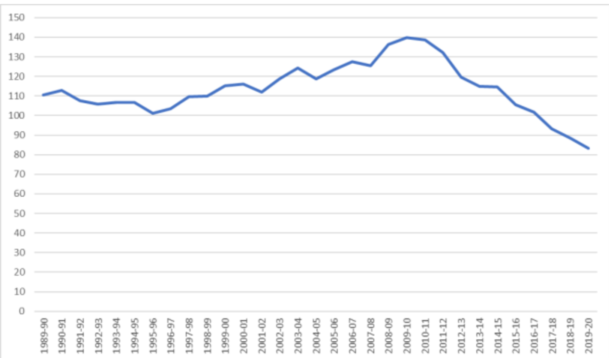
Forecast Victorian total average daily gas demand in 2020

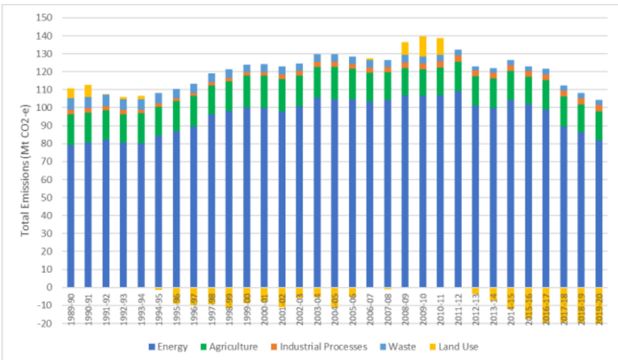
Due to declining production from the Bass Strait gas fields, Victoria faces a possible shortfall in natural gas supply during winter from as early as 2023.

We are still in the very early stages of the transition that will be required to achieve net zero emissions by 2050.

Victoria’s greenhouse gas emissions

Victoria’s total net greenhouse gas emissions in 2019-20 were 83.3 Mt CO_2-e, a reduction of 35.3 Mt CO_2-e (29.8%) since 2004-05. This is mainly due to reductions in emissions from Energy (22.7 Mt CO_2-e) and Land Use, Land Use Change and Forestry (10.0 Mt CO_2-e) since this time.


Victoria’s total net greenhouse gas emissions



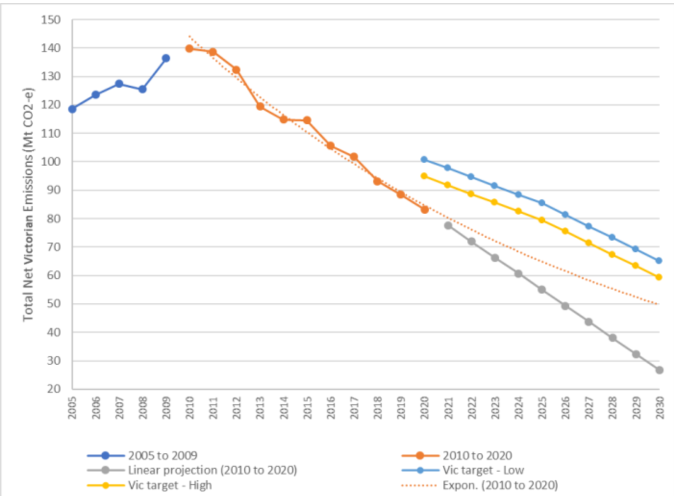
Victoria’s total greenhouse gas emissions by source

Since 2012-13, emissions from Land Use, Land Use Change and Forestry have been a net greenhouse sink in Victoria (negative emissions); in 2019-20 this category provided a net sink of 21.1 Mt CO_2-e. If these are ignored, Victoria's 2019-20 emissions of 104.3 Mt CO_2-e are dominated by Energy (78.4%) and Agriculture (15.4%). Emissions from Industrial processes (3.4%) and Waste (2.7%) were much less significant.

Victoria has 25.6% of Australia's population but in 2019-20 was responsible for only 16.7% of Australia's total net emissions. Our share of emissions from Energy, Agriculture, Industrial processes, Waste, and Land Use, Land Use Change and Forestry were lower than our population share. Emissions in Queensland, Western Australia and the Northern Territory were higher than their population share, and emissions in Western Australia and the Northern Territory are growing.

Victoria currently has the third highest share of Energy related greenhouse gas emissions in Australia, just above Western Australia, but these are reducing quickly due to increasing renewable generation.

All states and territories have net zero emission targets for 2050, and most have higher 2030 emission targets than the former Australian Government's weak target of a 26 to 28% reduction compared to 2005. New South Wales, Victoria, South Australia and the ACT have targets that are higher than the current Australian Government's target of a 43% reduction compared to 2005. If all states and territories *with published targets* meet these targets and other jurisdictions achieved at least at 26 to 28% reduction, Australia could achieve a 39 to 40% emissions reduction in 2030. If Queensland raised its target from 30% to 43%, and Western Australia, Tasmania and Northern Territory achieved a 43% reduction, Australia could achieve emission reductions of 46 to 47% in 2030.



Victoria's historical and projected greenhouse trajectory compared to our interim greenhouse targets[2]

Victoria's greenhouse gas emissions have fallen rapidly over the last decade and, based on projections of recent historical trends, seem likely to achieve an emission reduction of *at least* 58% by 2030, beating our interim target of a 45 to 50% reduction compared to 2005 by a significant margin.

Issues with the Australian Energy Statistics (AES) data

The discussion of energy consumption in this report (Chapter 2) is based on the data available in the 2021 issue of the AES Table F. This is Australia's official energy consumption data. Recent work undertaken by *EnergyConsult* when updating the 2015 *Residential Baseline Study* for the national Equipment Energy Efficiency (E3) program, plus work undertaken for this study, suggests that there are issues with the AES' electricity and natural gas consumption data, at least at the sectoral level, and that more accurate data is now available from information collected by the Australian Energy Regulator from gas and electricity distributors. We discuss these issues in more detail in Appendix 4. We have persisted with the AES data for this report even though it has known shortcomings, as it covers the full timeframe from 1989-90 to 2019-20 and covers all economic sectors and all fuels. We have

[2] Note that in this graph the years are financial years; 2005 corresponds to the financial year 2004-05 (July 2004 to June 2005).

contacted the team at the Department of Industry, Science, Energy and Resources (DISER) responsible for preparing the 2021 release of the AES used for this report and made them aware of these issues[3], with the hope that more accurate data will be published in future editions of the AES.

[3] The September 2022 release of the AES data includes some changes which have responded, in part, to the issues raised.

Abbreviations and Acronyms

ABS	Australian Bureau of Statistics
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AES	Australian Energy Statistics
AGEIS	Australian Greenhouse Emissions Information System
Av.	Average
BoM	Bureau of Meteorology
CO_2-e	Carbon-dioxide equivalent
^oC	degree Celsius
DISER	Department of Industry, Science, Energy & Resources
EV	Electric Vehicle
GDP	Gross Domestic Product
GJ	Gigajoule (1,000 MJ)
GSOO	Gas Statement of Opportunities
GSP	Gross State Product
GWh	Gigawatt-hour (1,000,000 kWh)
IPCC	Intergovernmental Panel on Climate Change
kW	kilowatt
kWh	kilowatt-hour
kt	kilo-tonne (1,000 tonnes)
LPG	Liquid petroleum gas (also called bottled gas)
LULUCF	Land use, land use change and forestry (one source of greenhouse gas emissions)
Max	Maximum
Min	Minimum
MJ	Mega joules
Mt	Mega-tonne (1,000,000 tonnes)
MW	Megawatt (1,000 kW)
NEM	National Electricity Market
NSW/ACT	New South Wales and Australian Capital Territory combined
PJ	Petajoule (1,000,000,000 MJ)
PV	Photovoltaic
RIN	Regulatory Information Notice
STC	Small scale Technology Certificate
SV	Sustainability Victoria
TJ	Terajoule (1,000,000 MJ)
VEET	Victorian Energy Efficiency Target
VEU	Victorian Energy Upgrades – this is the public name of the VEET Scheme
V2G	Vehicle to Grid
Yr	Year
ZEV	Zero Emission Vehicle

Glossary

Agriculture	Used in the report as shorthand for “Agriculture, Forestry and Fishery”, one of the economic sectors used in AES Table F for energy consumption.
Biogas	A type of renewable energy produced by the breakdown of organic matter such as food scraps, green waste, sewerage and animal waste. It generally consists of methane, carbon dioxide and hydrogen sulphide, and can be burnt to produce heat.
Biomethane	Methane, or natural gas, produced by refining Biogas.
Electricity demand	The amount of electrical power being consumed during a certain time period. For electricity systems it is generally the average power consumption measured over a half hour period, measured in megawatts (MW).
Electricity peak demand	The maximum electricity demand (MW) that occurs each day. Summer peak demand is the maximum electricity demand that occurs during the summer months, and winter peak demand is the corresponding winter value.
Electrification	Refers to the replacement of fossil fuel powered equipment with equipment powered by electricity. This could refer to gas heating replaced by a reverse-cycle air conditioner, a gas water heater with a heat pump water heater, or a petrol driven car with an electric car.
Emissions intensity	The amount of greenhouse gas emissions that occur when a unit of energy (e.g. a megajoule) is consumed. Commonly expressed as kg/MJ or tonnes/GJ. For electricity it may also be expressed as kg/kWh or tonnes/MWh.
Energy end-use	This is the energy used on-site in homes and businesses, or in vehicles, and includes electricity, natural gas, liquid-petroleum gas (LPG), wood, petroleum products, and coal. It does not include the energy that is used to generate electricity.
Energy intensity	GJ of energy consumption per million dollars of GDP or Gross State Product (GSP) generated – GJ/$ million.
Energy productivity	Million dollars of GDP (or GSP) per PJ of energy consumed.
Gas peaking plant	A type of gas-powered electricity generator that can be brought online quickly to supplement baseload electricity generation at times of higher electricity demand.
Land Use	Used in this report as shorthand for “Land use, land use change, and forestry” (LULUCF), one of the emission source categories used in the Greenhouse Gas Inventory.
Large solar	Large-scale PV (photovoltaic) generation, also referred to as a PV farm. Like other power stations, these feed electricity into the grid.
Load profile	This is a graph that shows how electricity demand (kW or MW) varies throughout the day.
Mains electricity	Electricity drawn from the electricity distribution system by households and businesses. Where a rooftop PV system is installed, some of the renewable electricity generated by this system on-site will also be used, offsetting some of the mains electricity use.
Small solar	Small-scale PV generation, usually rooftop mounted PV systems to generate electricity onsite at households or businesses.
Transport	Used as shorthand for “Transport, Postal and Warehousing” one of the economic sectors used in AES Table F for energy consumption.

Contents

1 Introduction

1.1 Victoria's net zero emissions target and the energy transition

Victoria's *Climate Change Act 2017* established a long-term greenhouse target of net zero emissions by 2050. Prior to the legislation of this target, the Victorian Government committed to reduce emissions by 15 to 20% below 2005 levels by 2020. The *Act* requires that 5-yearly interim emission targets be established to ensure that Victoria is on track to achieve the long-term net zero goal. To date, interim targets have been established for[4]:

- 2025 – 28 to 33% below 2005 levels
- 2030 – 45 to 50% below 2005 levels

In 2004-05, Victoria's total net greenhouse gas emissions were 118.6 Mt CO_2-e, with 104.5 Mt CO_2-e, or 88.1%, of this resulting from energy production and use in Victorian homes, institutions, and businesses, and for transport[5]. To achieve net zero emissions by 2050, the net emissions from this energy use will need to transition to zero by 2050, requiring significant changes to the way in which energy is produced and used. Electricity and gas use will need to result in net zero emissions, either because they are produced from renewable sources, or because any emissions generated are captured and stored. Transport will need to result in net zero emissions, either because it is powered by renewable electricity or by zero emission fuels. Further, to manage the costs involved in this energy transition and ensure the stability of the electricity supply system, it will be important to manage the way in which the energy is used, both the amount of energy and the timing of its use.

1.2 Overview of the report

This report tracks the key elements of Victoria's energy transition from 1989-90 to 2019-20[6], with a focus on the period 2004-05 to 2019-20, as 2005 is the benchmark year for our emission reduction targets.

In Chapter 2, we look at how energy consumption, or energy *end-use*, is changing, in terms of total energy consumption, the different energy sources consumed, and the energy consumption in different economic sectors. The analysis in this chapter relies on the data

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[4] https://www.climatechange.vic.gov.au/victorias-greenhouse-gas-emissions-reduction-targets
[5] Analysis of data from http://ageis.climatechange.gov.au, accessed 21 June 2022.
[6] The most recent greenhouse data available is for the 2019-20 financial year, and the 2021 release of the Australian Energy Statistics used in this report provides energy consumption data up to the 2019-20 financial year. Full-year electricity market data is available from AEMO and OpenNEM to end 2021.

from Table F of the 2021 release of the Australian Energy Statistics, Australia's official source of energy data. However, recent work has shown that there are some issues with this data, and that more accurate electricity and natural gas consumption data is now available from information collected from electricity and gas distributors by the Australian Energy Regulator. These issues are investigated in more detail in Appendix 4 and have been raised with the team at the Department of Industry, Science, Energy and Resources responsible for producing the AES.

In Chapter 3 we look at how Victoria's electricity system is changing, both in terms of electricity generation and supply, and Victoria's electricity system demand, and in Chapter 4 we look at Victoria's natural gas supply system and the challenges and changes that are expected for this over the coming decades.

Finally, in Chapter 5 we look at how Victoria's total net greenhouse gas emissions have changed, and the contribution that the different emission sources have made to this change. This highlights the importance of energy production and consumption to Victoria's total net emissions. A comparison is made between Victoria's total emissions and Australia's total emissions, to provide insights into how we have performed compared to the rest of the country.

More detailed information is provided in the Appendices. Appendix 1 provides more information on Victorian Residential energy consumption and energy related greenhouse gas emissions. Appendix 2 provides more information on energy consumption in the Victorian Manufacturing sector, and Appendix 3 provides more information on energy consumption and greenhouse gas emissions in the Victorian Transport sector. Appendix 5 provides information on how the different sources of greenhouse gas emissions have changed from 1990 to 2019 and compares Victoria with other states and territories.

2 Victorian energy consumption

2.1 Introduction

In this chapter we look at how Victoria's energy consumption, or energy *end-use*, has changed over the period 1989-90 to 2019-20[7], the most recent year for which data was available in the 2021 release of the Australian Energy Statistics. The key learnings are:

- In 2019-20, total Victorian energy *end-use* was 860.2 PJ. It was dominated by the Transport (41.4%), Residential (21.3%), Manufacturing (19.3%) and Commercial (11.3%) sectors.
- Since 2004-05, total energy use has declined in the Manufacturing sector, but has increased in the other key sectors.
- The onset of COVID-19 restrictions in the last four months of 2019-20 disrupted the long-term energy consumption trends. From 2018-19 to 2019-20, energy consumption increased in the Residential sector by 5.3%, but declined in the Transport (10.8%) and Commercial (4.4%) sectors.
- The Residential, Commercial and Road transport sectors are key drivers of increasing energy consumption and greenhouse gas emissions and are strongly influenced by population growth. Combined, they accounted for 59.1% of natural gas use, 54.7% of electricity use, 31.0% of other energy use, and 67.2% of Victoria's net greenhouse gas emissions.
- Transport energy consumption is dominated by Road (75.6%) and Air (18.8%) transport. Prior to the COVID-19 pandemic, energy use and emissions from Air transport were growing strongly, especially international air transport.

The analysis presented in this chapter is based on the 2021 release of the Australian Energy Statistics, Australia's official source of energy data. Recent work undertaken by *EnergyConsult* when updating the 2015 *Residential Baseline Study* for the national Equipment Energy Efficiency (E3) program, plus work undertaken for this study, suggests that there are issues with the AES' electricity and natural gas consumption data, at least at the sectoral level, and that more accurate data is now available from information collected by the Australian Energy Regulator from gas and electricity distributors. We discuss these

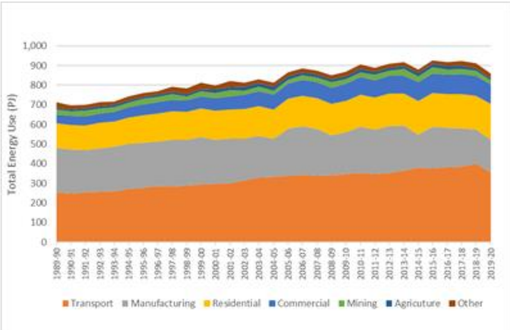
[7] The data is from the 2021 release of *AES Table F – Australian energy consumption, by state and territory, by industry and fuel tupe, energy units*, Dept. of Industry, Science, Energy & Resources, September 2021. For energy consumption, we use financial years, as this is the way the data is reported in the Australian Energy Statistics. The financial year 2019-20 covers the period July 2019 to June 2020.

issues in more detail in Appendix 4. We have persisted with the AES data for this report, as it covers the full timeframe from 1989-90 to 2019-20 and covers all economic sectors and all fuels. We have contacted the team at the Department of Industry, Science, Energy and Resources (DISER) responsible for preparing the 2021 release of the AES used for this report and made them aware of these issues[8].

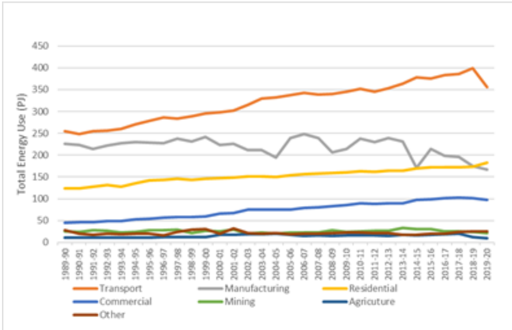
2.2 Overall energy consumption

Figure 1 shows the total annual energy consumption in the main energy end-use sectors in Victoria (excluding Electricity, Gas, Water and Waste services[9]) over the period 1989-90 to 2019-20. In 2019-20, the total energy consumption was 860.2 PJ. The sectors with the highest overall energy consumption were the Transport[10] (355.9 PJ, or 41.4% of the total), Residential (183.1 PJ, 21.3%), Manufacturing (166.4 PJ, 19.3%), and the Commercial sector (97.5 PJ, 11.3%). The Mining and Agriculture (Forestry and Fishing) sectors play only a minor role[11].

Figure 1: Total Victorian energy consumption by economic sector (excluding Elec, Gas, Water & Waste sector)



Total energy consumption



Energy consumption by sector

Up until 2018-19, energy consumption in the Transport, Commercial, and Residential sectors displayed a general increasing trend. A key underlying driver for energy use in these sectors is population growth – over the period under consideration, Victoria's population increased by nearly 50%. In contrast, energy consumption in the Manufacturing sector has been declining quite rapidly since 2006-07.

The longer-term energy consumption trends were disrupted in 2019-20, due to the onset of restrictions associated with the COVID-19 pandemic in the last four months of the year. Energy consumption decreased in the Transport and Commercial sectors and increased by more than expected in the Residential sector, due to increased working from home, restrictions on the distance and times that people could travel, and restrictions on air travel.

Between 2004-05 and 2019-20 energy consumption increased in the Residential (33.1 PJ, 22.1%), Transport (23.4 PJ, 7.0%), and Commercial Sectors (22.0 PJ, 29.1%), but

[8] The September 2022 release of the AES data includes some changes which have responded, in part, to the issues raised.

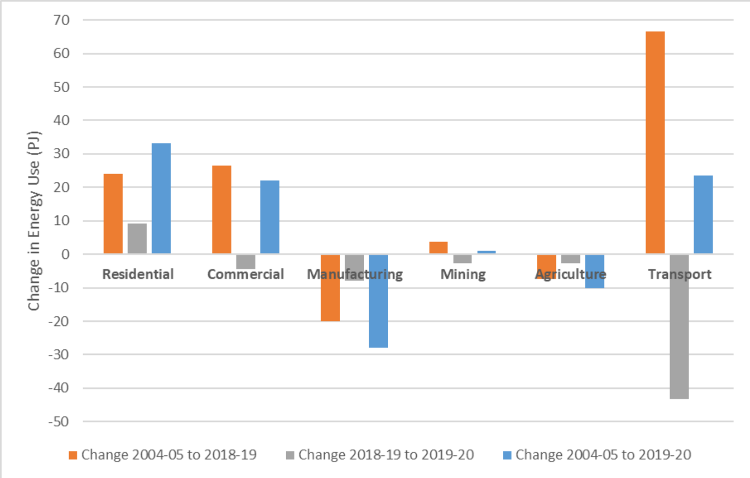
[9] There is some electricity and gas end-use in this sector, although much of the energy use for electricity supply is for the generation of thermal electricity (e.g., brown coal, natural gas, briquettes, etc).

[10] The full name for this sector is Transport, Postal and Warehousing – this sector is dominated by Transport, and the Postal and Warehousing sub-sectors represent only a small amount of energy consumption. For simplicity, in this report we refer to this generally as the "Transport" sector.

[11] In 2019-20, energy consumption in the Mining sector was 21.7 P (5.6%) and Agriculture was 9.9 PJ (1.1%). Energy consumption in the Construction sector, included in "Other", was 13.4 PJ, and consisted mainly of diesel (8.8 PJ).

decreased in the Manufacturing sector (27.8 PJ, 14.3%). However, as can be seen from Figure 2, the increase in Transport energy consumption would have been much larger if it had not been for the COVID-19 restrictions. This was also the case for the Commercial sector, but to a much lesser extent. Conversely, the increase in energy consumption in the Residential sector would not have been as large, as it increased significantly – by 9.2 PJ (5.3%) - between 2018-19 and 2019-20; the average annual increase between 2004-05 and 2018-19 was only 1.1%. This was partly due to increased working from home in the last four months of 2019-20, and partly due to an unusually cold start to winter in 2020[12].

Figure 2: Impact of COVID-19 on changes in total energy consumption since 2004-05



The disruption to the longer-term energy trends due to the COVID-19 restrictions is expected to last for several years but energy consumption, especially in the Transport and Commercial sectors, is expected to rebound after the end of restrictions. Even then, longer term changes to working patterns brought about by the COVID-19 restrictions, such as increased working from home, use of on-line meetings and reduced interstate travel for work meetings, reduced international air travel, and reduced use of public transport, could result in a new trajectory for Victorian energy consumption in the post-COVID era.

2.3 Energy consumption in key economic sectors

Figure 3 shows the energy consumption for key economic sectors[13] over the period 1989-90 to 2019-20, broken down into electricity, natural gas and other fuels[14]. Energy consumption in the Residential, Mining and Commercial sectors is dominated by electricity and natural gas, while energy use in the Transport and Agricultural sectors is dominated by “other” fuels, mainly petroleum products such as auto gasoline, diesel, aviation fuel, LPG and fuel oil. Energy consumption in the Manufacturing sector is much more evenly split between electricity, natural gas and other fuels (mainly crude oil and petroleum products). The high use of natural gas and other fuels in manufacturing, combined with the difficulty of

[12] SV analysis of the BoM’s weather data from Melbourne Airport estimates that the number of Heating Degree Days (HDD) for the period March to June increased from 468 in 2019 to 609 in 2020, an increase of 30%. Energy use for residential heating is roughly proportional to the number of HDD, and an increase in HDD also tends to increase water heating energy use due to greater heat losses from hot water cylinders and colder cold-water temperatures.

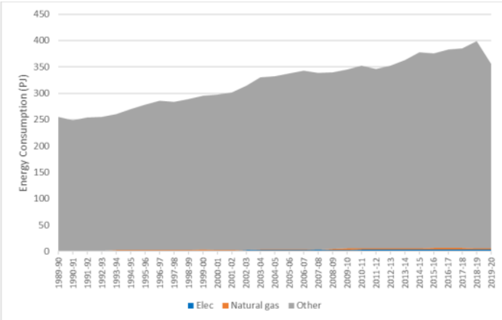
[13] These are based on the ANZSIC classifications used in the Australian Energy Statistics.

[14] Other fuels include quite a wide range of energy sources, including petroleum products, other gas fuels, and solid fuels. The estimate of energy consumption for other fuels is derived by subtracting the combined electricity and natural gas consumption listed under “Fuels consumed” from the “Energy consumption” figure in AES Table F.

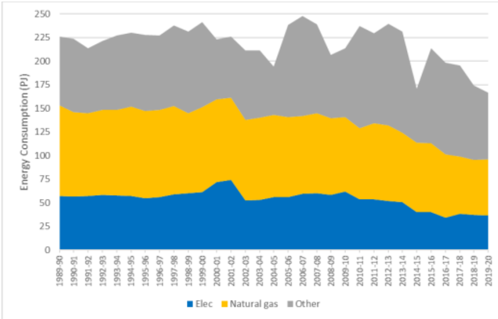
electrifying many of these end uses, will make it more challenging to reduce greenhouse gas emissions to very low levels in this sector.

The high, and increasing, use of other fuels in the Transport sector will also make this a challenging area for greenhouse abatement. While a shift to electric vehicles has started, ownership is currently very low, and will need to increase significantly over the next three decades to reduce transport related greenhouse gas emissions[15]. Electrification will be more complicated for long-haul transport by trucks and trains, and for air and sea transport. These may need to use alternative fuels such as “green” hydrogen or ammonia[16].

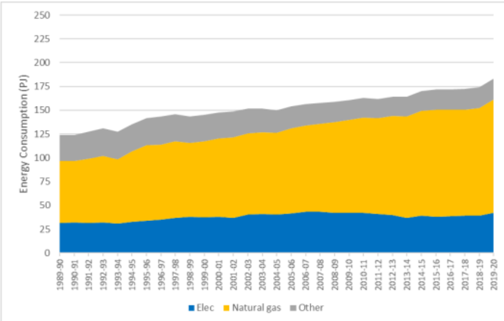
Figure 3: Victorian energy consumption in key economic sectors, by fuel



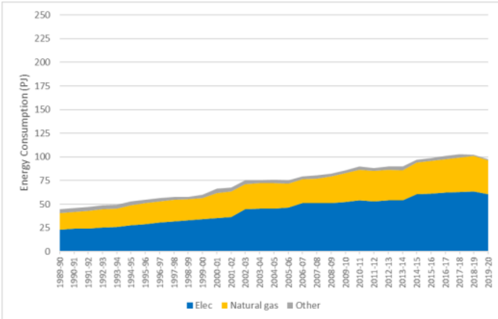
Transport, Postal & Warehousing



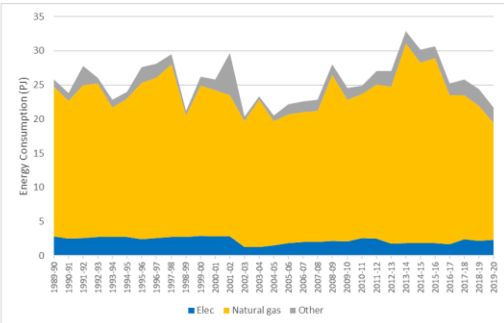
Manufacturing



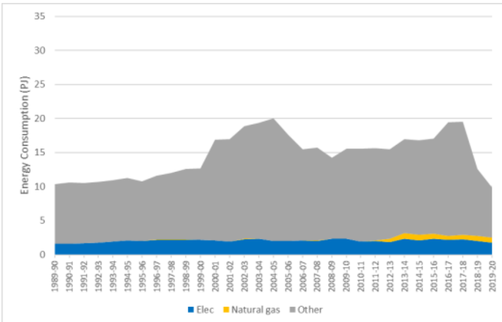
Residential



Commercial



Mining



Agriculture, Forestry and Fishing

The electrification of transport will also need to be supported by a corresponding increase in renewable electricity generation. What was once “mobile” energy consumption will become

[15] *Victoria’s Zero Emission Vehicle Roadmap* (May 2021) sets out a target for all public bus purchases to be zero emission vehicles (ZEV) from 2025, and for 50% of light vehicle sales to be ZEVs by 2030. It is supported by a $100 million funding package to facilitate the roll-out of electric vehicle charging stations, provide financial incentives for purchasing ZEVs, electric bus trials, purchase ZEVs for the government vehicle fleet, and consumer information. This package is expected to drive a significant uptake in electric vehicle sales during the 2020s.
[16] For further information, see *Victorian Renewable Hydrogen Industry Development Plan* (March 2021).

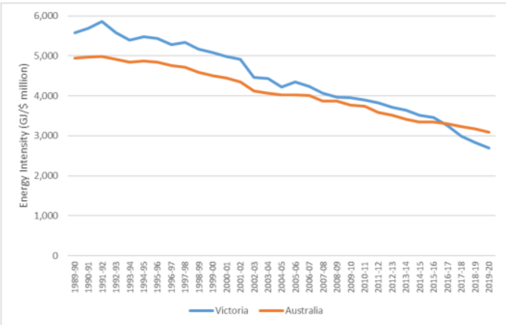
part of “stationary” energy consumption in households, businesses and public charging infrastructure, with significant implications for Victoria’s electricity supply system.

More detailed information on energy consumption in some key sectors is provided in the Appendices: Residential sector (Appendix 1); Manufacturing sector (Appendix 2) and Transport sector (Appendix 3).

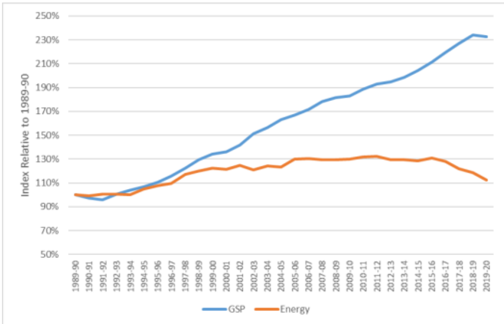
2.4 Energy intensity and energy productivity

Energy intensity[17] and energy productivity[18] are metrics that are widely used to track and compare the overall energy performance of countries or regions. The Victorian Government’s *Energy Efficiency and Productivity Strategy* (November 2017) contains an aspirational target of a 50% increase in Victoria’s energy productivity by 2030, compared to 2015. Increases in energy productivity can be due to structural changes in the economy (e.g., a shift from manufacturing to the less energy intensive commercial services), increases in renewable energy generation, and energy savings due to energy efficiency. The Australian Energy Statistics[19] provides data on both energy intensity and energy productivity for Australia as a whole, and for individual states and territories.

Figure 4: The energy intensity of Victoria’s economy compared to Australia



Energy intensity



GSP vs Energy consumption Index - Victoria

Figure 4 provides a comparison of Victoria and Australia’s energy intensity (left hand side) as well as a comparison of Victoria’s Gross State Product (GSP) index and energy consumption index relative to 1989-90 (right hand side)[20]. The energy intensity of both Victoria and Australia has been in general decline over the last three decades. Victoria’s energy intensity peaked in 1991-92 at 5,865 GJ/$ million and has since declined to 2,693 GJ/$ million in 2019-20, a reduction of 2,886 GJ/$ million (51.7%). Victoria’s energy intensity has declined at a faster rate than Australia as a whole and is now below the national average ($3,089 GJ/$ million). The reduction in Victoria’s energy intensity has been particularly rapid since 2015-16.

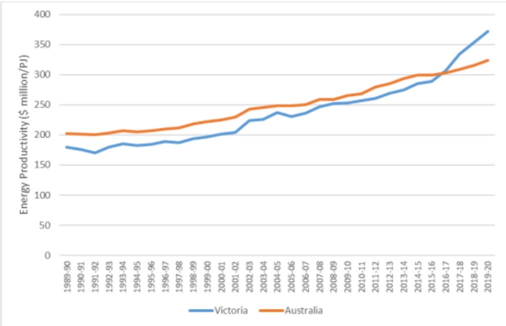
As can be seen in the right-hand graph in Figure 4, Victoria’s total energy consumption was on an upward trend from 1989-90 to 2006-07, when it reached 130.0% of the 1989-90 consumption level. It then grew more slowly to 2011-12, when it peaked at 132.5% of the 1989-90 consumption level. It has since started to decline, so that in 2019-20 it was 112.3% of the 1989-90 consumption level. In contrast, in 2019-20, GSP was 233% of the GSP level

[17] GJ of energy consumption per million dollars of GDP or Gross State Product (GSP) generated – GJ/$ million.
[18] Million dollars of GDP (or GSP) per PJ of energy consumed - $ million/PJ.
[19] *Australian Energy Statistics Table B, Australian population, GDP and energy consumption, by state and territory*, Dept. of Environment and Energy, September 2021. This bases GDP/GSP on a chain volume measure, with the series starting in 1989-90.
[20] The GSP and Energy consumption index are referenced to 1989-90, which is taken as 100%. For example, an index of 150% would indicate that GSP or Energy consumption had increased by 50% since 1989-90.

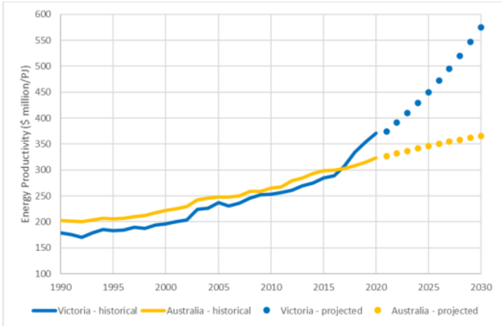
in 1989-90. This suggests that Victoria’s total energy consumption became largely uncoupled from economic growth from around 2006-07.

Victoria’s energy productivity remained below that of Australia from 1989-90 until 2016-17 (Figure 5), but from 2015-16 began increasing at a much faster rate so that, at $371.4 million/PJ, it now sits well above Australia’s energy productivity of $323.8 million/PJ. This is likely to be due to a combination of factors, including factory closures, a rapidly increasing proportion of renewable energy in electricity generation, and major energy efficiency policies and programs implemented in Victoria from the mid-2000s.

Figure 5: Victoria’s energy productivity compared to Australia



Historical



Historical & projected

Victoria’s energy productivity in 2014-15 was $285.0 million/PJ. Since then, it has increased by 30.3% to $371.4 million/PJ. Based on projected trends, this may increase to around $574.5 million/PJ in 2029-30, an increase of 102% and well above the Victorian Government’s aspirational target of 50%. The projections suggest it will reach this target in 2024. However, this projected large increase in energy productivity may be due to factory and power station closures in recent years causing a short-term rapid increase in energy productivity, and this trend might not be maintained over the entire decade to 2030.

2.5 Electricity consumption

In this section we provide a more detailed insight into how electricity consumption is changing in the key economic sectors[21]. Many houses and businesses now have rooftop PV systems that generate renewable electricity on-site. Some of this is consumed within the homes and businesses “behind the meter”, and so is not directly recorded, while some is exported back into the electricity network and becomes part of the renewably generated electricity supply.

The generation of electricity in fossil-fuel fired power stations for use in homes, businesses and government institutions is a major source of greenhouse gas emissions in Victoria. Achievement of Victoria’s interim and 2050 emissions targets will require both a reduction in the emissions intensity of the mains electricity used - through increased uptake of renewable electricity - and management of the amount of electricity consumed. Electrification of gas appliances and equipment, and of transport (via greater uptake of electric vehicles), will tend to increase electricity consumption. Increasing population is an underlying driver for increased electricity consumption in the Residential, Commercial and Transport sectors.

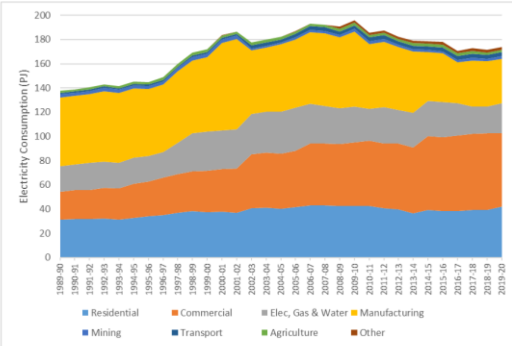
[21] In this analysis we also include the “Electricity, Gas and Water Sector”, which was not included in our analysis of overall energy end-use, as a large amount of “other” (mainly coal and gas) energy sources are consumed to generate electricity. The electricity consumption in this sector is for the production and delivery of gas and water, and electricity use associated with the generation and distribution (e.g., distribution losses) of electricity.

These tendencies for increased electricity consumption will be balanced, to some extent, by more efficient use of energy in these sectors.

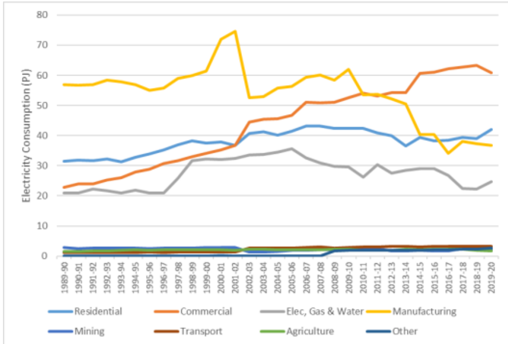
Total Victorian electricity consumption in 2019-20 was 174.0 PJ. The key sector for electricity consumption was the Commercial sector (60.8 PJ, 34.9% of the total), followed by the Residential (42.0 PJ, 24.1%), Manufacturing (36.7 PJ, 21.1%), and Electricity, Gas and Water (24.6 PJ, 14.2%) sectors. The Transport (1.8%), Mining (1.4%), Agriculture (1.0%) and Other (1.5%) sectors, played only a minor role.

Victoria's electricity consumption peaked in 2009-10 at 195.8 PJ and has since declined by 21.8 PJ (11.1%). The largest declines in electricity consumption since this time have been for the Manufacturing (25.3 PJ, 40.8%) – presumably driven mainly by factory closures - Electricity, Gas and Water (5.0 PJ, 16.8%), Agriculture (0.6 PJ, 25.1%) and Residential (0.5 PJ, 1.1%) sectors. Electricity consumption in the Commercial sector increased by 8.3 PJ (15.7%) during this period.

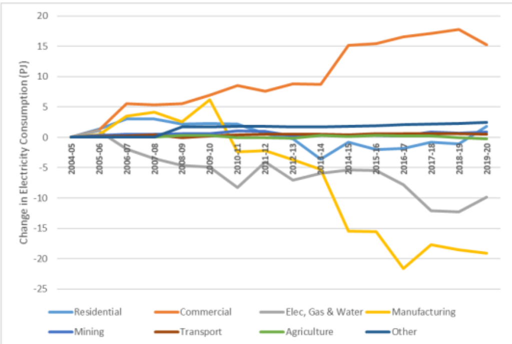
Figure 6: Total Victorian electricity consumption, by economic sector



Total electricity consumption, by sector



Electricity consumption by sector



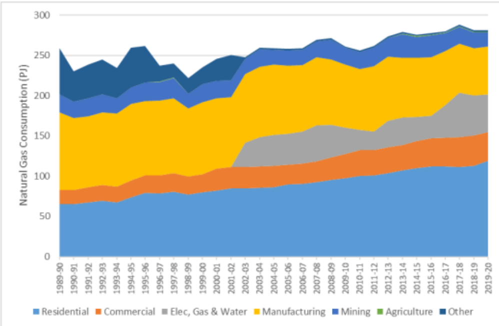
Change in electricity consumption since 2004-05

Since 2004-05, total Victorian electricity consumption has decreased by 8.3 PJ (4.6%). Consumption decreased in the Manufacturing (19.1 PJ, 34.2%), Electricity, Gas & Water (9.8 PJ, 28.6%) and Agriculture (0.3 PJ, 13.1%) sectors, but increased in the Commercial (15.2 PJ, 33.5%), Residential (1.8 PJ, 4.4%), Mining (0.8 PJ, 56.1%) and Transport (0.5 PJ, 20.0%) sectors. As was the case with Victoria's overall energy consumption, the longer-term electricity consumption trends were impacted by the onset of COVID-19 restrictions late in the 2019-20 financial year. Between 2018-19 and 2019-20, Residential electricity consumption increased by 2.9 PJ (7.3%) and electricity consumption in the Electricity, Gas and Water sector increased by 2.4 PJ (10.8%), while Commercial electricity consumption decreased by 2.5 PJ (4.0%).

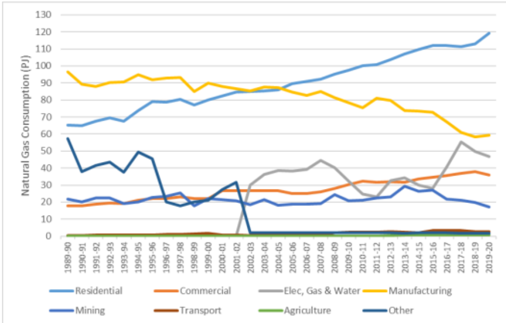
2.6 Natural gas consumption

This section provides a more detailed insight into how natural gas consumption is changing in the key economic sectors. According to AES Table F, total Victorian natural gas consumption was 283.4 PJ in 2019-20[22]. The key sector for natural gas consumption was the Residential sector (42.0%), followed by the Manufacturing (21.0%), Electricity, Gas and Water (16.5%)[23], Commercial (12.6%), and Mining (6.0%) sectors.

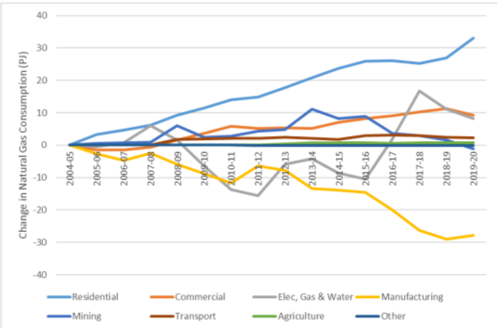
Figure 7: Total Victorian natural gas consumption, by economic sector



Total natural gas consumption, by sector



Natural gas consumption by sector



Change in natural gas consumption since 2004-05

According to the AES Table F data, there has been a general upward trend in Victorian natural gas consumption since the late 1990s. Since 2004-05, total consumption has increased by 24.3 PJ (9.4%). This increase has been mainly in the Residential (33.0 PJ, 38.3%), Commercial (9.3 PJ, 34.9%), Electricity, Gas and Water (8.1 PJ, 21.1%)[24], and Transport (2.3 PJ, 743%) sectors. It has decreased mainly in the Manufacturing (27.9 PJ, 31.9%) and Mining (1.1 PJ, 6.2%) sectors.

The longer-term natural gas consumption trends were also impacted by the onset of restrictions related to the COVID-19 pandemic. Between 2018-19 and 2019-20, natural gas consumption decreased by 0.48 PJ (0.2%). It increased in the Residential (6.13 PJ, 5.4%) and Manufacturing (1.08 PJ, 1.8%) sectors, but decreased in the Electricity, Gas and Water (2.89 PJ, 5.8%), Mining (2.67 PJ, 13.5%), and Commercial (2.0 PJ, 5.3%) sectors.

[22] Note that the data available from the Australian Energy Regulator, and the Australian Energy Market Operator, suggest that the total natural gas consumption is Victoria is much lower than this (total of around 220 PJ in 2020), especially in the commercial and industrial sectors. See Appendix 4 for further information.

[23] Note that of the 46.7 PJ of natural gas consumed in this sector in 2019-20, 41.9 PJ (89.6%) was for electricity supply and is likely to have been used largely for electricity generation. Natural gas consumption in this sector has varied considerably from year to year, and this reflects the changing requirement for natural gas peaking plant to generate electricity.

[24] Note that prior to 2002-03 the natural gas consumption in the "Elec, Gas and Water" sector seems to have been allocated to the "Other" sector. This explains the large drop in energy use in this sector after 2002-03 and the large increase in the "Electricity, Gas and Water" sector.

3 Victoria's electricity system transition

3.1 Introduction

As part of Victoria's transition to net zero emissions in 2050, Victoria's electricity system is transitioning from a traditional one-way system reliant on large coal-fired power stations to a distributed, smart, and two-way system with high levels of renewable electricity generation in which the supply and demand (or customer) sides of the electricity system interact. To help guide this transition, the Victorian Government has established renewable electricity targets of 25% in 2020, 40% in 2025 and 50% in 2030, backed by a range of policies to support both large- and small-scale renewable electricity generation.

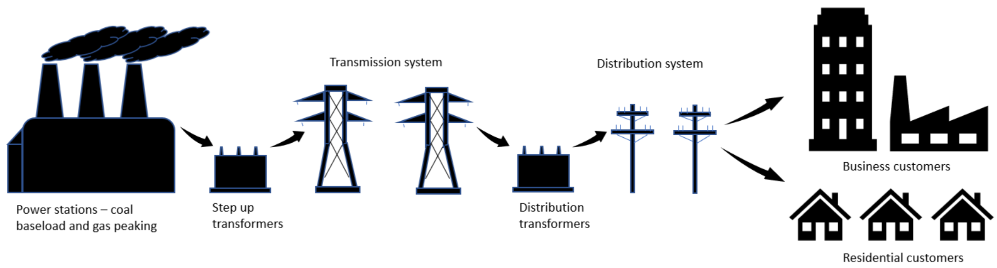
Key learnings:

- The transition to a fully renewable electricity supply is well under way to meet, or exceed, Victoria's renewable electricity targets. This is driven by a rapid increase in wind and rooftop PV generation and, more recently, in large-scale PV generation.
- Average total electricity system demand has decreased by 905 MW (16%) since 2005, while summer peak electricity demand has increased by 1,094 MW (13%). Increasing population, increasing numbers of electric vehicles, electrification of residential gas appliances, and hotter summers have the potential to further increase summer peak demand.
- A trend to electrification of residential gas appliances and uptake of electric vehicles will drive increases in total electricity consumption and peak demand, offset to some extent by rooftop PV generation. Residential electrification has the potential to significantly increase winter peak demand.
- The rapid increase in rooftop PV systems is hollowing out the electricity demand profile during the middle of the day at all times of the year and has shifted the timing of minimum system demand from the early morning to the middle of the day and is driving it to low levels. Minimum demand was only 2,037 MW in 2020, and Victoria's system requires a minimum demand of 800 to 1,600 MW to guarantee stability.
- Battery storage, shifting electricity use to the middle of the day, and smart controls for rooftop PV systems will be increasingly necessary to manage issues with excess PV generation. Battery storage and demand response will be increasingly necessary to manage summer, and looming winter, peak demand issues.

3.2 Victoria's electricity system in transition

In the early 2000s, Victoria had a traditional electricity generation and supply system (see Figure 8). This comprised a small number of large "base load" brown coal-fired power stations located mainly in the Latrobe Valley to generate most of the electricity, with the electricity flowing one way to households and businesses through the transmission and distribution network. Gas "peaking" plant and hydro generators, as well as electricity imports from other states[25], were used to meet system shoulder and peak demand[26]. There was no electricity storage. Simple "dumb" accumulation meters were used to record household and business electricity consumption, and these were only "read" every few months to produce the electricity bill. In the main, households and businesses were simply "passive" consumers of electricity, although on very hot summer days, larger commercial and industrial electricity users might have participated in load shedding to help keep system peak electricity demand within manageable levels.

Figure 8: Traditional electricity supply system[27]



By 2050, Victoria's electricity system will have undergone a major transformation (see Figure 9). Electricity generation will be fully renewable and will be comprised of both multiple large-scale renewables (on-shore and off-shore wind farms, PV farms, hydro) and many medium and small rooftop PV systems spread throughout the state. Battery storage at large generators, and at the regional, neighbourhood and household level will be used to soak up excess generation, especially the excess output of PV systems during the middle of the day. Battery storage, stored hydro, imports from other states and demand response will be used to meet system peaks in the morning, late afternoon, and early evenings. There may also be gas peaking plants, but these will be powered by zero emission hydrogen or biogas, rather than natural gas. All consumers will have smart meters[28], allowing them to understand how much electricity they are consuming from the grid, or exporting back to it from a PV system and/or battery storage, at any given time and enabling them to become active consumers, either manually or under automatic control. They might minimise consumption at times of high electricity prices and increase it or store electricity when prices are low, shift their electricity consumption to the middle of the day to soak up excess PV generation, and

[25] Victoria is part of the National Electricity Market (NEM), comprising Queensland, NSW, ACT, Victoria, South Australia, and Tasmania. There are two-way interconnectors between each region of the NEM, although there are limitations on the amount of power that can flow through these. This allows electricity to be imported into Victoria from NSW, South Australia and Tasmania, and Victoria can also export electricity to these states.

[26] Peak demands generally occur in the early morning, late afternoon or early evening (depends on the time of year), and shoulder demand during the middle hours of the day. The lowest demand generally occurs during the night-time.

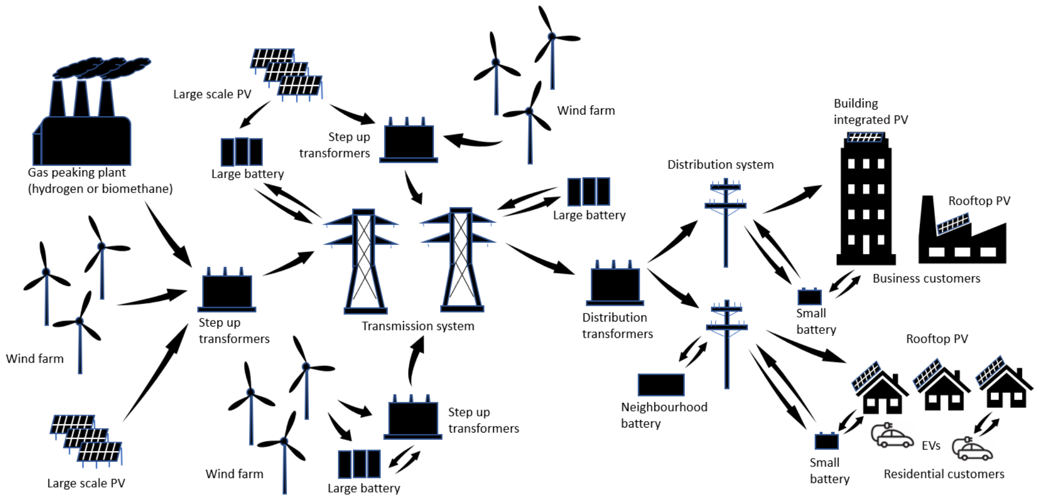
[27] Based on diagram in L Lynn Keisling*, Innovation and Decentralized Energy Markets: Technology and Institutions for a Clean and Prosperous Energy Future*, The Centre for Growth & Opportunity, Utah State University, Feb 2020

[28] Since the early 2010s, all Victorian households and small businesses have had smart meters installed. These record electricity consumption for every half hour of the day over the year. Data from these meters is available to consumers from web-portals provided by electricity retailers and distributors.

receive financial incentives to reduce (or increase) electricity demand when total system demand is too high (or too low).

Many gas end-uses will have been electrified, and most light vehicles will be electric, increasing the amount of electricity that needs to be generated. Electric vehicles have large storage batteries, and many of these will interact with the electricity grid via vehicle-to-grid (V2G) technology when they are plugged in and being charged.

Figure 9: The electricity system of the future[29]



The transition to the future electricity generation and supply system is now well under way and will gather pace during the 2020s. Major developments over the next decade are expected to be:

» A rapidly rising share of renewable electricity generation to meet Victoria's targets.

» A significant increase in electricity generation from rooftop PV systems, with over 700,000 systems expected to be installed under the Solar Homes program. This will significantly increase electricity generation during the middle of the day, significantly reducing the demand faced by large-scale generators at this time and has the potential to lead to "minimum demand" issues. It is likely that there will be increased usage of battery storage, load shifting and smart inverters to manage these issues.

» Increased uptake of electric vehicles (EVs), tracking towards Victoria's target of 50% of light vehicle sales to be zero emission vehicles[30] (ZEV) by 2030. This will increase overall electricity consumption and increase electricity demand at times when the electric vehicles are charging – most likely in the early evening or over-night. While it is likely to develop more slowly, the use of V2G technology in conjunction with the EVs, will mean that the EV batteries will start to interact with the electricity grid.

» Increased electrification of gas end-uses, especially residential heating, water heating and cooking. This will also increase electricity consumption and will increase electricity demand in the early morning and evenings during the colder months.

[29] Adapted version of diagram in L Lynn Keisling, *Innovation and Decentralized Energy Markets: Technology and Institutions for a Clean and Prosperous Energy Future*, The Centre for Growth & Opportunity, Utah State University, Feb 2020

[30] Zero emission vehicles include both battery electric vehicles and vehicles which use zero emission hydrogen – in this case, the hydrogen is used in a fuel cell to generate electricity, which is then used to drive the vehicle.

In the rest of this section, we look at how Victoria's electricity system has transformed from the early 2000s to 2020, as well as the longer-term implications of the current trends.

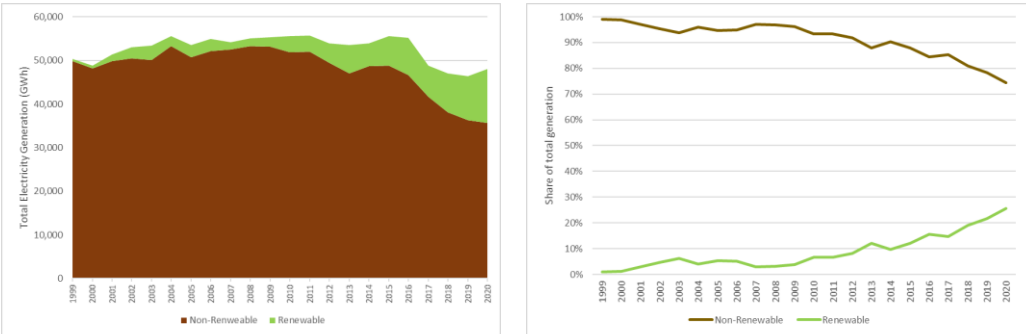
3.3 Electricity generation

Data for this section of the report was sourced from OpenNEM, an initiative of Energy Consumer's Australia and the University of Melbourne's Climate and Energy College using National Electricity Market data[31]. OpenNEM provides data on Victorian electricity generation from 1999 to 2021, broken down by fuel type, including the non-renewable and renewable 'fuels'.

Figure 10 shows how Victoria's total electricity generation has changed since 1999, including the breakdown between non-renewable and renewable electricity. In 1999, total Victorian electricity generation was 50,292 GWh, with non-renewable electricity accounting for 99.1% and renewable generation (entirely hydro) accounting for only 0.9%. Total electricity generation peaked in 2011 at 55,709 GWh, but by 2020 had declined to 50,376 GWh. The share of renewable generation increased steadily over this period, especially from the late 2000s, so that by 2020 it accounted for 25.7%[32], exceeding the Victorian Government's target of 25%. The share of non-renewable generation had dropped to 74.3%.

Between 2005 and 2020, electricity generation decreased from 53,571 GWh to 48,032 GWh, a reduction of 5,539 GWh (10.9%). Between 2019 and 2020, total generation increased by 1,619 GWh (3.5%). This is likely to have been due to the onset of the COVD-19 restrictions, amplified by the fact that 2020 was considerably colder than 2019.

Figure 10: Electricity generation in Victoria – non-renewables vs renewables



Total electricity generation, by main type

Share of non-renewable and renewable generation

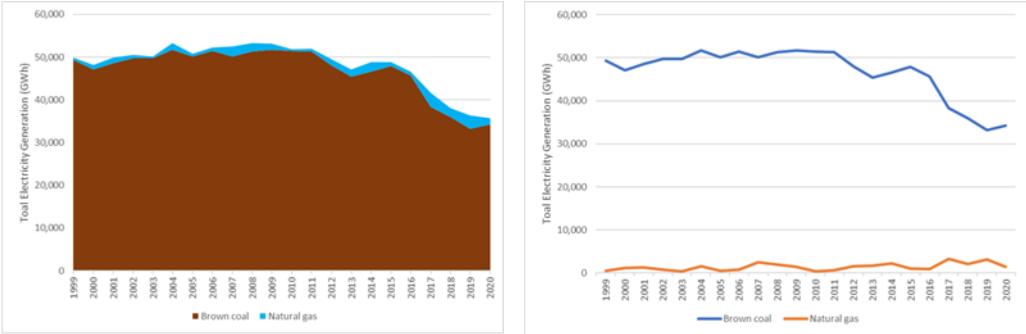
The total non-renewable generation over the period 1999 to 2020 is shown in Figure 11. Brown coal generation accounted for most of the non-renewable generation over this period (96.9%), with only a small proportion accounted for by natural gas peaking plant (3.1%). Between 2005 and 2020, total non-renewable generation decreased from 50,720 GWh to 35,702 GWh, a reduction of 15,018 GWh (29.6%). Most of this was due to brown coal generation, which reduced by 15,931 GWh (31.8%). Gas generation increased by 913 GWh over this period, but it should be noted that the amount of gas generation varies

[31] See: https://opennem.org.au/energy/vic1/?range=1y&interval=1w Generation data is also available from *Australian Energy Statistics Table O – Australian electricity generation by fuel type, physical units*, Dept. of Industry, Science, Energy & Resources. However, at time of writing, this provides data only for the period 2008-09 to 2019-20. The OpenNEM data is available for the period 1999 to 2021. AES Table O gives slightly higher estimates of renewable energy generation than OpenNEM. This seems to be because it includes generation from Biomass. There are also minor differences between the estimates for other generation sources.

[32] Renewable generation continues to grow strongly. Based on the OpenNEM data, renewables accounted for 31.7% of all generation in 2021.

considerably from year to year. Both gas and hydro generation are used to help meet the peak demand for electricity, and both will tend to be higher in years with hotter summer periods. Also, gas consumption can be higher in dryer years, due to less water being available for hydro generation.

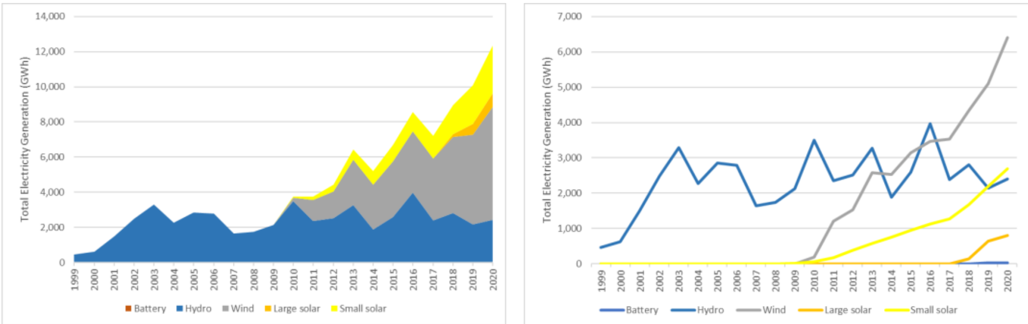
Figure 11: Non-renewable electricity generation in Victoria



Total non-renewable generation, by type

Non-renewable generation by type

Figure 12: Renewable electricity generation in Victoria



Total renewable generation, by type

Renewable generation by type

The total renewable generation over the period 1999 to 2020 is shown in Figure 12. From 1999 to 2006 this was entirely from hydro generation, and from 2010 wind power and solar (PV) generation started to increase rapidly. The amount of hydro generation varies considerably from year to year, based partly on the amount of water storage and partly on the need for peak generation.

From 2005 to 2020, renewable generation increased from 2,850 GWh to 12,330 GWh, an increase of 9,479 GWh (333%). Wind power and small (rooftop) solar systems have driven most of this growth. In 2005, there was essentially no, or close to zero, generation from wind power, or from both small and large-scale solar. By 2020, wind power generation had increased to 6,412 GWh (13.3% of total generation) and small solar generation to 2,687 GWh (5.6% of total generation). Large solar has been a late comer to the scene, first recording generation of 135 GWh in 2018, and growing to 800 GWh (1.7% of total generation) in 2020.

While it is still currently at a very low level, storage batteries are now starting to play a role in supplying electricity back into the grid. They are not exactly a generator; they just shift the time at which electricity generation is fed back into the grid. There are some energy losses when electricity is stored in a battery, but they can make better use of the renewably generated electricity, especially from PV systems[33], and are likely to become increasingly important for maintaining the stability of the electricity supply system[34].

The rapid increase in the share of renewable electricity generation, especially from 2017, means that Victoria is well on track to meet, or exceed the renewable energy targets established for the 2020s. Figure 13 shows renewable electricity's historical share of total generation from 2005 to 2016 (blue dots), and from 2017 to 2021 (orange dots, and a more rapid growth period), and a simple linear projection of the 2017 to 2021 data out to 2030. This is compared with the trajectory that is required to meet the renewable electricity targets established for 2020, 2025, and 2030 (grey dots). It is evident that in 2021 Victoria was tracking well ahead of the targets and seems likely to exceed the 2025 and 2030 targets by a significant margin[35]. DISER's 2021 emissions projection report estimates that renewables will account for 50% of Victorian generation in 2025 and 61% in 2030[36].

Figure 13: Historical and projected share of renewable generation vs targets

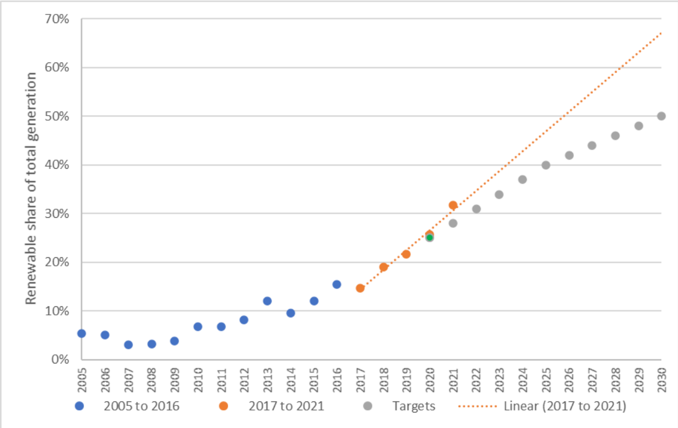
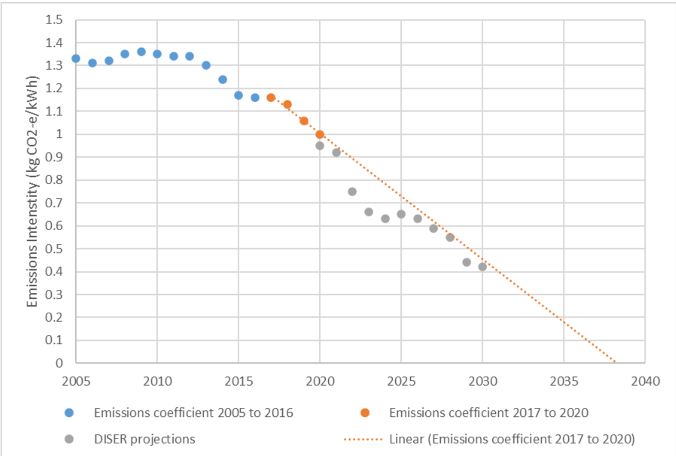


Figure 14: The greenhouse intensity of Victoria's mains electricity



[33] Batteries can store electricity during the middle part of the day when the output of PV systems is at its highest, and then feed this electricity back into the grid to help meet peak demands in the late afternoon, early evening, and early morning.

[34] See discussion on minimum operational electricity demand in Section 3.6 below.

[35] Note that the simple linear projection may be over-optimistic. In practice it will depend on the growth of electricity demand, the retirement of old brown coal power stations, and the rate at which small-scale generation is rolled out and large-scale generation is built. This will depend on both market settings and government policies.

[36] *Australia's emission projections 2021*, Dept of Science, Industry, Energy & Resources, October 2021.

The emissions intensity of the electricity used by Victorian households and businesses has declined in lockstep with the increase in the share of renewable electricity in the generation mix. Figure 14 shows the emissions intensity of Victorian mains electricity[37] from 2005 to 2016 (blue dots), 2017 to 2020 (orange dots), and a simple linear projection from the recent historical data out to 2040 (orange dotted line)[38]. It also shows DISER's recent projections of the Victorian emissions coefficient out to 2030 (grey dots)[39]. A comparison of Figures 13 and 14 highlights that the emissions intensity and share of renewable generation are quite closely correlated, with the rapid reduction in the emissions intensity from 2017 corresponding with the rapid increase in the share of renewable generation from this time.

The simple linear projection of the recent historical data suggests that the emissions intensity of Victoria's mains electricity will decline rapidly during the 2020s and will approach zero as early as the late 2030s. DISER's projections for the 2020s suggest a rapid decline in the early 2020s, presumably driven by a rapid increase in the share of renewable generation, the rate of decline stalling in the mid-2020s, and then continuing more slowly in the second half of the 2020s. Both the simple linear projection and DISER's projection are about the same in 2030.

DISER's projections are based on modelling the expected future electricity generation scenario, and this probably reflects increased electrification (gas appliances and electric vehicles) from the mid-2020s. Electrification of residential gas appliances will increase morning and evening peak demands in winter, while greater uptake of electric vehicles will tend to increase electricity demand in the late afternoon and early evening throughout the year. In the short term, this increased peak demand is likely to be satisfied by a combination of increased gas generation and imports from other states, both of which would tend to increase the Victorian emissions coefficient, or at least reduce the rate at which it declines.

The emissions intensity of Victoria's mains electricity determines the amount of greenhouse gas that is emitted from its use in homes and businesses, so the lower the emissions intensity the lower the greenhouse gas emissions for a given amount of electricity consumption. This will have the biggest impact in those economic sectors, such as the Commercial sector, which are dominated by electricity use.

The emissions intensity of Victoria's mains electricity also has implications for the impact of electrification on Victoria's greenhouse gas emissions. During the 2000s, at over 1.3 kg CO_2-e/kWh, the emissions intensity was very high. This meant that replacing gas appliances with electric ones was unlikely to reduce emissions. It has only been in the late 2010s that improvements in the performance of reverse-cycle air conditioner and heat pump water heater technology, combined with the rapidly declining emissions intensity of electricity, meant that electrification of residential gas appliances was a viable strategy for reducing emissions.

As the emissions intensity of Victorian electricity continues to decrease rapidly over the next few decades, the emissions savings from replacing gas appliances with high efficiency electrical equivalents will increase. Similarly, the emissions savings from replacing petrol (and diesel) driven vehicles with electric vehicles will also increase. However, as noted above, both types of electrification tend to drive increases in peak electricity demand and, in the short term, this is likely to be met by a combination of increased gas generation and imports from other states, and this tends to increase the emissions coefficient. In the longer term, increased battery and pumped hydro storage will be used to meet these peak

[37] The graph shows the emissions coefficient for electricity *at point of end use*. This is largely determined by the electricity generation mix in Victoria but is also impacted by the imports and exports of electricity to Victoria. Note that this graph is based on financial years, so 2005 corresponds to the 2004-05 financial year.

[38] The coefficients are the full fuel cycle (scope 2 & 3) emission factors from the *National Greenhouse Accounts Factors – Australian National Greenhouse Accounts*, Dept of Science, Industry, Energy & Resources, August 2021.

[39] *Australia's emission projections 2021*, Dept of Science, Industry, Energy & Resources, October 2021.

demands using stored renewable electricity, maximising the impact of electrification as a strategy to reduce emissions.

3.4 Electricity system demand

Victoria's electricity system is characterised by both the "supply side" (electricity generation in Victoria and electricity imports from other states) and the "demand side", or the aggregate consumption resulting from electricity use in millions of Victorian homes and businesses. The supply side and the demand side interact, and ultimately the total amount of electricity supplied needs to match the total amount of electricity consumed, at all times throughout the year. If there is an excess of generation in Victoria, some could be exported to other states or could be stored using batteries or pumped hydro. Otherwise, the amount of generation needs to be reduced, by shutting down or scaling back some generators or reducing imports. During periods of higher electricity demand, the total electricity supply needs to be increased, usually by bringing gas or hydro "peaking plant" online, importing electricity from other states or, more recently, discharging large-scale battery storage[40]. If demand is too high for the available supply, then the demand needs to be reduced to an acceptable level. This could be through a combination of load-shedding[41] and demand response[42].

In this section, we use Victorian historical (aggregated) price and demand data from the Australian Energy Market Operator's (AEMO) national electricity market (NEM) data dashboard[43] from 2005 to 2020 to explore how Victoria's total electricity system demand is changing. The NEM Dashboard provides half hourly demand data for each month of each year, enabling the calculation of: the total annual and monthly electricity consumption (GWh); the average annual and monthly electricity demand (MW); the average daily "demand profile"[44] in each month; and the annual, or monthly, maximum and minimum demand (MW), as well as the time of year and day that this occurs.

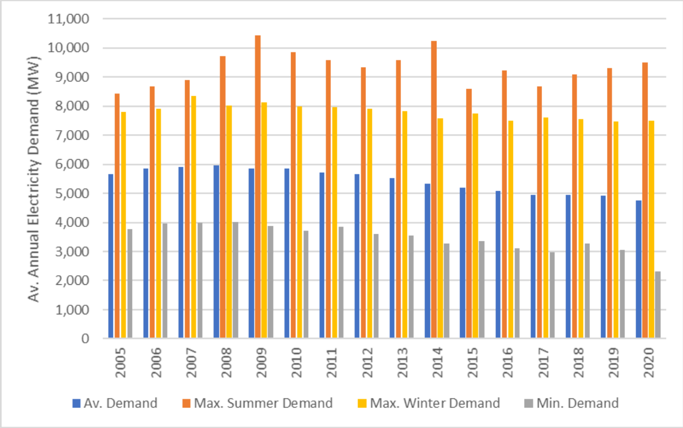
It's important to note that the AEMO data is based on the Victorian electricity demand 'seen' by the electricity supply system. Many homes and businesses now use rooftop PV systems to generate electricity on-site, some of which is used to off-set their mains electricity consumption and some of which is fed back into the electricity grid as part of the renewably generated electricity supply. This electricity generation is largely uncontrolled. From the perspective of the Victorian electricity system demand, it appears as a demand reduction, reducing the amount of electricity that needs to be produced by the large-scale generators.

Figure 15 provides a high-level overview of how Victoria's electricity system demand has changed over the period 2005 to 2020. It shows how the average[45], maximum summer, maximum winter, and minimum electricity system demand has changed. The average electricity demand peaked in 2008 at 5,956 MW and has been on a downward trend ever since. Between 2005 and 2020 it decreased by 905 MW (16.0%). Winter maximum demand peaked at 8,349 MW in 2007 and has shown a slow decline since, with some variation due to the severity of winters. From 2005 to 2020 it declined by 3.8%. Summer maximum demand peaked at 10,415 MW in 2009 and has shown a high degree of variability since, linked to the severity of the summer months. From 2005 to 2020 it increased by 1,094 MW

[40] Currently this plays only a minor role. In future, both battery and pumped hydro storage are expected to play a much greater role in helping to stabilise the electricity system by helping to match supply and demand.
[41] Larger commercial and industrial customers will usually be requested to shut down part of their operation to reduce demand, either as a condition of their supply contract or based on an incentive payment. In the worst cases, and as a last resort, whole sections of the distribution network might be disconnected.
[42] In this case, small and medium consumers might either be requested to shut down or scale back key electrical equipment such as air conditioners manually, or this equipment might be shut down or scaled back automatically based on a prior agreement. Incentive payments would normally be provided to consumers who reduce demand.
[43] https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/data-nem/data-dashboard-nem
[44] This is also referred to as the "load profile". It shows how the average electricity demand (MW) varies across the day in half hour increments.
[45] The average demand (MW) is the average of the half hourly demand data over the entire calendar year. It is related to the total electricity consumption (GWh) in the year in question.

(13.0%), suggesting an underlying trend for increased summer peak demand[46]. Minimum demand peaked at 4,004 MW in 2008 and has declined significantly since, especially since 2018. In 2020 it was only 2,307 MW, a reduction of 1,473 MW (39.0%) since 2005.

Figure 15: Changes in Victoria's electricity system demand since 2005



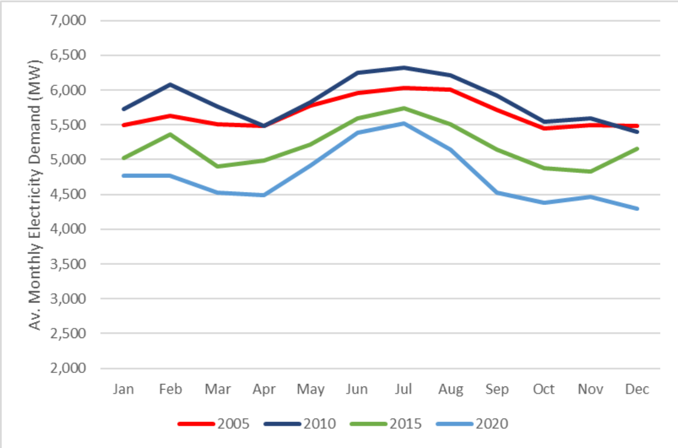
The data presented in Figure 15 highlights some of the key trends and challenges for Victoria's electricity system. Average system demand is decreasing, due mainly to the rapid increase in rooftop PV systems, reduced electricity use in the Manufacturing sector, and the more efficient use of electricity. However, peak summer demand remains high and is quite variable from year to year. The rapid uptake of rooftop PV is likely to be reducing this peak demand to some extent but is having a much lower impact compared to its impact on average demand[47]. Winter peak demand is currently declining, but large-scale electrification of residential gas appliances will drive increases in both morning and evening peak demand in the coldest months, and rooftop PV systems will have little impact on this. The minimum electricity demand has shown a general downward trend, and from 2018 the rate of decline has increased considerably. This is also being driven by the rapid uptake of rooftop PV systems, which generate most of their electricity during the middle part of the day.

Figure 16 provides further insights into the changes that are taking place. It shows the average monthly electricity demand (MW) for selected years between 2005 and 2020. In general, average demand tends to be highest during winter, due mainly to energy demand for heating, and lowest in autumn and spring when both heating and cooling energy demand is low. Average electricity demand is also relatively high during the summer months, due to energy demand for cooling. Electricity demand increased between 2005 and 2010 across much of the year; in both years, electricity generation from rooftop PV systems was negligible or very low. From 2010, the average electricity demand has declined across the entire year, most noticeably during the autumn, spring, and summer months. This reflects both declining electricity consumption – especially in the Manufacturing sector – and the rapid increase in electricity generation from rooftop PV systems since this time. The demand reductions are largest in the autumn, spring, and summer months, because this is when the output of rooftop PV systems is greatest.

[46] Electricity use by residential and commercial air conditioners on hot summer afternoons is a key driver of summer peak demand. Expansion of the number of air conditions installed since 2005, combined hotter summers resulting from climate change, would be expected to drive increased peak demand. This will be offset to some extent by the electricity generation from rooftop PV systems.

[47] Peak summer demand often occurs late in the afternoon on very hot summer days during a working week. The output of PV systems is much lower at this time of day. Further, PV output tends to reduce as the ambient air temperature rises, so is lower on very hot days.

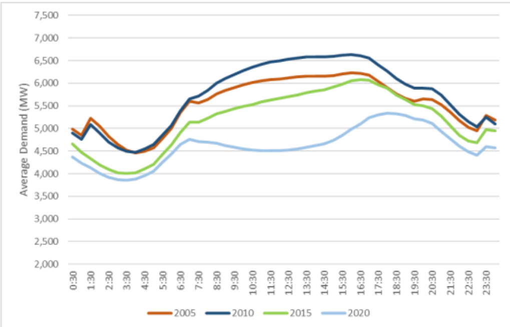
Figure 16: Changes in average monthly electricity demand – selected years



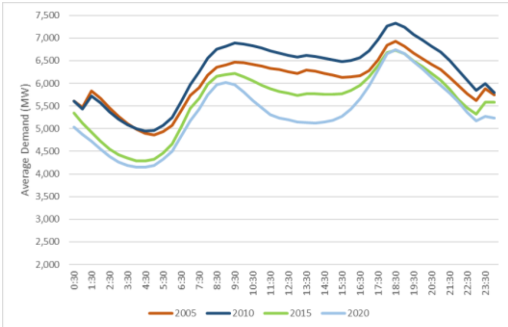
3.5 Electricity system daily demand profile

The daily demand profile[48] shows how electricity demand varies across the day. As with the average annual and monthly electricity demand, there have been significant changes to Victoria's daily electricity system demand profile since 2005 (see Figure 17).

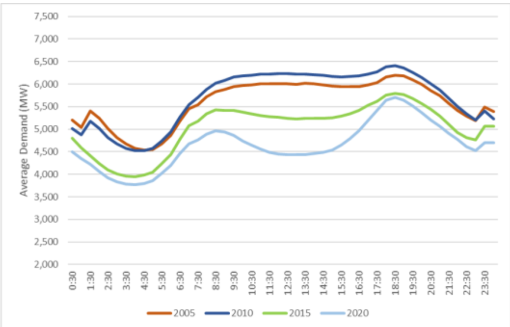
Figure 17: Change in Victoria's average daily demand profile during different seasons



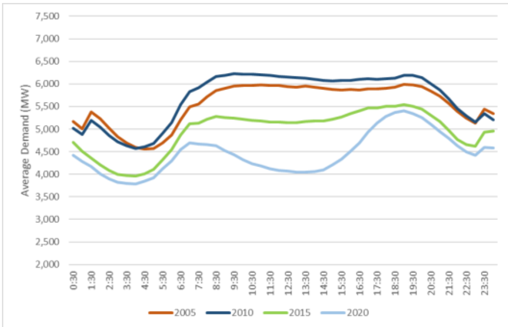
Summer



Winter



Autumn



Spring

In all years shown, the average electricity demand (MW) is higher in winter than in summer throughout the day, and the average demand peaks are higher. In winter there are well

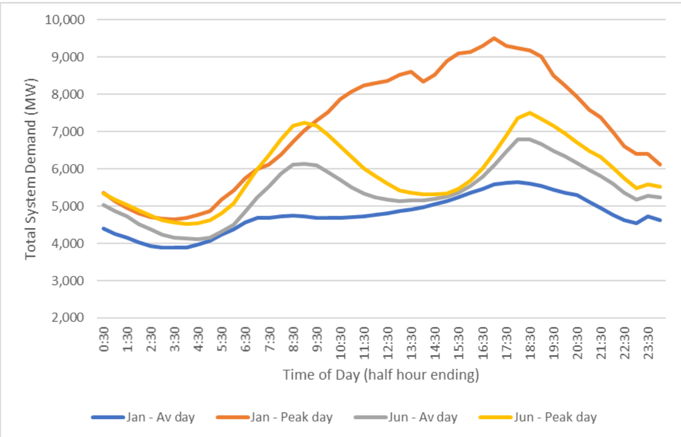
[48] This is also called the "load profile". The AEMO data provides the average electricity system demand for each half hour of each day over an entire year. In this report we have used this data to calculate the average daily demand profile for each season over the period 2005 to 2020.

pronounced demand peaks in the morning and evening, largely related to heating (and cooking in the evening), and in summer there is a single broad peak in the late afternoon largely due to cooling. Electricity demand is lower in both autumn and spring, mainly because the demand for both heating and cooling is low. Average demand tends to be lowest in the early morning hours (midnight to 6 am) when many businesses are not operating, and most people are asleep.

Between 2005 and 2010, electricity demand increased across the day in all seasons, but has since been decreasing. The reduction in demand since 2010 is most pronounced during the middle of the day and is due to increasing generation from rooftop PV systems. This results in the classic "duck curve" series of load profiles. It is most pronounced in spring and autumn when electricity demand tends to be lower but there are sunny days. This reduction in demand during the middle of the day is likely to keep growing as the amount of rooftop PV generation installed grows and has the potential to create minimum demand issues for the electricity supply system (see Section 3.6 below).

While average electricity demand is higher in winter than in summer, the maximum electricity demand on the peak day in summer is currently much higher than the maximum demand on the peak day in winter. Victoria is still very much a 'summer peaking' state. Very high electricity demand can be experienced during the afternoon on hot summer days during the working week when businesses are also operating. Electricity demand for residential air conditioning is a key contributor to this demand peak. Figure 18 shows the average daily demand profile for Victoria in January 2020, and the daily load profile on the peak summer day. The electricity demand in the late afternoon is around double the demand on the average January day. The graph also shows the average and peak June day in 2020. There is also an increase in the size of the morning and evening demand peaks on the coldest winter days, but it is not as pronounced as in summer. The morning and evening demand peaks in June are due mainly to electricity consumption associated with residential heating, although cooking and lighting also contribute to the evening peak.

Figure 18: Victoria's daily electricity demand profile on the average and peak summer and winter days



The large variation between the demand profile on the average and peak summer day is a challenge for the electricity system, as it needs to be capable of meeting demand on the peak day. The increasing number of days of extreme heat (>40ºC) due to global warming will put increasing pressure on the electricity supply system in summer. Increasing electricity generation from rooftop PV systems will help to reduce this demand to some extent, but PV output tends to be low at the time the summer peak occurs, and the output of PV systems is lower at such high temperatures. A combination of increased battery storage and increased use of automated demand response of residential appliances such as air conditioners and pool pumps may be required in future to effectively managed the summer demand peaks.

Electrification of residential gas appliances will increase morning and evening demand peaks in winter. Large-scale electrification could mean that the winter peak is comparable to or higher than the summer peak. Increasing the energy efficiency of buildings, especially older houses, could play an important role in mitigating the impact of electrification on winter peak demand[49]. Battery storage could also be used to provide additional electricity to meet these morning and evening demand peaks. This might be provided by conventional storage batteries or by utilising the batteries of electric vehicles that are plugged-in and charging overnight via the use of V2G technology.

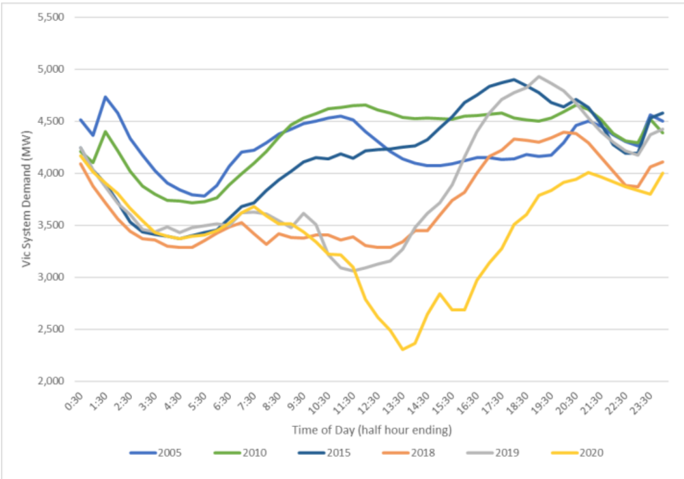
Electrification of residential gas appliances will also increase demand on hot summer afternoons, where gas heaters are replaced with reverse-cycle air conditioners that provide both heating and cooling, and where gas cooktops are replaced with electric or induction cooktops.

A large-scale transition to electric vehicles has the potential to significantly increase electricity demand in the late afternoon and evenings throughout the year. This could be avoided by controlling the times at which electric vehicles charge, either using special tariffs or via control of the charging systems. Ideally, electric vehicles would charge overnight on “off peak” tariffs – similar to those currently used for larger electric storage water heaters – or during the middle of the day, to help soak up excess PV generation.

3.6 Minimum operational electricity demand

Minimum operational electricity demand is the lowest level of total electricity system demand in any given year[50]. Historically, this has occurred during the early hours of the morning when both residential and business electricity demand are lowest. However, as can be seen from Figure 15 (above) and Figure 19 (below), the rapid uptake of rooftop PV systems is now impacting on both the magnitude and the timing of the minimum operational electricity demand. The key shift in the timing of the minimum demand started in 2018, and the magnitude of the minimum demand has declined quite rapidly from this time. PV systems generate their highest output during the middle hours of the day. On sunny days with mild temperatures and low business energy use, this results in electricity demand during the middle of the day being much lower than at other times. PV uptake is expected to continue strongly during the 2020s, potentially driving minimum demand to very low levels.

Figure 19: Change in Victoria’s daily demand profile on the minimum demand day



[49] This reduces the ‘heat load’ of the building, reducing the amount of electricity that needs to be used to meet this heat load, and therefore the morning and evening peak demand of the heating system.

[50] *Energy Explained: Minimum Operational Demand*, AEMO 25/08/20 – see: https://aemo.com.au/en/learn/energy-explained/energy-101/energy-explained-minimum-operational-demand

Victoria’s electricity supply system currently relies on large synchronous coal-fired generators to meet the “baseload” demand and to maintain the “strength” of the electricity supply system. These need a total minimum system demand of 800 to 1,600 MW to operate satisfactorily. If total Victorian electricity demand falls below this level, Victoria must export excess generation to other states to remain in secure operation[51].

A rapidly decreasing minimum operational demand driven by increasing generation of electricity by rooftop PV systems has the potential to create a range of issues for Victoria’s electricity supply system. These include[52]:

- Voltage management – as demand levels decrease, it can become increasingly challenging to manage transmission network voltages.
- Unintended disconnection of rooftop PV systems – these can disconnect when exposed to power system disturbances, and this can adversely impact the operation of the electricity supply system.
- Reduces the effectiveness of under-frequency load shedding as an emergency frequency control mechanism.
- Reduces the ability to restart the large-scale generation after a major blackout.

A range of approaches can be used to manage the minimum system demand, including battery storage and shifting loads to the middle of the day to soak up excess PV generation, and smart control of rooftop PV systems, to curtail output when necessary.

The Victorian Government recently released the *Harnessing Victoria’s distributed energy resources* strategy to guide a greater uptake of rooftop PV systems while continuing to address the challenges created when this is connected to the “old electricity system”[53]. This strategy envisions that by 2025 one in every three households will have rooftop PV systems to generate renewable electricity and that a total of 740 MWh of distributed battery storage will be installed across the state.

[51] *2021 Electricity Statement of Opportunities*, AEMO, August 2021
[52] *Energy Explained: Minimum Operational Demand*, AEMO 25/08/20
[53] *Harnessing Victoria’s distributed energy resources*, DELWP, 29 April 2022.

4 Victoria's gas system transition

4.1 Introduction

Natural gas has been a major energy source in Victoria for over four decades. It is used widely for residential heating, water heating and cooking, is an important energy source for business, especially manufacturing, and is used to power gas peaking plants that generate electricity at times of high demand. However, to achieve Victoria's target of net zero emissions by 2050, the greenhouse gas emissions from the energy end-uses that consume natural gas today will need to transition to net zero by this time. There are several ways in which this could be achieved: gas appliances and equipment could be replaced with high efficiency electrical equivalents powered by fully renewable electricity – this is known as "electrification"; replacing natural gas with hydrogen produced from a renewable or net zero emission process[54]; or replacing natural gas with biomethane. The policies and programs to set Victoria on this trajectory are set out in the *Gas Substitution Roadmap*[55], released in July 2022.

In this section we look at Victoria's natural gas supply system, the challenges that this system currently faces, and the expected transition over the coming decades. Key learnings are:

- Most natural gas is used in gas appliances and equipment in homes and small businesses. Residential gas use is particularly important and drives increased gas consumption during the winter months, both the daily gas demand and the demand peaks in the morning and evenings.
- Due to declining production from the Bass Strait gas fields, Victoria faces a possible shortfall in natural gas supply during winter from as early as 2023.
- We are still in the very early stages of the transition that will be required to achieve net zero emissions by 2050 from the end-uses that currently use natural gas.

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[54] Renewable, or "green" hydrogen is produced by electrolysis using renewable electricity. In Victoria, low or net zero emission hydrogen, could be produced from natural gas ("blue" hydrogen) using a process known as steam reforming, in conjunction with carbon capture and storage. "Brown" hydrogen could be produced from brown coal but would need to use carbon capture and storage to achieve zero emissions.
[55] *Gas Substitution Roadmap*, Victoria State Government, 2 July 2022.

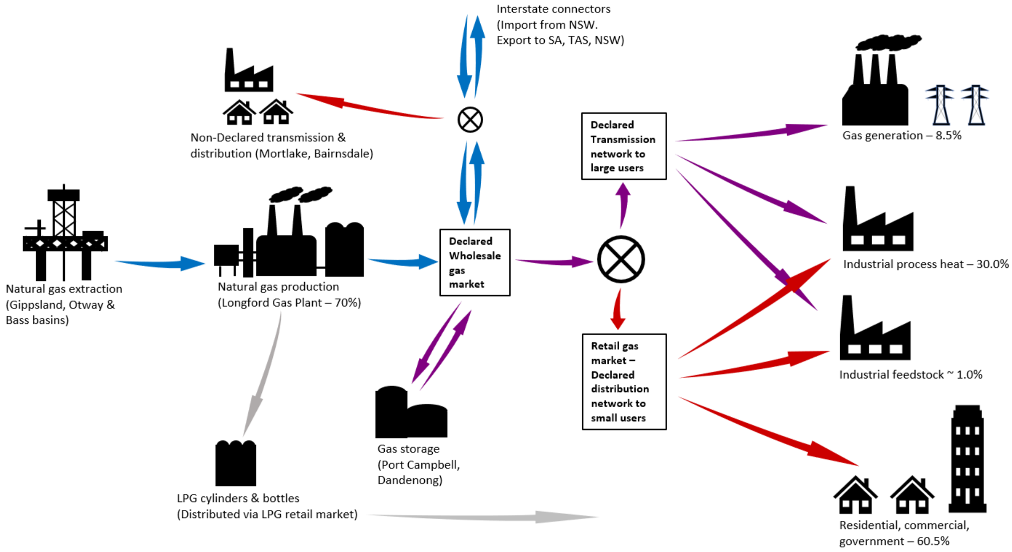
4.2 Gas system transition

Victoria's natural gas system (see Figure 20) consists "primarily of gas fields and processing facilities that extract and process gas, high pressure pipelines that transport this gas around the state, and low-pressure distribution pipelines that deliver gas to customers"[56]. Most of the gas comes from offshore gas fields located in the Gippsland and Otway basins, and the largest processing facility is located at Longford in the south-east of the state. The Victorian gas network is also connected to NSW, South Australia and Tasmania, allowing gas from the Cooper Basin to be imported into Victoria and gas to be exported from Victoria to other states[57]. Excess natural gas can be stored, with the largest storage facility being an underground facility at the Iona Gas Plant located near Port Campbell in the south-west of the state. This helps to ensure that the gas supply is sufficient to meet the demand on the days of high usage that occur during the coldest months.[58]

Some towns located in regional Victoria are not connected to the main gas network but are supplied by trucking in compressed natural gas (CNG), which is then reticulated through local distribution networks[59].

The Victorian natural gas system is operated through a commercial market, "which allows gas to be traded between producers and users, and balances supply and demand. A range of national and state regulatory bodies ensure that this system operates safely and efficiently"[60].

Figure 20: Victoria's natural gas system[61]



Source: *Help Build Victoria's Gas Substitution Roadmap*.

[56] *Help Build Victoria's Gas Substitution Roadmap – Consultation Paper*, Victoria State Government, June 2021
[57] These pipelines in turn connect Victoria into the wider east coast gas network, which also includes Queensland, the ACT and the Northern Territory.
[58] *Help Build Victoria's Gas Substitution Roadmap – Consultation Paper*, Victoria State Government, June 2021. https://www.energy.vic.gov.au/gas/about-the-gas-sector
[59] *Help Build Victoria's Gas Substitution Roadmap – Consultation Paper*, Victoria State Government, June 2021.
[60] https://www.energy.vic.gov.au/gas/about-the-gas-sector
[61] Based on diagram in *Help Build Victoria's Gas Substitution Roadmap – Consultation Paper*, Victoria State Government, June 2021

Victorian natural gas consumption is dominated by the residential and small commercial sectors, which currently account for 60.5% of the total[62]. It shows considerable variation throughout the year; consumption is lowest during the summer months and highest during the winter months, with most of this variation due to the residential and small commercial sectors (see Figure 21). The large increase in consumption during the colder months (April to October) is mainly due to the increased gas use for residential heating during these months. The highest daily gas consumption peaks occur during the winter months, generally in the mornings and evenings on the coldest days. Figure 22 shows the average daily gas demand profile for Victoria's gas system in 2020 (red line) and the forecast profiles on the 1-in-2 year peak day (yellow line) and 1-in-20 year peak day (grey line).

Figure 21: Forecast total average daily gas demand in Victoria in 2020[63]

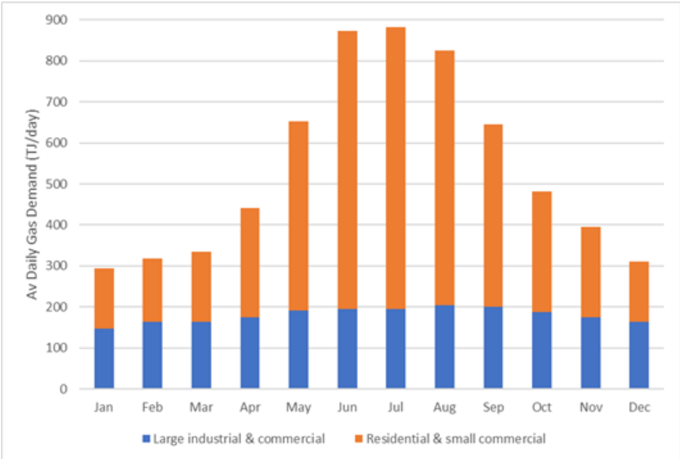
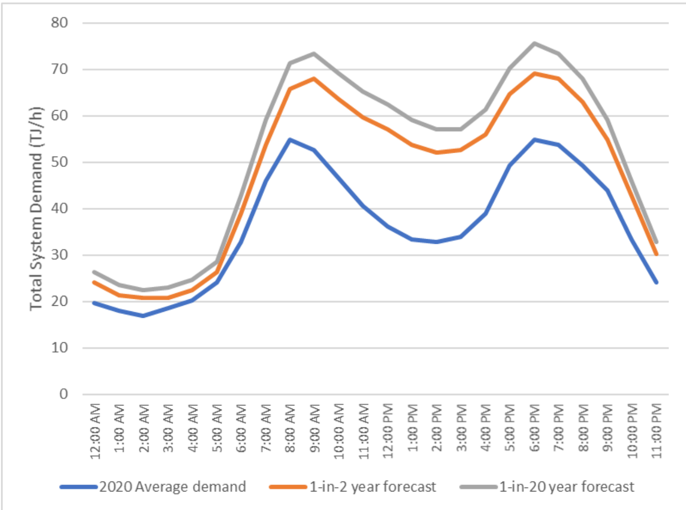


Figure 22: Victorian daily gas demand profile vs forecast peak demand profile[64]



As seen in Section 2.6, Figure 7, Victoria's natural gas consumption has shown a general increasing trend since 1989-90, although in recent years it seems to have plateaued. However, Victoria faces possible natural gas supply constraints over the next decade, especially on cold winter days. Our historical sources of natural gas are starting to decline,

[62] *Help Build Victoria's Gas Substitution Roadmap – Consultation Paper*, Victoria State Government, June 2021.
[63] *Victorian Gas Planning Report – Update*, AEMO, March 2020
[64] Adapted from *Victorian Gas Planning Report*, AEMO, March 2021

and the gas supply-demand balance is expected to become tighter from around 2023, unless new sources of gas supply can be found. According to the 2021 Victorian gas planning report[65]: “Overall production from existing gas production facilities is forecast to decline each year between 2021 and 2025. Significant declines are expected from the existing fields, predominantly in the Gippsland zone, with the largest annual reduction of 72 PJ forecast for 2023. This is mainly due to the forecast reduction of capacity associated with depletion of the large legacy gas fields that supply the Longford Gas Plant prior to winter 2023”. The development of the Port Kembla LNG import terminal in NSW and modification the Eastern Gas Pipeline to supply gas into the main high pressure gas network from winter 2023 was expected to provide the additional supplies necessary to compensate for reduced production at the Longford Gas Plant, but the most recent planning report notes that the Port Kembla terminal is now not expected to be completed until late 2023[66].

The reduction in annual gas production in Victoria will create challenges meeting the gas demand on the peak winter days. The 2022 Victorian gas planning report found: “Winter 2023 peak day supply capacity … is just above the forecast 1-in-20-year peak day system demand under both the Step Change and Progressive Change scenarios. The 2022 GSOO forecasts that extreme gas demand (including gas generation) in severe cold weather may exceed supply available in Victoria and New South Wales from winter 2023.[67]” In the worst cases, given the short timeframe, demand response or curtailment might be required to ensure that gas supply was adequate to meet gas demand on the peak winter days.

Potential future shortfalls in the gas supply require investment in new gas production infrastructure (in this case the development of new gas fields or gas import facilities) and gas transmission and supply infrastructure, and this can lead to increased gas prices[68]. Demand side measures such as energy efficiency and electrification of gas end-uses could also be used to reduce gas demand.

In addition to the short-term supply issues, the longer-term aim is to reduce the greenhouse gas emissions that result from Victoria’s natural gas use to net zero by 2050. The Consultation Paper for the *Gas Substitution Roadmap* outlines several approaches that could be used[69]:

» **Energy efficiency.** More efficient use of gas in households and businesses reduces gas consumption, and therefore the greenhouse emissions from using gas appliances and equipment. It would also help to address the predicted shortfall in gas consumption from 2023, although large programs would need to be rolled out very quickly to have much impact on this. A key focus for energy efficiency is likely to be the residential sector as this accounts for around 42% of total natural gas consumption. This might be through replacing older gas heating, water heating and cooking appliances with energy efficient new ones, more stringent minimum energy performance standards (MEPS) for new gas appliances[70], increasing the efficiency of older houses through building shell retrofits (insulation, draught sealing, etc), or higher efficiency standards for new houses. Increasing the energy efficiency of older houses with gas heating both saves gas and has the potential to significantly reduce the morning and evening gas demand peaks associated with heating. More efficient use of gas has the potential to significantly reduce

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[65] *Victorian Gas Planning Report*, AEMO, March 2021
[66] *Victorian Gas Planning Report Update*, AEMO, March 2022
[67] *Victorian Gas Planning Report Update*, AEMO, March 2022. The “Step Change” scenario assumes rapid electrification and declining gas demand, while the “Progressive Change” scenario is based on a slower rate of electrification. GSOO = Gas Statement of Opportunities report.
[68] For a discussion of the measures that are planned to address Victoria’s gas supply shortfall see AEMO’s 2020 and 2021 Victorian Gas Planning Reports.
[69] *Help Build Victoria’s Gas Substitution Roadmap – Consultation Paper*, Victoria State Government, June 2021. Here we provide a summary of these approaches. For more detail, refer to the Consultation Paper.
[70] Currently, through the national Equipment Energy Efficiency (E3) Program, Australian governments only apply MEPS to residential gas water heaters. MEPS are not currently applied to gas heaters, cooking equipment or to gas boilers.

emissions but is not sufficient in itself to achieve net zero emissions if the natural gas comes from conventional sources.

- **Addressing fugitive gas emissions.** Natural gas, or methane, is a potent greenhouse gas and gas leaks, or fugitive emissions, can occur during gas extraction, production and distribution. Reducing these leaks will help to reduce greenhouse gas emissions from natural gas, although it does not reduce the greenhouse gas emissions from burning natural gas obtained from conventional sources.
- **Electrification.** Replacing gas appliances and equipment with high efficiency electric alternatives, combined with an increasingly renewable electricity supply, can significantly reduce greenhouse gas emissions from these end-uses, and can achieve net zero emissions if the electricity supply is 100% renewable. Heat pump technology[71] can be used for low and medium temperature heating and water heating, and induction cooktops can replace gas cooktops. However, high temperature air and water heating applications are more difficult to electrify and are likely to require the use of a renewable gas (hydrogen or biomethane). Electrification has the potential to both help address the predicted shortfall in the gas supply[72], and to play a major role in achieving net zero emissions.
- **Substituting natural gas with hydrogen.** Renewable (or "green") hydrogen can be produced from water by electrolysis using renewable electricity. Net zero or low emission hydrogen can also be produced from fossil fuels (natural gas or coal) and capturing and storing the carbon dioxide produced. The hydrogen can then be used to partially or fully replace the natural gas burnt in appliances and equipment, reducing the greenhouse intensity of the gas supply. Mixes of up to 10% hydrogen are compatible with the current gas supply system, meters and most appliances, but modification of the gas supply system, meters and appliances and equipment are likely to be required for higher level blends. Hydrogen's potential contribution to achieving Victoria's net zero emission target is currently being assessed. Its main contribution is likely to be for replacing natural gas use in higher temperature industrial heating applications that are difficult to electrify, and possibly for powering gas "peaking plant' to generate electricity at times of peak demand.
- **Substituting natural as with biogas or biomethane.** Biogas is derived from the anaerobic digestion of organic material such as industrial and agricultural waste, wastewater, or energy crops. It can be upgraded into biomethane which can then be injected into the existing gas supply system without the need for modifying gas pipelines or appliances. Blending biomethane with conventional natural gas reduces the greenhouse intensity of the reticulated gas supply. However, limitations on the supply of biomethane mean that it is unlikely to be possible to fully replace natural gas.
- **Emerging technologies.** Technologies such as solar thermal and geothermal could replace natural gas in a range of commercial and industrial low, medium and high temperature heating applications. Carbon capture and storage also has the potential to decarbonise some existing and new industries, by permanently removing the greenhouse emissions produced by burning natural gas from the atmosphere.

Victoria is in the early stages of the transition required to achieve net zero emissions from the end-uses that currently use natural gas but, as yet, there is little evidence of this transition in the available data. Several energy efficiency programs[73] are helping to reduce

[71] Heat pumps use a refrigeration cycle to extract heat from the outside air, ground or water, and use this to heat water or air. Reverse-cycle air conditioners and heat pump water heaters are examples of this technology.
[72] As with energy efficiency, large-scale programs would need to be rolled out quickly to have a significant impact on the gas shortfall predicted from around 2023.
[73] Since 2009, the *Victorian Energy Upgrades* program has provided financial incentives for replacing old gas heaters with high efficiency new ones, replacing gas water heaters with gas-boosted solar water heaters, and for a range of simple draught sealing measures. Minimum efficiency standards for gas water heaters were introduced in 2013 through the national Equipment Energy Efficiency Program. Through the building code, the minimum efficiency of

the rate of growth in natural gas consumption and, through Solar Victoria's Home Heating and Cooling Upgrade program[74], rebates have been available for low income households to replace gas heaters with high efficiency reverse-cycle air conditioners since May 2021. The Victorian Government is also exploring the potential for the development of hydrogen production facilities, including supporting the development of hydrogen supply chains through both the Hydrogen Energy Supply Chain (HESC) project[75] and the implementation of a Renewable Hydrogen Industry Development Plan[76].

The Victorian Government's *Gas Substitution Roadmap*[77] was released in early July 2022. It sets out a range of additional measures to reduce gas consumption and greenhouse emissions, including through electrification and energy efficiency, with the key ones being:

» Introducing new measures into the *Victorian Energy Upgrades* scheme in 2023 to incentivise the replacement of gas heating and water heating with high efficiency (heat pump[78]) electrical options. At the same time, incentives for installing efficient gas heating and water heating will be removed from the scheme by the end of 2023;

» Changes to the Victorian Planning Provisions in 2022 to remove the requirement for new housing developments to be connected to gas. In addition to this, the Victorian "water heating" variation to the National Construction Code - which required a gas boosted solar water heater to be installed in gas-reticulated areas if there was not a suitable rainwater tank installed – will be retired. Together, these changes will facilitate the construction of all-electric new homes; and,

» An increase of the minimum thermal efficiency requirement from 6 Stars to 7 Stars, and the introduction of new whole of home requirements with the update to the National Construction Code in 2022 (NCC2022).

There have always been links between Victoria's electricity and gas systems. Electricity is used in the production and distribution of natural gas, and gas peaking plant have been used to generate electricity at times of high demand. However, the transition to net zero emissions by 2050 will lead to even stronger links between these systems. Electrification of gas appliances and equipment will increase both the total demand for electricity, and the demand peaks, especially during the winter months. Renewable electricity can be used to produce renewable hydrogen, which could be used to replace natural gas in those heating applications that are difficult to electrify. This will also increase demand for electricity but has the potential to utilise low cost electricity by soaking up excess PV generation during the middle of the day, helping to avoid minimum demand issues. Hydrogen produced in this way could also be used to power gas peaking plant, to help meet peak electricity demands in both summer and winter.

new dwellings was increased in 2005 (5 Star) and 2013 (6 Star) and will increase to 7 Stars in October 2023 under changes to the National Construction Code agreed in 2022 (NCC2022). Minimum efficiency requirements for heating in rental properties, introduced in March 2021, are expected to lead to around 100,000 heaters to be upgrade to more efficient systems.

[74] This $355 million program targets the replacement of 250,000 inefficient heaters, including around 150,000 old inefficient gas heaters. For further information see: https://www.heatingupgrades.vic.gov.au/upgrades-rental-properties

[75] For further information see: https://www.hydrogenenergysupplychain.com/

[76] For further information see: https://www.energy.vic.gov.au/renewable-hydrogen/renewable-hydrogen

[77] *Gas Substitution Roadmap*, Victoria State Government, 2 July 2022. For further information see: https://www.energy.vic.gov.au/gas/victorias-gas-substitution-roadmap

[78] This includes reverse-cycle air conditioners for heating and heat pump water heaters.

5 Victorian greenhouse gas emissions

5.1 Introduction

In this chapter we look at how Victoria's greenhouse gas emissions have changed over the period 1989-90 to 2019-20 and compare the Victorian experience with Australia as a whole. More detailed information on Victoria's emissions, broken down by emission sources and compared to other states and territories, is provided in Appendix A5.

The key learnings are:

- Victoria's total net greenhouse gas emissions in 2019-20 were 83.3 Mt CO_2-e, a reduction of 35.3 Mt CO_2-e (29.8%) since 2004-05. This is mainly due to reductions in emissions from Energy (22.7 Mt CO_2-e) and Land Use, Land Use Change and Forestry (10.0 Mt CO_2-e).
- Since 2012-13, emissions from Land Use, Land Use Change and Forestry have been a net greenhouse sink in Victoria (negative emissions). If these are ignored, Victoria's 2019-20 emissions are dominated by Energy (78.4%) and Agriculture (15.4%). Emissions from Industrial processes (3.4%) and Waste (2.7%) are much less significant.
- Victoria has 25.6% of Australia's population but is responsible for only 16.7% of Australia's total net emissions. Our share of emissions from Energy, Agriculture, Industrial processes, Waste, and Land Use, Land Use Change and Forestry are lower than our population share. Emissions in Queensland, Western Australia and the Northern Territory are higher than their population share, and emissions in Western Australia and the Northern Territory are growing.
- Victoria has the third highest share of Energy related emissions, just ahead of Western Australia, but these are reducing quickly due to increasing renewable generation.
- All states and territories have net zero emission targets for 2050, and most have higher 2030 emission targets than the former Australian Government's weak target of a 26 to 28% reduction compared to 2005[79]. New South Wales, Victoria, South Australia and ACT have targets that are higher than the current Australian Government's national target of a 43% reduction. If these states meet their published targets, and the remaining jurisdictions (Queensland, Western Australia, Tasmania and the Northern Territory)

[79] This was the target Australia confirmed at COP26 in November 2021. On 16 June 2022, the new Australian Government lodged an updated Nationally Determined Contribution with the UNFCC Secretariat committing Australia to a 43% reduction. See: https://www.industry.gov.au/news/australia-submits-new-emissions-target-to-unfccc

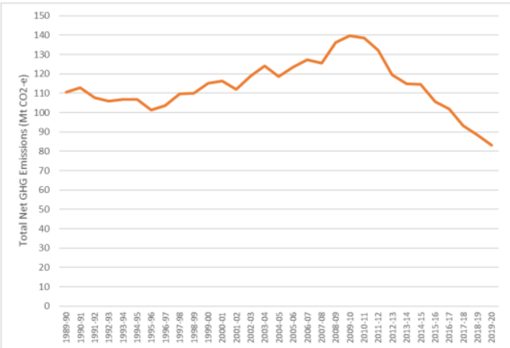
achieve reductions consistent with the proposed 43% national target, Australia could achieve a 46 to 47% emissions reduction in 2030.

- Victoria's greenhouse gas emissions have fallen rapidly over the last decade, and we seem likely to achieve *at least* a 58% emission reduction by 2030, beating our current interim target of a 45 to 50% reduction compared to 2005 by a significant margin.

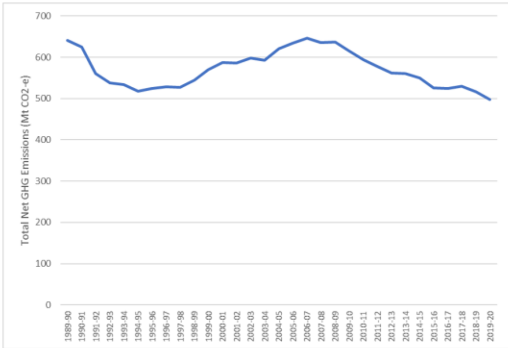
5.2 Victorian greenhouse gas emissions

National and state greenhouse gas inventories are published on the Department of Industry, Science and Energy and Resource's Australian Greenhouse Emissions Information System (AGEIS) website (http://ageis.climatechange.gov.au/)[80]. The annual greenhouse gas emissions are categorised by the source of the emissions – Energy, Agriculture, Industrial process emissions, Waste, and 'Land Use'[81]. The Land Use category can sometimes be a net source of emissions and sometimes a net emissions sink (or negative emissions). The total net emissions are the sum of all emission sources minus any net emission sink. Victoria's total net greenhouse gas emissions over the period 1989-90 to 2019-20 are shown in Figure 23 and compared to Australia's total net emissions.

Figure 23: Total Net Greenhouse Gas Emissions – Victoria vs Australia



Victoria



Australia

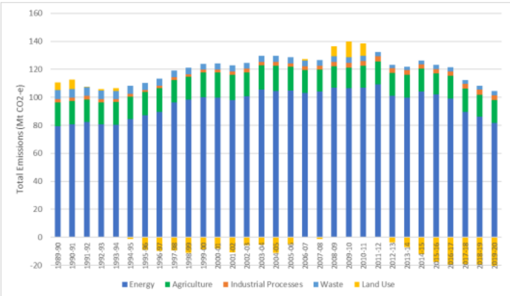
Victoria's total net emissions peaked in 2009-10 at 139.8 Mt CO_2-e. In 2004-05, they were 118.6 Mt CO_2-e and by 2019-20 had declined to 83.3 Mt CO_2-e, a reduction of 35.3 Mt CO_2-e (29.8%) compared to 2004-05. This means that Victoria exceeded the upper end of its 2020 target of a 15 to 20% reduction compared to 2005. Australia's total net emissions peaked in 2006-07 at 646.3 Mt CO_2-e. In 2004-05, they were 621.1 Mt CO_2-e and by 2019-20 had declined to 497.7 Mt CO_2-e, a reduction of 123.4 Mt CO_2-e (19.9%), significantly lower in percentage terms than in Victoria. Victoria's total net emissions have been on a steep downward trend since 2009-10, while Australia's net emissions have declined more gradually.

[80] These greenhouse gas inventories are "based on the IPCC classification system used to report Australia's greenhouse gas emission inventory to track Australia's progress towards its 2030 Paris target" and are "compiled using the global warming potentials from the IPCC 5th Assessment Report".

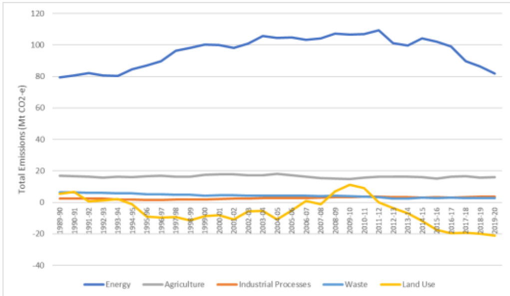
[81] In this report we use the term "Land Use" as shorthand for Land Use, Land Use Change and Forestry (LULUCF), the full name of this emissions category.

A breakdown of the greenhouse gas emissions by emission source is shown in Figures 24 (Victoria) and 25 (Australia)[82]. Victorian emissions are dominated by Energy[83], and in 2019-20 this source accounted for 98.3% of Victoria's total net emissions and for 78.4% of our total emissions excluding land use (104.3 Mt CO_2-e). Agriculture is the other main source of greenhouse gas emissions (19.3% of total net emissions), and Industrial processes (4.3%) and Waste (3.4%) make only a minor contribution[84]. Australian emissions are also dominated by Energy, with this accounting for 84.2% of total net emissions and 78.1% of total emissions excluding land use in 2019-20. Like Victoria, the other main sources of emissions are Agriculture (14.6% of total net emissions) and Industrial processes (6.4%), and Waste (2.6%) makes only a minor contribution to the total.

Figure 24: Victoria's Greenhouse Gas Emissions by Source

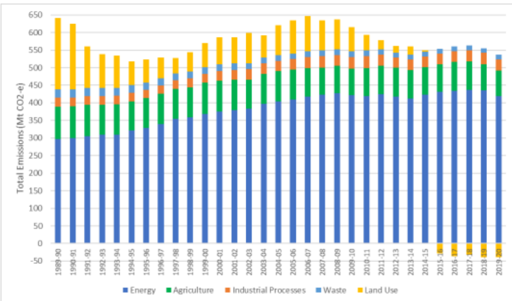


Total greenhouse emissions, by source

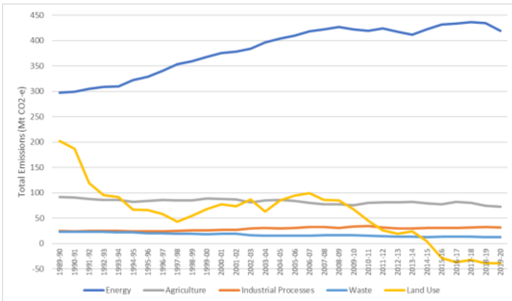


Total emissions from different sources

Figure 25: Australia's Greenhouse Gas Emissions by Source



Total greenhouse emissions, by source



Total emissions from different sources

Australia's Energy related emissions showed a general upward trend from 2004-05 to 2018-19, but declined between 2918-19 and 2019-20, probably in response to the COVID-19 restrictions reducing transport energy consumption. In contrast, Victoria's Energy related emissions have shown a significant decline since 2011-12, largely due to the increase in renewable electricity generation. Between 2004-05 and 2019-20, Victoria's Energy related emissions reduced by 22.7 Mt CO_2-e (21.7%), while over the same period Australia's energy related emissions *increased* by 15.5 Mt CO_2-e (3.8%). Over the analysis period, emissions

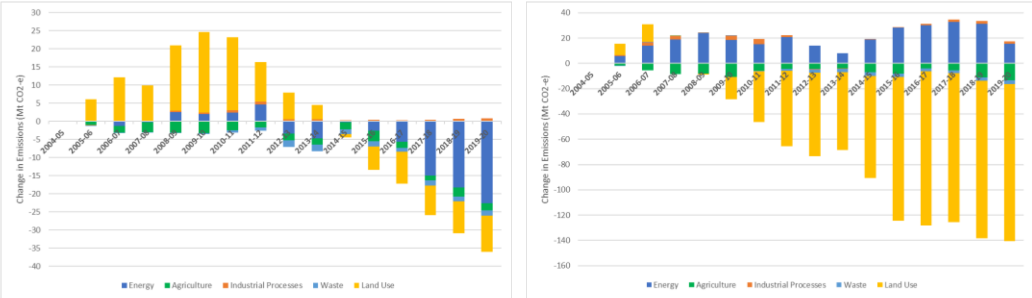
[82] Over much of this period "Land Use" acted as a sink for greenhouse gas emissions (e.g., negative emissions) in Victoria rather than as a source of emissions. For the total net emissions, any greenhouse sinks (e.g., negative emissions) are subtracted from the greenhouse sources. Land Use can sometimes be a source of emissions and sometimes a sink for emissions.

[83] The Energy source category includes fuel consumption (coal and gas) for electricity generation, fuel consumption (gas, wood, petroleum products) in homes and businesses, fuel consumption (mainly petroleum products) in transport, and fugitive emissions from fuel distribution (e.g. natural gas). The *Victorian Greenhouse Gas Emissions Report 2020*, Dept. of Environment, Land, Water & Planning, October 2022, provides a more detailed breakdown of the Energy emissions category.

[84] Adding these together gives a total greater than 100%, because Land Use was an emissions sink for both Vicrtoria and Australia.

associated with Land Use have made a significant contribution to Australia's total net emissions, especially in the early 1990s, but since 2015-16 have become a small emissions sink. The reduction in these emissions since 2006-07 is the main reason for the decline in Australia's total net emissions since this time. Declining emissions from Energy since 2011-12, and declining emissions from Land Use since 2009-10 (it became a net emission sink in 2011-12), are the key reasons for Victoria's declining emissions since 2004-05 (see Figure 26).

Figure 26: Change in total emissions since 2004-05 – Victoria vs Australia



Victoria Australia

Australia's Land Use emissions declined strongly during the 1990s, and from 2006-07 to 2018-19. They became a net emission sink in 2015-16, but the negative emissions provided by this sink seems to have levelled off from 2018-19. In Victoria, emissions from Land Use have declined significantly since 2009-10, and have been a net sink since 2011-12, but also levelled off from 2016-17. Overall, the net sink provided by Land Use seems to have plateaued, and this will place increasing importance on emissions reductions from Energy and Agriculture to achieve emission targets. This is especially the case for Australia's national emissions target.

5.3 Comparison with other states and territories

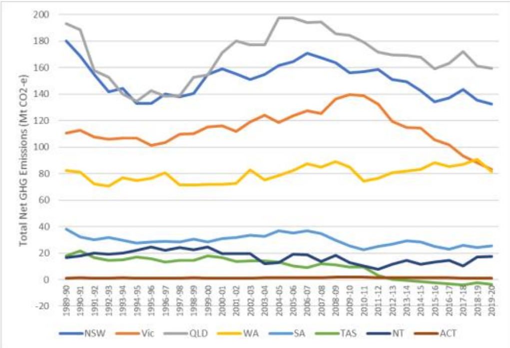
The net total greenhouse gas emissions in the different states and territories over the period 1989-90 to 2019-20 are shown in Figure 27 (left hand side)[85] as well as each jurisdiction's share of Australia's total population and total net emissions (right hand side). Victoria makes a significantly lower contribution to national emissions than would be expected from its population share. In 2019-20, Victoria accounted for 25.6% of Australia's population but was responsible for only 16.7% of Australia's total net emissions. New South Wales', Victoria's, South Australia's, Tasmania's, and the ACT's share of total net emissions is lower than their population share. Queensland's, Western Australia's, and the Northern Territory's share of emissions are much higher than their population share. This is mainly due to LNG and other resource extraction industries that operate in these jurisdictions.

In 2019-20, Queensland had the highest total net emissions (159.2 Mt CO_2-e), followed by New South Wales (132.5 Mt CO_2-e), Victoria (83.3 Mt CO_2-e) and Western Australia (81.7 Mt CO_2-e). The total net emissions in all other jurisdictions combined was only 39.9 Mt CO_2-e. The total net emissions in Queensland and New South Wales peaked during the mid-2000s and have shown a general decline since. Victorian net emissions peaked in 2009-10 and have shown a strong downward trend since then, dropping to around the same level as Western Australia from 2018-19. The net emissions in Western Australia increased between

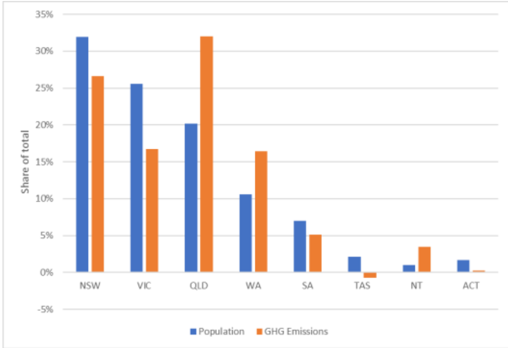
[85] A comparison of the greenhouse emissions from the different emission sources is provided in Appendix A1.

2010-11 and 2018-19, but now may have started to decline[86]. The net emissions in the Northern Territory are increasing.

Figure 27: Victoria's emissions compared to other states & territories



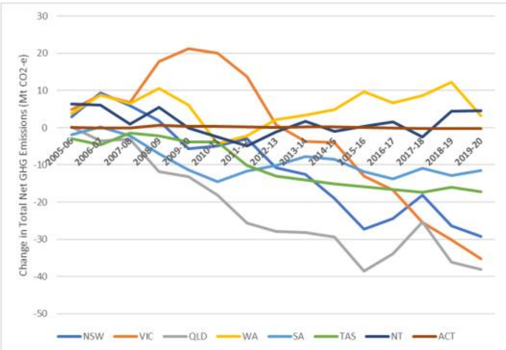
Net total greenhouse gas emissions



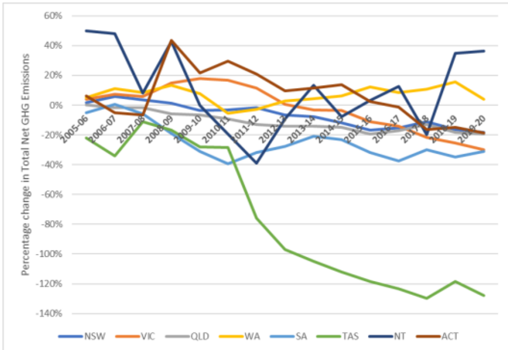
Share of population and total emissions in 2020

Since 2004-05, the largest reductions in net total emissions have occurred in Queensland (38.1 Mt CO_2-e, 19.3%), Victoria (35.3 Mt CO_2-e, 29.8%), New South Wales (29.2 Mt CO_2-e, 18.1%), Tasmania (17.2 Mt CO_2-e, 128.3%), and South Australia (11.5 Mt CO_2-e, 31.1%). Net emissions have increased in Western Australia (3.2 Mt CO_2-e, 4.0%) and the Northern Territory (4.6 Mt CO_2-e, 36.2%). Overall, during this time Australia's total net emissions decreased by 123.4 Mt CO_2-e (19.9%), significantly lower in percentage terms than in Victoria, South Australia, and Tasmania. This contrasts with Australia's new international commitment to reduce emissions by 43% of the 2005 emissions by 2030.

Figure 28: Comparison of changes in net state & territory emissions since 2004-05



Change in net emissions since 2004-05



Percentage change in net emissions since 2004-05

5.4 Emission reduction targets

All states and territories have set targets to achieve net zero greenhouse gas emissions by 2050, and the Australian Government also made a commitment to achieve this target at the COP26 meeting held in Glasgow in November 2021. However, unlike many countries, Australia did not make it's 2030 target more stringent at this time[87], retaining it as a 26 to

[86] This may be mainly due to the start of the COVID-19 restrictions, and these emissions may start to increase again after the restrictions are lifted.

[87] Under the so-called "ratchet mechanism" that formed part of the Paris Agreement (COP21), it was intended that countries would submit new "intended nationally determined contributions" every five years, outlining their emissions reduction targets, with the emissions targets becoming more ambitious, or ratcheting up, every five years.

28% reduction compared to 2005. Angus Taylor, then Minister for Industry, Energy and Emissions reduction, claimed that Australia was on track to achieve a reduction of at least 35% by this date[88].

Leading into the 2022 Federal election, the Labor Party's *Powering Australia* plan[89] made a commitment to raise Australia's 2030 emission target to a 43% reduction compared to 2005, significantly higher than the COP26 target. On 16 June 2022, the new Australian Government lodged an updated Nationally Determined Contribution with the UNFCC Secretariat committing Australia to this higher target[90].

Table 1: Comparison of 2030 emission reduction targets

	NSW	VIC	QLD	WA+	SA	TAS+	NT+	ACT	Aust
Emissions in 2004-05 (Mt CO_2-e)	161.6	118.6	197.3	78.5	36.8	13.4	12.7	1.4	**621.1**
Emissions in 2019-20 (Mt CO_2-e)	132.4	83.3	159.2	81.7	25.4	-3.7	17.3	1.1	**497.7**
Reduction to 2019-20 (Mt CO_2-e)	29.2	35.3	38.1	-3.2	11.5	17.2	-4.6	0.3	**123.4**
Reductions to 2019-20 (%)	18.1%	29.8%	19.3%	-4.0%	31.1%	128%	-36.2%	18.5%	**19.9%**
Emission reduction target in 2030 (%)	50%	45 – 50%	30%	26 - 28%	50%	26 – 28%	26 – 28%	65 – 75%	**43%**
Emission reductions in 2030 (Mt CO_2-e)	80.8	53.4 – 59.3	59.2	20.4 – 22.0	18.4	3.5 – 3.8	3.3 – 3.6	0.9 – 1.0	**267.1**

+ It is assumed that WA, TAS and NT would at least meet the COP26 target.

New South Wales, Victoria, Queensland, South Australia, and the ACT all have published emission reduction targets for 2030 that are more ambitious than Australia's COP26 target. New South Wales, Victoria, South Australia and ACT have 2030 targets that are higher than Australia's new 43% target. Western Australia has no target for 2030 but has previously indicated it would assist meeting Australia's national target, then 26 to 28%.

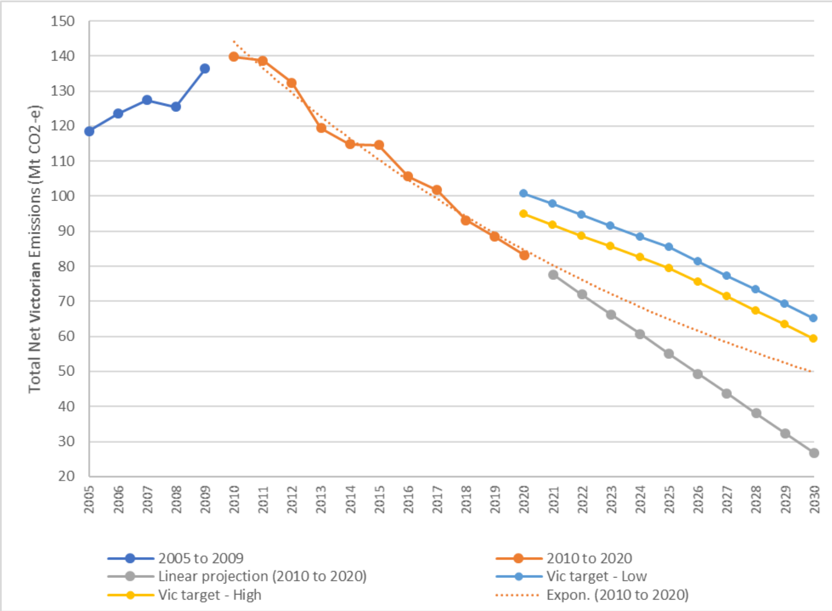
Table 1 provides a comparison of the 2030 emission reduction targets of the different jurisdictions, their progress towards meeting these targets in 2019-20, and the expected emission reduction in 2030 if they meet these targets[91]. If the five jurisdictions with published targets meet them, this will result in a total emission reduction in 2030 of 212.7 to 218.8 Mt CO_2-e, or 34.2 to 35.2% of Australia's net emissions in 2004-05. If Western Australia, Tasmania, and the Northern Territory also achieve emission reductions consistent with Australia's COP26 target, this would result in a total emission reduction in 2030 of 239.9 to 248.1 Mt CO_2-e, or 38.6 to 39.9% of Australia's 2005 emissions. A significantly higher target (45.6 to 46.6%) could be achieved if Queensland, Western Australia, Tasmania and the Northern Territory achieved emission reductions in line with the new Australian target of 43%.

Based on our analysis of recent historical data (2009-10 to 2019-20), Victoria seems very likely to exceed its 2030 interim emissions reduction target of a 45 to 50% reduction compared to 2005 by a significant margin. Victoria's total net emissions peaked at 139.8 Mt

[88] https://www.minister.industry.gov.au/ministers/taylor/media-releases/australia-welcomes-positive-outcomes-cop26
[89] https://www.alp.org.au/policies/powering-australia
[90] https://www.industry.gov.au/news/australia-submits-new-emissions-target-to-unfccc
[91] In the case of Western Australia, Tasmania and the Northern Territory it is assumed that they will meet Australia's national target. Note, however, that Tasmania achieved net zero emissions in the mid-2010s and now has net negative emissions.

CO_2-e in 2009-10 and have been declining quite rapidly since then. From 2009-10 to 2019-20, Victoria's total net emissions reduced by 56.5 Mt CO_2-e, or by 40.4%. During this period the annual emissions reduced at an average rate of 5.7 Mt CO_2-e per year (or 4.8% of the 2005 emissions). In 2019-20, Victoria's emissions had reduced by 29.8% compared to 2004-05, well above the upper end of the 2020 target of 20%. It seems very likely that the upper end of the 2025 target (a 33% reduction) will be achieved between 2021 and 2022, and that the upper end of the 2030 target (a 50% reduction) will be achieved between 2024 and 2027. Our simple projections of the historical data suggest that in 2030, Victoria's net emissions are likely to be *at least* 58% below the 2004-05 emissions.

Figure 29: Total net Victorian greenhouse gas emissions – historical and projected



It is important to note that there are a range of factors that will impact on the rate at which Victoria's net emissions decline over the coming decade. There may be some emissions 'rebound' following the COVID-19 lockdowns, as energy consumption and emissions in the Transport and Commercial sectors increase, offset to some extent by reduced Residential sector consumption. Population growth is an underlying driver of increased energy use in the Residential, Commercial and Transport sectors, although the impact of this on emissions will be reduced or offset by increased efficiency of energy use and the transition to renewable energy. Increased electrification of gas appliances and equipment, and increased uptake of electric vehicles, will increase electricity consumption and the rate at which we transition to a fully renewable electricity supply will determine the impact that this has on emissions. As can be seen from Figures 24 and 26, the size of the emissions sink that is provided by Land Use has largely plateaued in the last few years and is no longer increasing. This means that Energy related emissions are likely to be the key determinant of Victoria's emissions trajectory over the next decade.

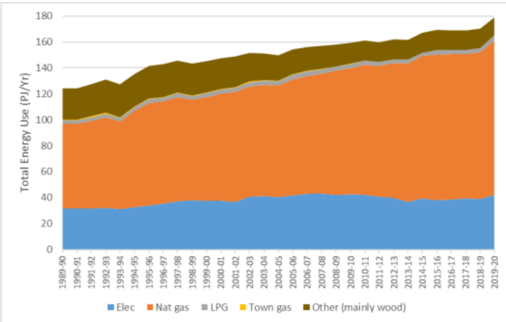
Changes in Commonwealth and Victorian government policies will also impact on the rate at which Victoria's net greenhouse gas emissions decrease over the next decade. Increased support for renewable electricity generation, fuel efficiency standards for vehicles, and increased support for the uptake of electric vehicles and electrification of gas appliances and equipment could lead to a more rapid reduction in greenhouse gas emissions.

5.5 Energy related greenhouse gas emissions in the built environment sector

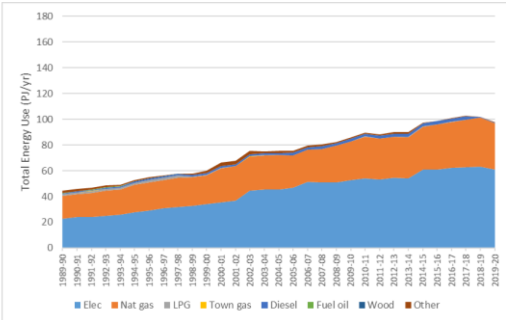
The Residential and Commercial sectors are sometimes referred to as the “built environment” sector. As only a limited number of fuels are used in homes and commercial premises (mainly electricity, gas and wood), it is straightforward to estimate the greenhouse gas emissions from this energy end-use[92]. Estimation of greenhouse gas emissions from energy end-use in the Mining and Manufacturing sectors is more complicated, due to the much wider range of fuel sources used and to the use of “derived fuels” and requires specialist expertise.

Victorian Residential and Commercial energy consumption, broken down by the main fuel sources is shown in Figure 30, as well as the combined Residential and Commercial energy end-use. Electricity use is now highest in the Commercial sector, but gas use is dominated by the Residential sector. In 2019-20, the combined “built environment” sector accounted for 59.1% of total Victorian electricity consumption, and 54.7% of total Victorian natural gas consumption, highlighting the importance of these sectors to our overall energy use.

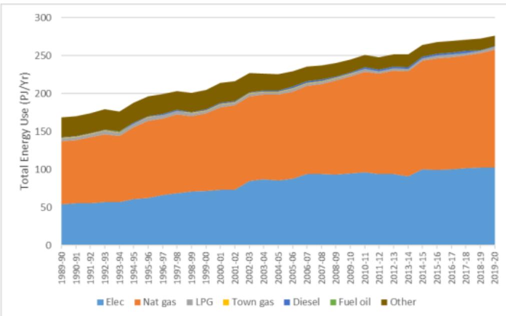
Figure 30: Victorian residential and commercial energy use by energy source



Residential



Commercial



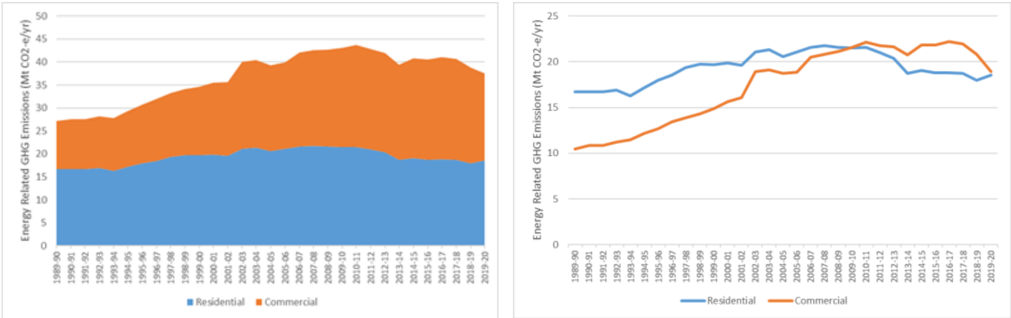
Combined Residential & Commercial

The estimated annual greenhouse gas emissions from *energy end-use* in the combined Residential and Commercial sectors is shown in Figure 31. In 2019-20, these sectors accounted for an estimated 37.5 Mt CO_2-e of greenhouse gas emissions, 45.0% of Victoria’s total net emissions. The greenhouse gas emissions from the Commercial sector overtook the Residential sector in 2009-10 and have continued to stay higher. The Residential sector emissions have been on a downward trend since 2010-11, although increased between

[92] The energy consumption data is from the September 2021 update to the Australian Energy Statistics Table F [DISER2021c]. Full fuel cycle greenhouse gas emissions can be applied to the energy end use, to calculate the greenhouse gas emissions. The figures are taken from the *National Greenhouse Accounts Factors – Australian National Greenhouse Accounts*, Dept of Science, Industry, Energy & Resources, October 2021, supplemented by greenhouse coefficients in *Residential Energy Baseline Study: Australia*, August 2015, EnergyConsult for Dept. of Industry & Science (DoIS) (on behalf of the E3 Program).

2018-19 and 2019-20, largely due to the initial COVID-19 lockdowns resulting in many people working from home. The Commercial sector emissions continued to rise until 2016-17, peaking at 22.2 Mt CO_2-e, and since then have started to decline quite rapidly. Between 2016-17 and 2019-20 they decreased by 3.3 Mt CO_2-e, (14.7%), largely due to the declining greenhouse intensity of Victoria's electricity supply. The initial onset of the COVID-19 lockdowns late in the 2019-20 financial year also resulted in a significant reduction in Commercial sector energy consumption, both electricity and gas. Between 2018-19 and 2019-20, total Commercial sector electricity and gas consumption decreased by 4.5 PJ (4.4%). This recent upward trend in Residential energy consumption and emissions, and downward trend in Commercial energy consumption is likely to continue for several years. However, as Commercial sector energy use is dominated by electricity it is likely that the emissions from this sector will continue to decline as the share of renewable electricity increases.

Figure 31: Estimated greenhouse gas emissions from energy end-use in the Victorian built environment

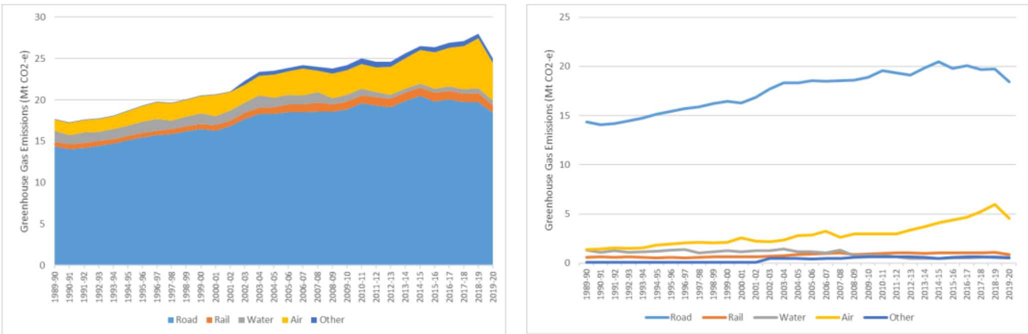


Emissions from the Built Environment

Residential & Commercial Sector emissions

5.6 Key drivers of Victorian greenhouse gas emissions

Figure 32: Victorian transport sector greenhouse gas emissions from energy use – by mode



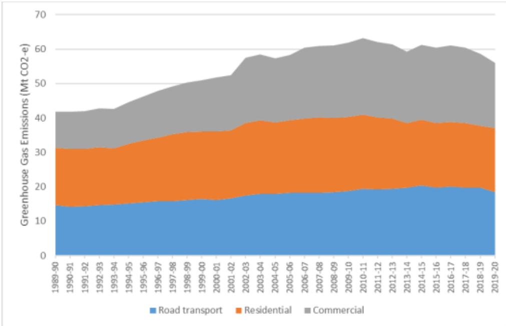
Transport emissions by mode

Emissions of different transport modes

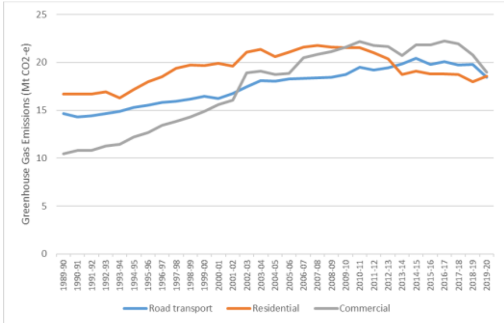
As was seen in Section 2.2, the Transport, Postal and Warehouse (or "Transport") sector is the largest area of energy consumption in Victoria, and the one which shows the highest rate of growth. This means that it also makes a significant contribution to Victoria's greenhouse gas emissions. Most of the energy consumption in this sector is for Road, Air, Water, and Rail transport, with Road transport playing the dominant role. Detailed information on energy consumption and greenhouse gas emissions in the Transport sector is provided in Appendix 3, and the estimated total greenhouse gas emissions *from all energy end-use* in this sector is shown in Figure 32, broken down by transport mode[93].

Taken together, the “built environment” and Road transport sectors, make a significant contribution to Victoria’s greenhouse gas emissions. The energy consumption in these sectors is strongly influenced by population growth, so there will be strong upward pressure on energy consumption in these areas over the coming decades. Figure 33 shows how the estimated total greenhouse gas emissions from energy end-use in these combined sectors has changed between 1989-90 and 2019-20.

Figure 33: Combined emissions from Residential, Commercial and Road Transport sectors



Total Road transport, Residential & Commercial sector emissions



Emissions from Road transport, Residential & Commercial sectors

In 2019-20, we estimate the combined greenhouse gas emissions were 55.9 Mt CO_2-e, or 67.2% of Victoria’s total net emissions and 68.4% of our energy emissions. In 2019-20, the emissions from each of these sectors was about the same, although this is partly due to the reduction in Commercial and Road Transport sector emissions, and the increase in Residential sector emissions, that occurred between 2018-19 and 2019-20 due to the onset of the COVID-19 restrictions. Aside from the recent disruption due to COVID19, emissions in the Residential sector have been declining for around a decade and emissions from the Commercial sector have recently started to decline due to the reduction in the greenhouse intensity of the electricity supply. Going forward, the emissions in the Commercial and Residential sectors will be strongly influenced by the rate at which Victoria’s electricity supply transitions to 100% renewables. In the Road transport sector, it will be influenced by the rate of uptake of electric vehicles and the rate at which the electricity supply transitions to 100% renewables.

[93] This is an estimate of the emissions from *all energy used* in the Transport, Postal and Waterhouse sector, including international air transport and shipping, and electricity consumption for railways and road transport. Emissions from international transport are not included in Victorian (or Australian) greenhouse gas inventories, and emissions from electricity consumption are included in the Electricity source emissions and not the Transport emissions.

6 References

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VSG 2022	*Gas Substitution Roadmap*, Victoria State Government, July 2022

7 Appendix 1 - Residential energy consumption and greenhouse gas emissions

7.1 Introduction

Residential energy consumption currently accounts for a bit over one fifth (21.3%) of Victoria's total energy end-use. In this Appendix we take a more detailed look at Victorian Residential energy consumption, including the consumption of the different fuels – mainly electricity, gas and wood – and the changes in consumption that have taken place over the last three decades. We look at both total Residential energy consumption and the energy consumption of the average household, against a backdrop of quite rapidly increasing household numbers.

As with the analysis in Chapter 2, this more detailed review of Victoria's Residential energy consumption is based on the data in the 2021 edition of AES Table F and there seems to be several issues with this for both electricity and gas consumption (see Appendix 4).

The consumption of energy in Victorian homes generates greenhouse gas emissions. We also look at these energy related greenhouse emissions from the residential sector, as well as the greenhouse gas emissions of the average Victorian household.

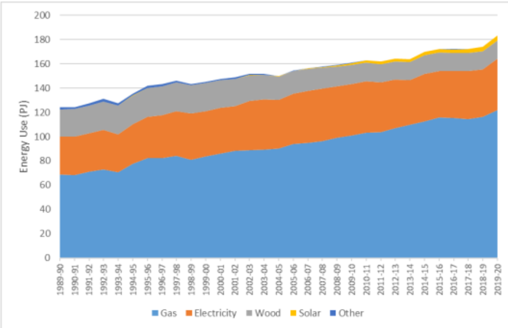
7.2 Energy consumption

Total Victorian Residential energy consumption in 2019-20 was 183.1 PJ, dominated by gas (66.7%), mains electricity (22.9%) and wood (8.2%). This consumption has shown a general increasing trend since 1989-90, driven mainly by increasing gas[94] use, as well as increasing solar energy use since 2006-07.

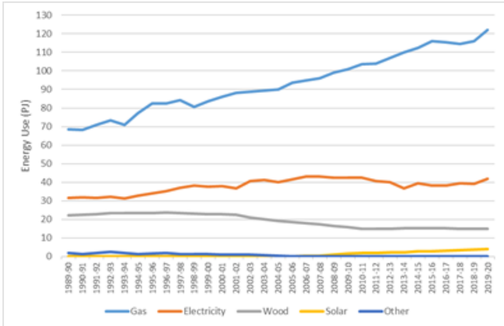
Residential energy consumption increased sharply between 2018-19 and 2019-20, due to the on-set of working from home requirements at the start of the COVID-19 pandemic. In the fourteen years between 2004-05 and 2018-19, it increased by 23.9 PJ (15.9%), with gas use increasing by 26.1 PJ (29.0%) and solar by 3.6 PJ (2,643%). During the same period, electricity use fell by 1.1 PJ (2.7%) and wood use by 4.3 PJ (22.5%). However, between 2018-19 and 2019-20, Residential energy consumption increased by 9.2 PJ (5.3%) in one year, with gas use increasing by 5.9 PJ (5.1%) and electricity use increasing by 2.9 PJ (7.3%). The net impact is that since 2004-05, Residential energy consumption has increased by 33.1 PJ (22.1%), with gas use increasing by 32.1 PJ (35.6%) and electricity use increasing by 1.8 PJ (4.4%).

[94] In this analysis "gas" includes natural gas, LPG and town gas (no longer used). It is dominated by natural gas use.

Figure 34: Total Victorian Residential energy consumption – by energy source



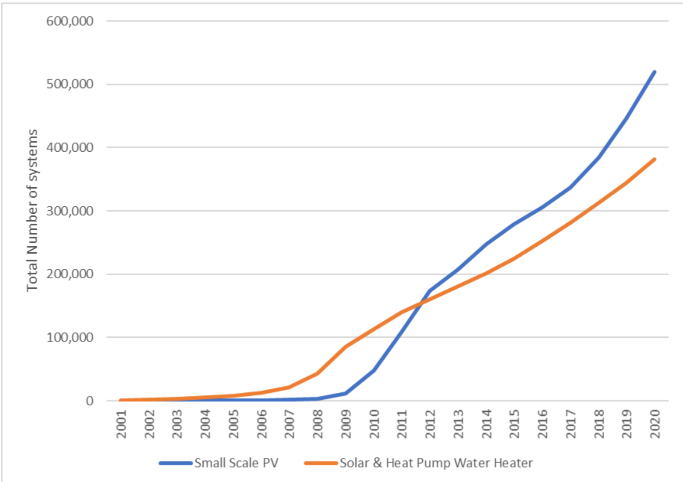
Total Residential energy consumption, by source



Residential energy consumption by energy source

After peaking at 43.2 PJ in 2006-07, total Residential electricity consumption declined significantly (4.1 PJ, 9.4%) to be 39.1 PJ in 2018-19. It re-bounded in the following year due to the COVID restrictions to be 42.0 PJ, resulting in an overall reduction of 1.2 PJ (2.8%) since 2006-07. During this period, Victoria's population increased by 26.0% and the number of occupied dwellings increased by 26.8%. The reduction in electricity consumption is likely to be due mainly to increased uptake of rooftop PV systems[95] (see Figure 35), the large-scale roll-out of more energy efficient technologies through the Victorian Energy Upgrades (VEU) Scheme[96], appliance minimum energy performance standards (MEPS), and the consumer response to rising electricity prices.

Figure 35: Total installations of small-scale solar systems since 2001[97]



While there has been a general downward trend in total Residential electricity consumption since 2006-07, since 2015-16 it has started to increase again, from 38.2 PJ to 39.1 PJ in 2018-19, an increase of 2.3%. It then increased again in 2019-20, largely due to increased

[95] Some of the electricity generated by the PV system is used in the home, offsetting mains electricity consumption, and some is exported back to the grid to become part of the renewable electricity supply. According to Clean Energy Regulator data, by the end of 2020 around 520,000 small-scale PV systems had been installed in Victoria, and most of these would have been residential systems.

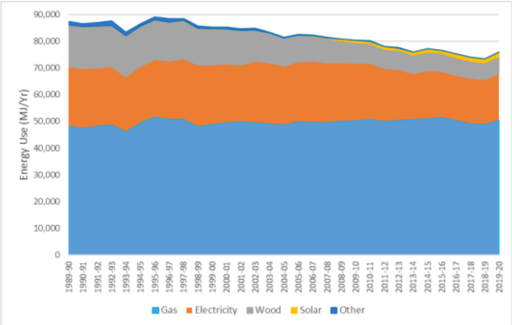
[96] There has been large scale replacement of residential lighting with high efficiency lighting, initially with compact fluorescent lamps and more recently with high efficiency LEDs. From 2009 to 2021, lighting upgrades were undertaken at 2.5 million residential sites (some may have had several types of upgrades). Also, during this period, electric water heaters were replaced with either heat pump or solar systems at 104,656 residential sites.

[97] Based on annual installation data from the Clean Energy Regulator - http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations#Small-generation-unit-SGU-installations

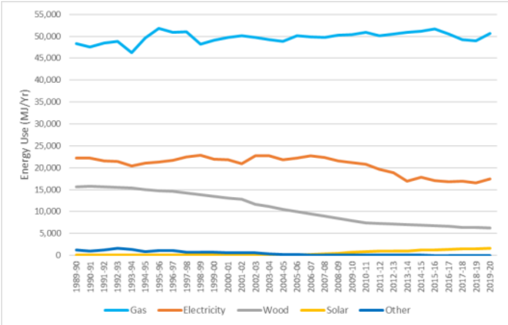
working from home requirements. The increase in total Residential electricity consumption since 2015-16 suggests that the Victorian population has been increasing at a faster rate than the rate at which energy efficiency and rooftop PV programs are reducing per capita electricity consumption. This trend could be amplified over the next decade or so by electrification of residential gas appliances, and by the uptake of electric vehicles.

The consumption of solar energy has increased significantly since 2004-05 (3.9 PJ, 2,884%) to now be 4.0 PJ. This is likely to be due to the increased penetration of solar water heating since the mid-2000s, driven largely by the water heating requirements in Victoria's 5- and 6-Star building standards, and the roll-out of rooftop PV systems since the late 2000s (see Figure 35).

Figure 36: Energy consumption of the average Victorian dwelling – by energy source



Total energy consumption, by energy source



Energy consumption by energy sources

The energy consumption of the average Victorian household[98] peaked in 1995-96 at 89,090 MJ/yr and has been in general decline since. Since 2004-05, average household energy consumption has declined by 5,511 MJ/yr (6.8%) to now be 75,944 MJ/yr. Between 2004-05 and 2018-19, it decreased by 8,026 MJ/yr (9.9%), but between 2018-19 and 2019-20 it increased by 2,524 MJ/yr (3.4%) due to the onset of the COVID-19 restrictions.

Average Victorian household electricity consumption decreased by 5,312 MJ/yr (1,476 kWh/yr), or 24.3%, between 2004-05 and 2018-19, but increased by 895 MJ/yr (249 kWh/yr or 5.4%) between 2018-19 and 2019-20. The net change to 2019-20 was a decrease of 4,417 MJ/yr (1,227 kWh/yr), or 20.2%. The increase in rooftop PV systems to generate electricity since the late 2000s, means that some mains electricity consumption has been displaced by 'solar' electricity, although the extent to which this has happened is difficult to determine from the AES data. This means that the overall reduction in household electricity consumption (mains electricity plus solar electricity) would have been less than 20.2%.

The 2021 AES Table F data suggests that average household gas use increased by 140 MJ/yr (0.3%) between 2004-05 and 2018-19 but increased by 1,607 MJ/yr (3.3%) in the year to 2019-20. The net change to 2019-20 was an increase of 1,747 MJ/yr (3.6%).

One of the most rapid changes in household energy consumption has been for solar energy. Between 2004-05 and 2019-20 it is estimated that the solar energy consumption of the average house increased by 1,597 MY/yr (2,197%). During this time its share of average household energy consumption increased from only 0.1% to 2.2%. This is due to the increasing penetration of both rooftop PV systems and solar water heaters.

[98] This is based on "occupied private dwellings", using ABS Census data from 1991 to 2016, with interpolation between the Census dates, and backward and forward projection for the years before and after this. This does not include un-occupied dwellings or dwellings such as caravans.

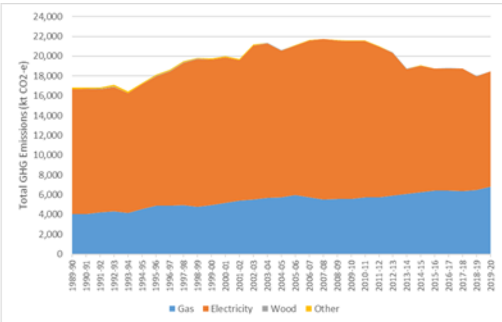
The average consumption of wood-related energy declined by 4,265 MJ/yr (40.6%) between 2004-05 and 2019-20, with little impact evident from the commencement of the COVID-19 restrictions.

7.3 Greenhouse gas emissions

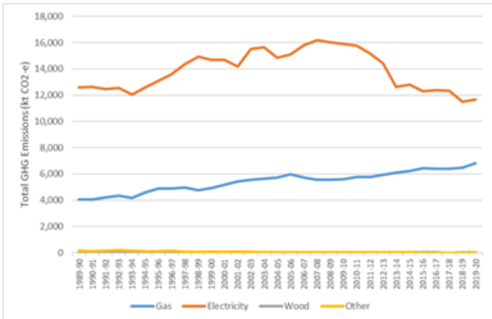
The energy end-use data from the 2021 issue of AES Table F has been combined with end-use (full fuel cycle) greenhouse gas coefficients[99] to estimate the greenhouse gas emissions resulting from *energy end-use* in the Victorian Residential sector (Figure 37). For electricity, we have used the data from the *National Greenhouse Accounts Factors – Australian National Greenhouse Accounts*, Dept. of Science, Industry, Energy & Resources (August 2021) for 2004-05 to 2019-20, and historical coefficients from EnergyConsult's 2016 *Residential Baseline Study* for the E3 Program prior to this. For natural gas, we have used data from the *National Greenhouse Accounts Factors* workbooks (various years) for 2015-16 to 2019-20. For the years prior to 2015-16, and for all other fuel sources, we have used coefficients from EnergyConsult's 2016 *Residential Baseline Study*.

It's important to note that this analysis does not account for the impact of the renewable electricity that is *exported* to the electricity grid from rooftop PV systems. Some of the electricity generated by the PV systems is used in the homes to off-set mains electricity consumption, and a significant proportion is exported to the grid to form part of the renewable electricity supply. This helps to reduce the emissions intensity of Victoria's electricity supply and will contribute to lower emissions from the mains electricity used in all homes *and* businesses. The *net greenhouse emissions* from residential energy end-use *and* generation will be lower than is estimated from this end-use analysis.

Figure 37: Victorian Residential GHG Emissions from Energy End-Use, by Energy Type



Total Residential emissions, by energy source



Emissions from Residential energy sources

In 2019-20, we estimate that total Victorian Residential greenhouse gas emissions from *energy end-use* were 18,481 kt CO_2-e, with electricity consumption responsible for 11,654 kt CO_2-e (63.1%) and gas consumption responsible for 6,808 kt CO_2-e (36.8%). The contribution of wood and other fuels to the emissions was negligible (0.1%). The residential emissions peaked in 2007-08 at 21,769 kt CO_2-e and in 2019-20 had decreased by 3,288 kt CO_2-e (15.1%), due mainly to reduced emissions from electricity consumption.

Since 2004-05, total Residential emissions from energy end-use have decreased from 20,617 kt $CO_{2\text{-e}}$ to 18,481 kt $CO_{2\text{-e}}$, a reduction of 2,136 kt $CO_{2\text{-e}}$ (10.4%). The onset of the COVID-19 restrictions mean that the reduction is not as large as might have been expected. From 2004-05 to 2018-19, the emissions decreased by 2,617 kt $CO_{2\text{-e}}$ (12.7%), but between

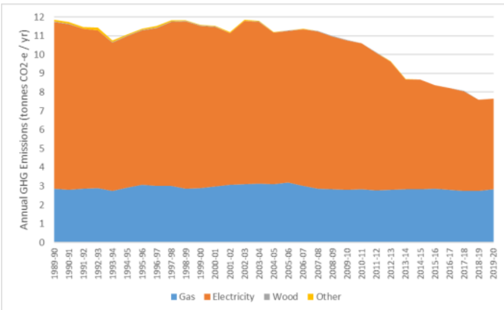
[99] These coefficients take into account greenhouse gas emissions in the entire supply chain for the energy used in Victorian houses.

2018-19 and 2019-20, the emissions increased by 481kt CO_2-e (2.7%) due to increased electricity and gas consumption.

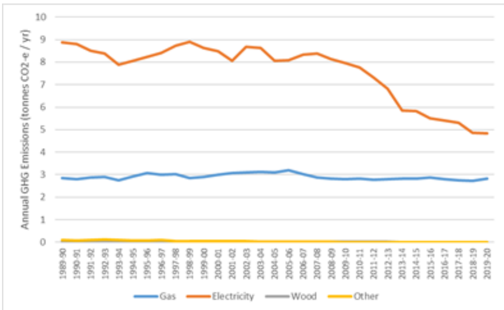
From 2004-05 to 2018-19, Victorian emissions from Residential electricity consumption declined from 14,845 kt CO_2-e to 11,512 kt CO_2-e, a reduction of 3,333 kt CO_2-e (22.5%), but between 2018-19 and 2019-20 the emissions increased by 141 kt CO_2-e (1.2%) to 11,654 kt CO_2-e. The net impact was that between 2004-05 and 2019-20, emissions from residential electricity consumption decreased by 3,191 kt CO_2-e (21.5%). The declining greenhouse gas emissions from Residential electricity use reflects the reduction in the emissions intensity of mains electricity over this period (see Figure 14 above). Up until 2015-16, the reduction in electricity consumption was also playing a roll, but total electricity consumption has increased since then, especially in the year to 2019-20.

From 2004-05 to 2018-19, Victorian emissions from gas consumption increased from 5,721 kt CO_2-e to 6,468 kt CO_2-e, an increase of 747 kt CO_2-e (13.1%), but between 2018-19 and 2019-20 the emissions increased by 340 kt CO_2-e (5.3%) to 6,808 kt CO_2-e. The net impact was that between 2004-05 and 2019-20, emissions from gas consumption increased by 1,087 kt CO_2-e (19.0%). The increased emissions from gas are driven almost entirely by increased gas consumption as, unlike electricity, the emissions intensity of gas is essentially constant. In future, the emissions intensity of gas might reduce, if some of the reticulated natural gas is replaced with renewable hydrogen or biomethane, or if the fugitive emissions from natural gas production and distribution are reduced. However, any reduction in the emissions intensity of natural gas is expected to happen much more slowly than for mains electricity.

Figure 38: Greenhouse Gas Emissions of the Average Victorian Household, by Energy Source



Average household emissions, by energy sources



Average emissions from household energy sources

In 2019-20, the greenhouse gas emissions from the average Victorian household due to energy end-use are estimated to be 7.66 tonnes CO_2-e, with electricity responsible for 4.83 tonnes CO_2-e and gas consumption responsible for 2.82 tonnes CO_2-e. Average household emissions have reduced considerably (by 4.2 tonnes CO_2-e or 35.4%) since 1989-90, when they were 11.9 tonnes CO_2-e.

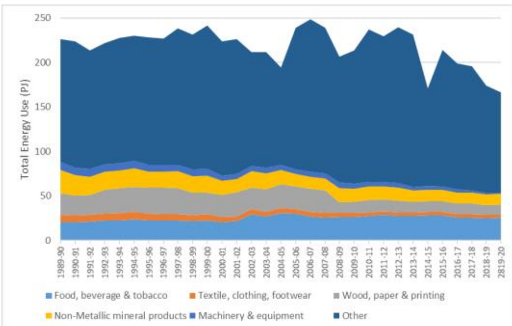
Between 2004-05 and 2018-19, the total average household emissions reduced by 3.60 tonnes CO_2-e (32.1%); average emissions from mains electricity decreased by 3.20 tonnes CO_2-e (39.7%) while average emissions from gas decreased by 0.38 tonnes CO_2-e (12.1%). However, in the year to 2019-20, average emissions from gas increased by 0.09 tonnes CO_2-e (3.4%) while average emissions from mains electricity decreased by 0.03 tonnes CO_2-e (0.5%). The net result was that between 2004-05 and 2019-20, total emissions reduced by 3.53 tonnes CO_2-e (31.5%). It's clear that there has been a very significant reduction in the greenhouse gas emissions from the average Victorian household, even in the face of the increased electricity and gas consumption resulting from the onset of the COVID-19 restrictions. This is due to increased efficiency of energy use, increasing penetration of rooftop PV systems, and an increasing share of renewable electricity.

8 Appendix 2 – Manufacturing energy consumption

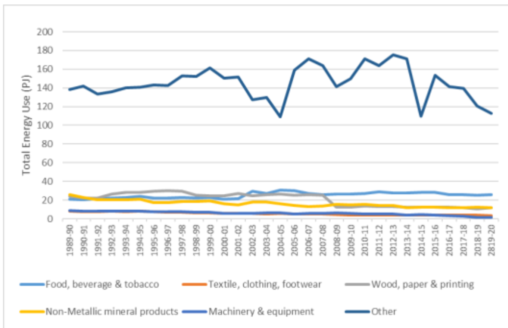
8.1 Overall energy consumption

Manufacturing currently accounts for around 19.3% of Victoria's total energy end-use. The 2021 AES Table F data provides a breakdown of the Manufacturing sector into several sub-sectors, and this has been used to provide a deeper insight into the energy use in these sub-sectors. The AES provides data for some sub-sectors (see below), but for others does not provide a breakdown, due to confidentiality issues and the small number of businesses operating in these sub-sectors. In Victoria, this includes the Petroleum and Coal Product Manufacturing, Basic Chemical and Chemical, Polymer and Rubber Product Manufacturing, Iron and Steel, Basic Non-Ferrous Metals, and Fabricated Metal Products sub-sectors. In our analysis, these are aggregated and shown as the "Other" sub-sector. It is likely that aluminium manufacturing (Basic Non-Ferrous Metals) accounts for much of the energy consumption in this sub-sector, especially the electricity consumption.

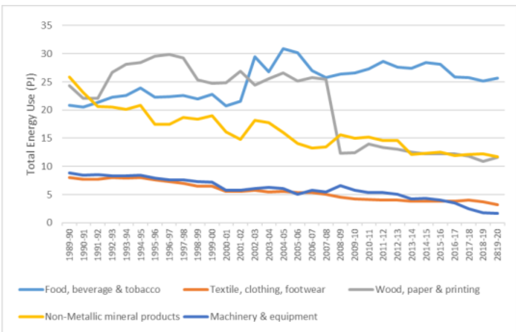
Figure 39: Total Victorian Manufacturing Energy Consumption – by sub-sector



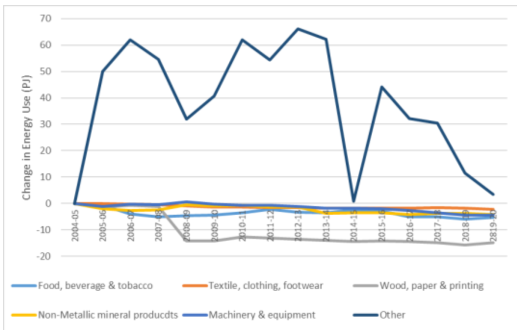
Total energy consumption, by subsector



Energy consumption of the sub-sectors



Energy consumption by sub-sector, excluding "Other"



Change in energy consumptin since 2004-05

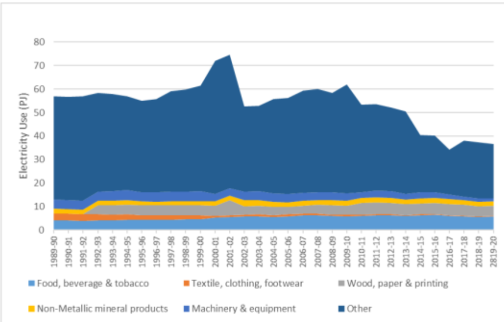
Total Victorian Manufacturing energy consumption in 2019-20 was 166.4 PJ. Consumption was largest in the “Other” sub-sector, accounting for 112.6 PJ or 67.6% of the total. Other key sub-sectors were Food, Beverage and Tobacco (25.6 PJ, 15.4%), Non-Metallic Mineral Products (11.7 PJ, 7.0%), and Wood, Paper and Printing (11.6 PJ, 7.0%). Manufacturing energy consumption peaked at 248.2 PJ in 2006-07 and has declined by 81.8 PJ (32.9%) since. The reduction in energy consumption occurred across all fuel types: electricity (22.6 PJ, 38.1%); natural gas (23.2 PJ, 28.1%); and other fuels (36.0 PJ, 33.9%). It is likely that much of this reduction in energy consumption has been due to factory closures.

There was a reduction in total Victorian Manufacturing energy consumption between 1999-00 and 2004-05. Consumption then increased each year to 2006-07 and has trended down since then, although with significant fluctuation from year to year. Between 2004-05 and 2019-20, total Victorian Manufacturing energy consumption decreased by 27.8 PJ (14.3%). The largest reductions during this period occurred in the Wood, Paper and Printing (15.0 PJ, 56.3%), Food, Beverage and Tobacco (5.3 PJ, 17.2%), Machinery and Equipment (4.4 PJ, 72.4%), Non-Metallic Mineral Products (4.3 PJ, 26.9%) and Textile, Clothing and Footwear (2.3 PJ, 41.5%) sub-sectors. Energy consumption in the “Other” sub-sector increased slightly, by 3.5 PJ (3.2%). The annual change in energy consumption in the Other sub-sector was responsible for most of the variability in total Manufacturing energy consumption since 2004-05.

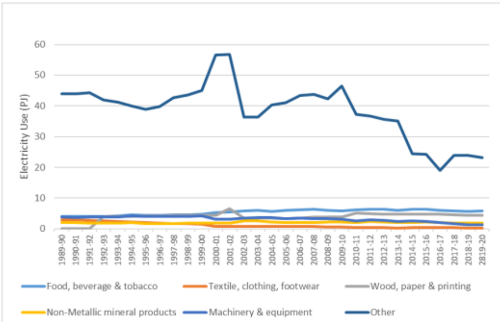
8.2 Electricity consumption

Total electricity consumption in the Victorian Manufacturing sector in 2019-20 was 36.7 PJ, accounting for 21.1% of Victoria’s total electricity consumption. Electricity consumption was highest in the “Other” manufacturing sector, accounting for 23.2 PJ (63.3%) of the total. Other key sub-sectors were Food, Beverage and Tobacco (5.8 PJ, 15.7%), Wood, Paper and Printing (4.4 PJ, 11.9%), and Non-Metallic Mineral Products (1.8 PJ, 5.0%).

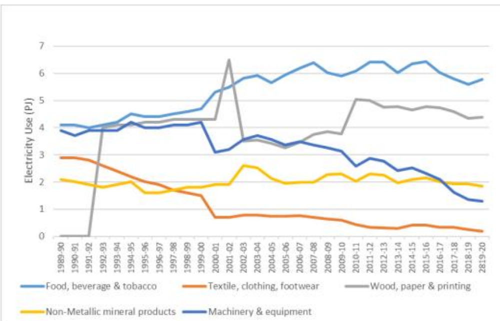
Figure 40: Total electricity consumption in Victorian Manufacturing – by sub-sector



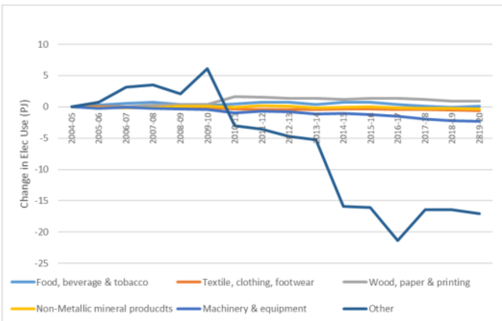
Total electricity consumption



Electricity consumption by sub-sector



Electricity by sub-sector, excluding “Other”



Change in electricity consumption since 2004-05

Electricity consumption peaked at 74.5 PJ in 2001-02 and has declined by 37.8 PJ (50.7%) since. It is likely that much of this has been due to factory closures, particularly in the “Other” and Machinery and Equipment sub-sectors.

Since 2004-05, electricity consumption has declined in most Victorian Manufacturing sub-sectors. The largest reductions have occurred in the “Other” manufacturing (17.1 PJ, 42.4%), Machinery and Equipment (2.3 PJ, 63.9%), and Textile, Footwear and Clothing (0.6 PJ, 74.2%) sub-sectors. Electricity consumption has increased in the Wood, Paper and Printing (1.0 PJ, 28.3%), and Food, Beverage and Tobacco (0.1 PJ, 2.1%) sub-sectors.

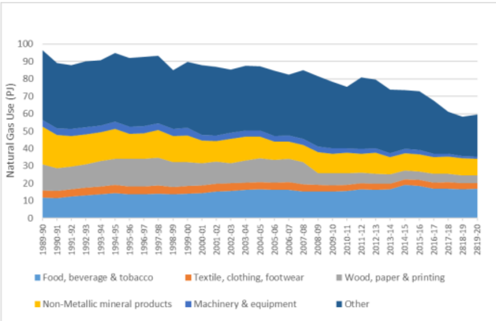
8.3 Natural gas consumption

Total natural gas consumption in the Victorian Manufacturing sector in 2019-20 was 59.4 PJ, accounting for 21.0% of Victoria’s total natural gas consumption. Natural gas consumption was largest in the “Other” sub-sector, accounting for 24.0 PJ (38.8%) of the total. Other key sub-sectors were Food, Beverage and Tobacco (17.0 PJ, 28.5%), Non-Metallic Mineral Products (9.5 PJ, 16.9%), Wood, Paper and Printing (4.7 PJ, 7.6%), and Textile, Footwear and Clothing (3.0 PJ, 5.8%).

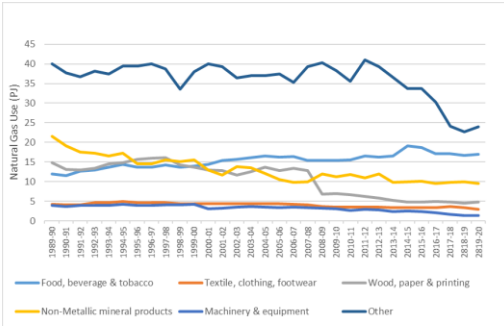
Over the time-period analysed, natural gas consumption was highest in 1989-90 at 96.4 PJ and has declined by 37.0 PJ (38.4%) since. During this time, natural gas consumption has declined significantly in all sub-sectors except Food, Beverage and Tobacco, where it increased by 5.1 PJ (42.5%).

Since 2004-05, natural consumption has declined in all sub-sectors except Food, Beverage and Tobacco (0.5 PJ, 2.7% increase). The largest reductions in natural gas use have occurred in the “Other” manufacturing (16.0 PJ, 40.0%), Wood, Paper and Printing (9.0 PJ, 65.4%), Non-Metallic Mineral Products (2.7 PJ, 22.1%), Machinery and Equipment (2.3 PJ, 63.9%) and Textile, Footwear and Clothing (1.4 PJ, 31.6%) sub-sectors.

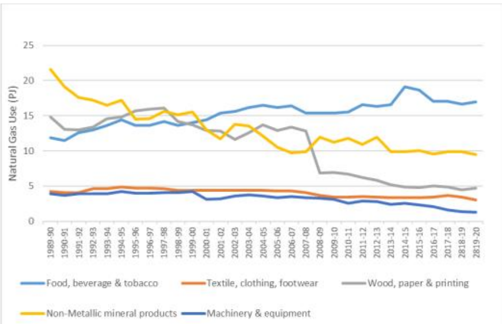
Figure 41: Total natural gas consumption in Victorian Manufacturing – by sub-sector



Total energy consumption, by subsector



Energy consumption by sub-sectors



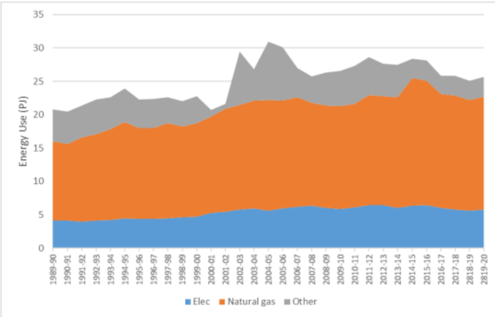
Energy consumption by sub-sector, excluding Other

Change in energy consumption since 2004-05

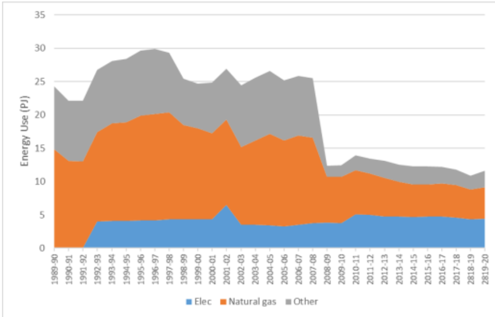
8.5 Snapshot of sectors

The 2021 AES Table F data has been used to provide some “snapshots” of energy use in the different sub-sectors over the period 1989-90 to 2019-20. This gives an idea of the relative size of the total energy consumption in each of the sub-sectors, how this has changed over this period, and the relative importance of electricity, natural gas, and other energy in the sub-sectors’ energy mix.

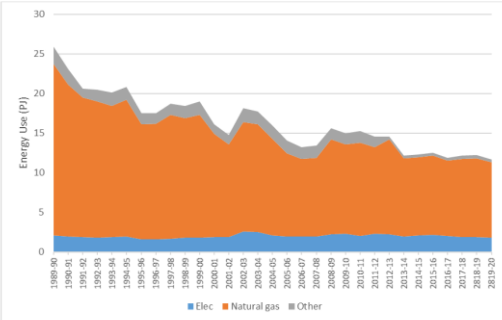
Figure 42: Energy Use by Fuel in the Victorian Manufacturing Sub-Sectors



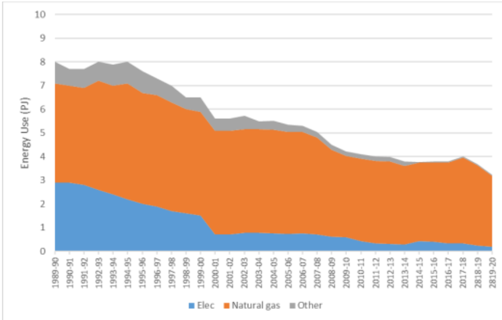
Food, Beverage and Tobacco



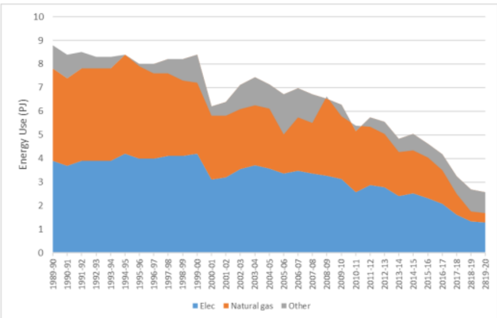
Wood, Paper and Printing



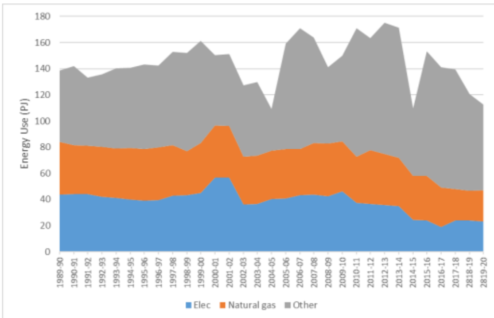
Non-Metallic Minerals



Textile, Clothing and Footwear



Machinery and Equipment



Other

9 Appendix 3 – Transport energy consumption

9.1 Introduction

The Transport, Postal and Warehouse sector[100] is the largest area of energy consumption in Victoria, and the one which shows the highest rate of growth. This means that it also makes a significant contribution to Victoria's greenhouse gas emissions. The "Transport" sector currently accounts for 41.4% of Victoria's total energy end-use. Most of the energy consumption in this sector is for Road, Air, Water, and Rail transport.

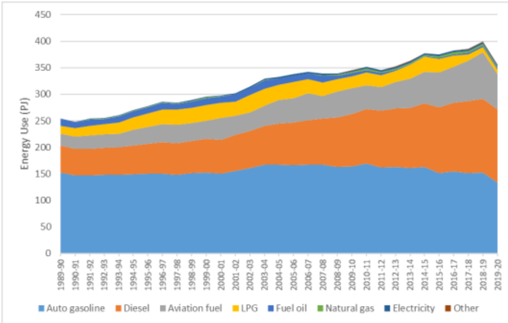
In this Appendix, we take a more detailed look at energy consumption in Victoria's Transport sector, as well as the greenhouse gas emissions that result from this energy consumption. We look at both the energy sources (or transport fuels) consumed, as well as the energy consumption by the different modes of transport: - Road, Air, Water, Rail and Other. Given the size and growth of the energy consumption and greenhouse gas emissions from this sector, it will need to undertake a significant transition over the next few decades for Victoria to achieve net zero emissions.

9.2 Energy consumption

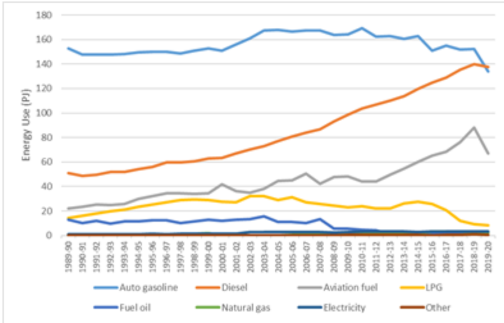
Total energy end-use in the Transport sector in Victoria, broken down by fuel source is shown in Figure 43. In 2019-20, the total consumption was 355.0 PJ, significantly lower than the total consumption of 399.9 PJ in 2018-19. This large single-year reduction of 43.2 PJ (10.8%) reflects the impact of the initial COVID-19 lockdowns implemented in the last months of 2019-20. In 2019-20, Transport energy consumption was dominated by auto gasoline (37.6%), diesel (38.6%) and aviation fuel (18.8%) – these three fuels accounted for 95.0% of all energy use in this sector. Between 1989-90 and 2018-19, Transport energy consumption grew by 144.4 PJ (56.7%), with the key growth areas being diesel (increased by 88.7 PJ, 173.9%) and aviation fuel (66.1 PJ, 302.0%). However, as noted above, the onset of the COVID-19 restrictions in late 2019-20 led to a significant reversal of this long-term growth trend.

[100] For simplicity, in this report we refer to this as the "Transport" sector. It is dominated by mobile energy consumption in the different modes of transport (road, air, water and rail) but also covers some stationary energy consumption for a range of transport related services. These include postal services, pipeline transport, the provision of goods warehousing and storage, and the provision of support services for the transportation of passengers and freight, e.g. stevedoring, harbour and navigation services, airport operations and customs agency services. https://www.abs.gov.au/ausstats/abs@.nsf/0/AF04F89CEE4E54D6CA25711F00146D76?opendocument#:~:text=DIVISION%20I%3A%20TRANSPORT%2C%20POSTAL%20AND,%2C%20rail%2C%20water%20or%20air.

Figure 43: Energy consumption in Victoria’s Transport, Postal and Warehouse sector – by fuel



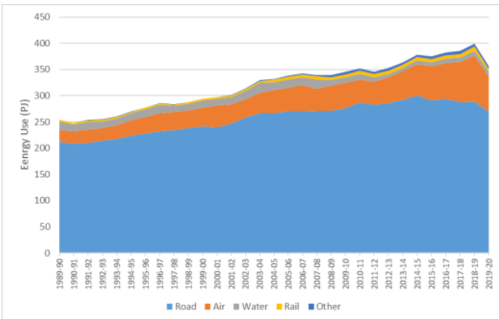
Transport energy consumption, by fuel



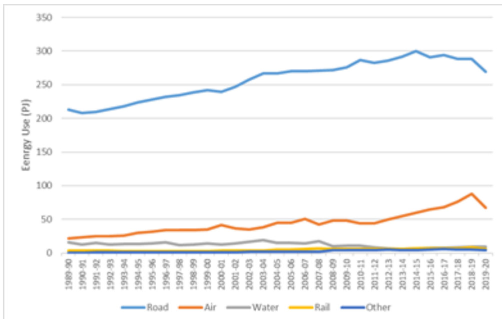
Energy consumption of transport fuels

Figure 44 shows Victorian Transport energy consumption broken down by the main mode of transport. This energy consumption is dominated by Road transport[101]. In 2019-20 this accounted for 269.1 PJ (75.6% of the total), compared to 66.9 PJ (18.8%) for Air transport[102]; Water, Rail and Other modes of transport collectively accounted for only 19.9 PJ (5.6%) of the total. The impact of the COVID-19 restrictions is evident for both Road and Air transport. Between 1989-90 and 2018-19, Road transport energy consumption increased by 75.9 PJ (35.7%) while Air transport energy consumption increased by 66.1 PJ (302%). However, between 2018-19 and 2019-20, energy consumption for Road transport decreased by 19.5 PJ (6.8%) and for Air transport decreased by 21.1 PJ (24.0%).

Figure 44: Energy consumption in Victoria’s Transport, Postal and Warehouse sector – by mode



Transport energy consumption, by mode



Energy consumption of transport modes

It is also evident from Figure 44 that energy consumption for Road transport has declined since 2014-15, when it peaked at 300.2 PJ. Between 2014-15 and 2018-19, it decreased by 11.6 PJ (3.8%), before declining by a further 19.5 PJ in the year to 2019-20 due to the onset of the COVID-19 restrictions. The decline in energy consumption from 2014-15 suggests that there has been an increase in the efficiency of Road transport since this time, sufficient to offset the growth in vehicle numbers and the total distance travelled.

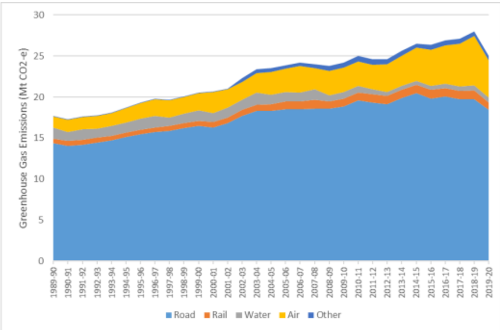
[101] This includes energy consumption in cars and motorcycles, light commercial vehicles, heavy duty trucks and busses.
[102] This includes energy consumption for both domestic aviation and international aviation.

9.3 Greenhouse gas emissions

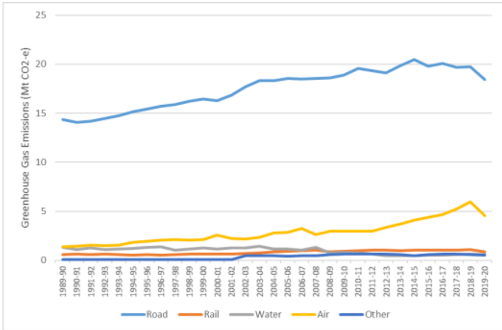
Figure 45 shows the estimated total greenhouse gas emissions from *all energy* used in the “Transport” sector[103]. In 2019-20, we estimate that energy consumption in *all modes of transport* in Victoria was responsible for 25.0 Mt CO_2-e of greenhouse gas emissions. If emissions from international air transport and shipping and electricity consumption are omitted[104], the total is reduced to 20.8 Mt CO_2-e, or 25.0% of Victoria’s 2019-20 total net emissions.

Estimated total emissions from *all modes* of transport increased by 10.3 Mt CO_2-e (58.2%) between 1989-90 and 2018-19. This growth was dominated by Road (5.4 Mt CO_2-e, 37.4%) and Air (4.6 Mt CO_2-e, 335%) transport. However, due to the introduction of the COVID-19 restrictions in late 2019-20, the total Transport sector emissions decreased by 3.0 Mt CO_2-e (10.8%) between 2018-19 and 2019-20. The largest emission reductions occurred for Air transport (1.4 Mt CO_2-e, or 23.8%) and for Road transport (1.3 Mt CO_2-e, or 6.6%).

Figure 45: Victorian Transport sector greenhouse gas emissions from energy end use – by mode



Total transport greenhouse emissions, by mode



Greenhouse emissions of transport modes

For the transport modes that are included in Victoria’s greenhouse gas inventory, the total energy related emissions were 20.2 Mt CO_2-e in 2004-05. Between 2004-05 and 2019-20, these emissions increased by only 0.6 Mt CO_2-e (2.9%). However, this increase would have been much higher if the emissions hadn’t reduced by 1.9 Mt CO_2-e (8.4%) between 2018-19 and 2019-20 due to the onset of the COVID-19 restrictions.

Between 2004-05 and 2018-19, the total Transport emissions included in Victoria’s greenhouse gas inventory increased by 2.5 Mt CO_2-e (12.3%). Road transport emissions increased by 1.4 Mt CO_2-e (7.8%), domestic Air transport emissions by 0.7 Mt CO_2-e (71.8%), and Railway emissions by 0.2 Mt CO_2-e (62.4%). However, between 2018-19 and 2019-20, Road transport emissions reduced by 1.3 Mt CO_2-e (6.6%), domestic Air transport emissions by 0.4 Mt CO_2-e (23.7%) and Railway emissions by 0.2 Mt CO_2-e (32.2%).

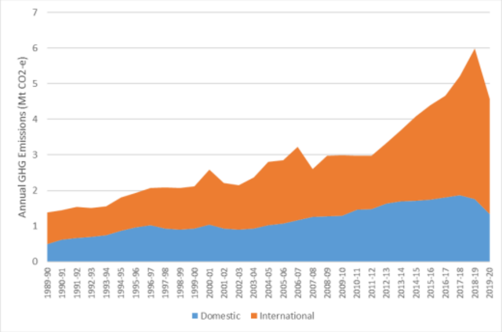
More detailed breakdowns of the Transport emissions which are included in Victoria’s greenhouse gas inventory are available from annual reports published by the Department of

[103] This is based on the Transport greenhouse gas emissions reported in the *Victorian Greenhouse Gas Emission Report 2020*, DELWP October 2022, plus estimated emissions from international air and sea transport (not included in the inventory) and emissions from electricity consumption (included under Electricity generation in the inventory). The estimate of the additional emissions uses the energy/fuel consumption reported in the AES multiplied by the relevant emission coefficients.

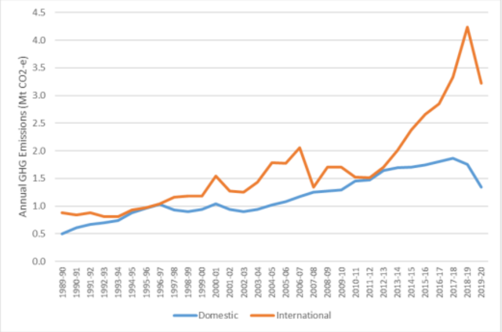
[104] These are not counted in the official Australian or Victorian greenhouse gas inventory under the Transport category. Emissions from international air and sea transport are not included, and emissions from electricity use are included under Electricity generation (part of the larger Energy source category).

Environment, Land, Water and Planning[105], including further disaggregation of Road transport emissions and insights into the underlying drivers for these emissions.

Figure 46: Victorian greenhouse gas emissions from air transport – by type



Total Air transport emissions by type



Emissions of domesstic and internatioal air transport

A key reason for Victoria's increasing emissions from the energy used in all modes of Transport has been Air transport. As can be seen in Figure 46, these emissions increased steadily from 1989-90 to 2011-12 but started to grow rapidly from 2013-14, driven largely by emissions from International Air transport. Between 1989-90 and 2018-19 total Air transport emissions increased by 4.6 Mt CO_2-e (335%). Domestic Air transport emissions increased by 1.3 Mt CO_2-e (255%) and International Air transport emissions by 3.4 Mt CO_2-e (379%). Between 2018-19 and 2019-20, total Air transport emissions decreased by 1.4 Mt CO_2-e (23.8%), with Domestic Air transport decreasing by 0.4 Mt CO_2-e (23.7%) and International Air transport decreasing by 1.0 Mt CO_2-e (23.8%).

Between 2004-05 and 2019-20, emissions from Domestic Air transport increased by 0.3 Mt CO_2-e (31.1%) and emissions from International Air transport increased by 1.4 Mt CO_2-e (80.9%). The emission increases would have been much higher if it were not for the large reduction in emissions due to the onset of the COVID-19 restrictions. This lower energy use and emissions from Air transport is likely to continue for several years, but it is likely that they will rebound once the COVID-19 restrictions on domestic and international air travel are lifted. This highlights the importance of measures that can limit the growth in emissions from air travel.

The energy consumption for International Air travel is included in the Australian Energy Statistics, but the greenhouse gas emissions from this energy use are not included in the Australian or State and Territory greenhouse gas inventories. Our estimates suggest that emissions from International Air travel are now significantly higher than emissions from Domestic Air travel and growing at a much faster rate. These emissions will also need to be addressed and reduced to net zero to fully achieve net zero emissions by 2050.

[105] *Victorian Greenhouse Gas Emission Report 2020*, DELWP October 2022. Road transport is further broken down into cars, heavy trucks and busses, and light commercial vehicles.

10 Appendix 4 – Issues with the Australian Energy Statistics

10.1 Introduction

The energy consumption data for this report has come from the 2021 edition of the Australian Energy Statistics (AES) Table F. This provides data on annual energy consumption for all states and territories, and for Australia as a whole, broken down by economic sector, by industry and by fuel type. This data, prepared by the Energy Statistics and Analysis section of the Department of Industry, Science and Energy, is considered to be "the authoritative and official source of energy statistics for Australia to support decision making and international reporting, and to help understand how our energy supply and use is changing"[106]. A key advantage of the dataset is that it is historical (it goes back to 1973-74) and it provides data on energy consumption in all economic sectors and by all fuels.

The data used to prepare the AES comes from a range of sources, including "facility level reporting from the National Greenhouse and Energy Reporting Scheme (NGERS), the Australian Petroleum Statistics (APS), the Resources and Energy Quarterly, datasets and estimates from other Australian and state government agencies, internal estimates using statistical techniques, and public company reporting. Datasets from private subscription services and industry associations are also used for comparison." Energy consumption in the industrial (manufacturing and mining sectors) is obtained from NGERS reporting, supplemented by econometric estimates (industry gross value added and employment) in industry sectors with low NGERS coverage. In the residential sector, both electricity and gas consumption are estimated using econometric techniques; for example, for electricity this includes "the number of households, income, electricity price, and the number of heating and cooling degree days". No detail is provided about how total Australian electricity and gas consumption is allocated between states and territories, and then allocated to the residential sector. The energy consumption of solar water heaters, and the energy generation and consumption of electricity associated with rooftop PV systems are both estimated using installation data provided by the Clean Energy Regulator[107].

Modelling studies undertaken for the national Equipment Energy Efficiency (E3) Program[108] have previously raised some concerns regarding the accuracy of the AES data for the Residential sector. The 2015 *Residential Baseline Study* (RBS) compared modelled

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[106] *Guide to the Australian Energy Statistics 2021*, Commonwealth of Australia, September 2021

[107] *Guide to the Australian Energy Statistics 2021*, Commonwealth of Australia, September 2021

[108] Discrepancies between modelled electricity and gas consumption and the AES data were first noted in *Energy Use in the Australian Residential Sector 1986 - 2020*, June 2008, prepared by Energy Efficient Strategies for the Dept. of Environment, Water, Heritage and the Arts. Issues were also noted in the more recent 2015 Residential Baseline Study.

electricity and gas consumption estimates with data from the AES[109], the Energy Supply Association of Australia (whose data was sourced from electricity distributors), and gas distributors. It found differences between the AES data and that obtained from electricity and gas distributors, especially for gas consumption. It noted that[110]: “Ideally the reported measurements of historic residential energy use would be consistent, allowing the RBS results to be compared to the historic findings in a simple manner. However, this has not proven to be the case, as the different sources of energy use data use different measurement methodologies that produce different results.”

An updated version of the 2015 *Residential Baseline Study* has been prepared by Paul Ryan (*EnergyConsult*) for the E3 Program[111]. For this new study, Ryan used publicly available data provided by electricity and gas distributors to the Australian Energy Regulator (AER) in their responses to Regulatory Information Notices (RIN), to build up a more accurate estimate of residential electricity and gas consumption based on *metered consumption data*[112]. We have used Ryan’s data, supplemented with data on non-residential energy consumption obtained from the RIN responses, to prepare estimates of Victorian electricity and natural gas consumption. For electricity, data is available on electricity consumption and export from embedded generators for both residential and non-residential customers. For natural gas, data is available on gas consumption for residential, commercial and industrial customers, and for electricity generation. In this Appendix, we compare the data obtained from the AER Regulatory Information Notice responses[113] with the data provided in the 2021 edition of the AES.

10.2 Electricity consumption

Residential electricity consumption is comprised of both mains electricity consumption and, in houses that have rooftop PV systems, the consumption of some of the electricity generated by the PV system (known as PV self-consumption). In houses that have small PV systems (less than 2 kW) the proportion of self-consumption is high (generally 50% or more). However, in houses with larger PV systems (5 kW or more) the proportion of self-consumption is quite low (generally 40% or less) and most of the electricity generated is exported to the electricity network to form part of the renewable electricity supply.

We have used data from the RIN responses of the Victorian electricity distributors[114], as well as data on Victorian small-scale PV installations from the Clean Energy Regulator and estimates of the average size of the residential PV systems installed in each year derived from Australian PV Institute data, to estimate the self-consumption of rooftop PV systems installed on Victorian houses, and this is shown in Figure 47 along with the PV export reported to AER[115]. The PV self-consumption plus the export is the total (or gross) electricity

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[109] At this time the AES was compiled by the Office of the Chief Economist, in the Department of Industry and Science.

[110] *Residential Baseline Study for Australia 2000 – 2030*, EnergyConsult for Dept. of Industry & Science (on behalf of the E3 Program), August 2015

[111] See: https://www.energyrating.gov.au/document/report-2021-residential-baseline-study-australia-and-new-zealand-2000-2040

[112] See: https://www.aer.gov.au/networks-pipelines/performance-reporting Data on the electricity delivered to residential customers and exported to the network from residential embedded generation (e.g., rooftop PV systems) is contained in the *Economic Benchmarking RIN - Template* spreadsheets. Data on natural gas delivered to residential consumers in contained in the *Annual Benchmarking RIN – Template* spreadsheets. The AER publishes RIN responses received from each electricity and gas distributor. For electricity it currently covers the years 2006 to 2021, and for gas it currently covers the years 2011 to 2020. The data is updated annually.

[113] For simplicity, we refer to this as the AER data, although in practice it comes from the RIN responses of the individual electricity and gas distributors.

[114] AusNet Services (SP AusNet), Powercor, Citipower, Jemena and United Energy.

[115] We used data from the Australian PV Institute (https://pv-map.apvi.org.au/analyses) to estimate the average size of PV systems less than 6.5 kW installed over the period 2010 to 2021, and assumed smaller systems prior to this. This has been combined with SV data linking different PV system sizes and annual electricity consumption to the % of self-consumption to estimate the % self-consumption for each annual cohort of PV systems installed. Data on the total MW of residential PV systems installed in each year, represented as a percentage of the cumulative total

generation from the residential PV systems. It is evident that total residential PV generation was very low prior to 2009-10, and has grown strongly since, to be an estimated 9.2 PJ (2,562 GWh) in 2019-20. Initially, the average size of the PV systems installed was quite low (around 1.9 kW in 2009-10) and the proportion of PV self-consumption was high (around 63% in 2009-10). However, over the decade to 2019-20 the average size of the residential PV systems installed increased significantly and the proportion of self-consumption declined. We estimate that in 2019-20, PV self-consumption from all residential rooftop PV systems in Victoria was 3.32 PJ (923 GWh), or 36% of the electricity generated by the PV systems. This self-consumption replaces, or offsets, the mains electricity that would otherwise be consumed in the residential sector if there were no rooftop PV systems.

Figure 47: Electricity generation by Victorian residential PV systems

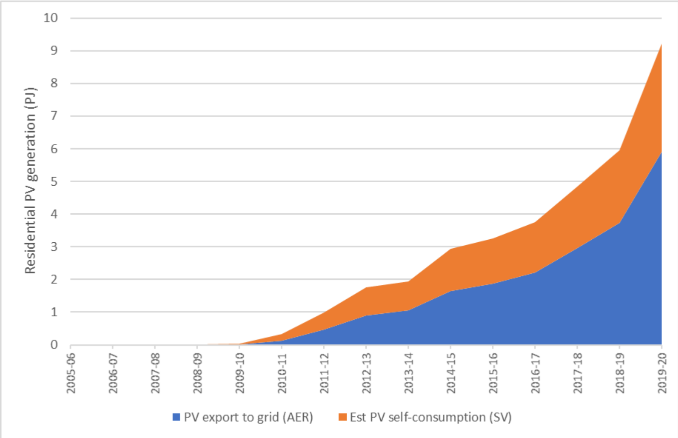
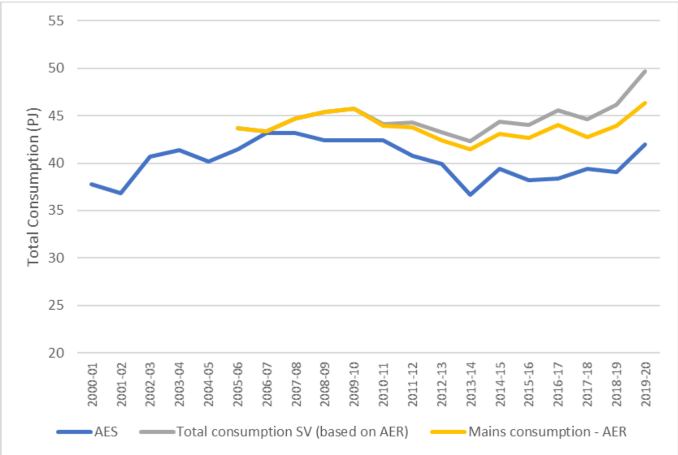


Figure 48: Total Victorian residential electricity consumption – AES compared to AER

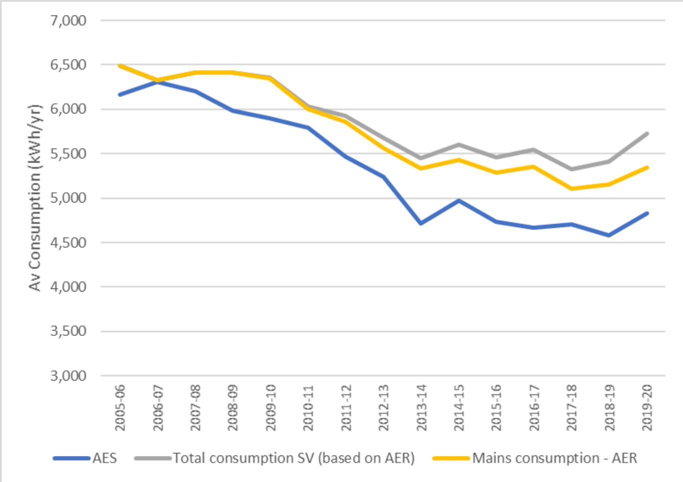


The estimated PV self-consumption has been added to the distributor data on electricity delivered to residential customers (or mains electricity consumption) to estimate total Victorian residential electricity consumption, and this has been compared to the 2021 AES data (see Figure 48). Our analysis suggests that the AES has significantly under-estimated the residential electricity consumption in Victoria since at least 2005-06. While the AES data shows total Victorian residential electricity consumption declining from 2006-07 to 2015-16, our estimates derived from the AER data suggests that it continued to increase until 2009-

installed MW in each year from 2006 to 2020 has then been used to estimate the weighted PV self-consumption in each year. This has been applied to the PV export data to estimate the annual gross PV generation and self-consumption in each year.

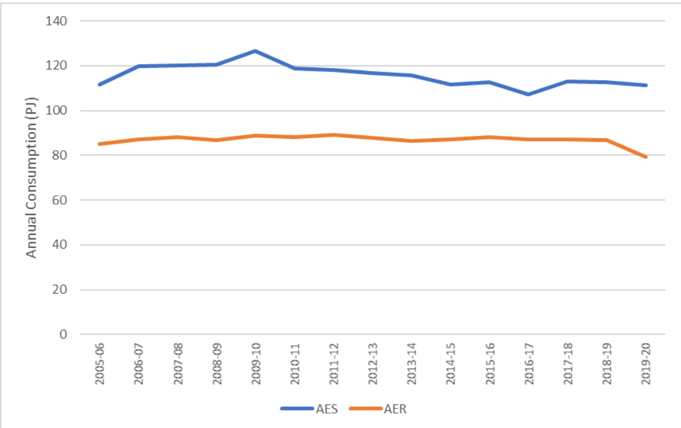
10, declined to 2013-14, and has increased quite strongly since. Both sets of data show that consumption increased between 2018-19 to 2019-20 due to the onset of the COVID-19 restrictions. The AER data enables us to distinguish between mains electricity consumption (yellow line) and total electricity consumption (grey line), and to understand the extent to which rooftop PV generation has reduced mains electricity consumption. The mains electricity consumption recorded in the AER data is also higher than the total electricity consumption shown in the AES data.

Figure 49: Electricity consumption of the average Victorian household – AES vs AER



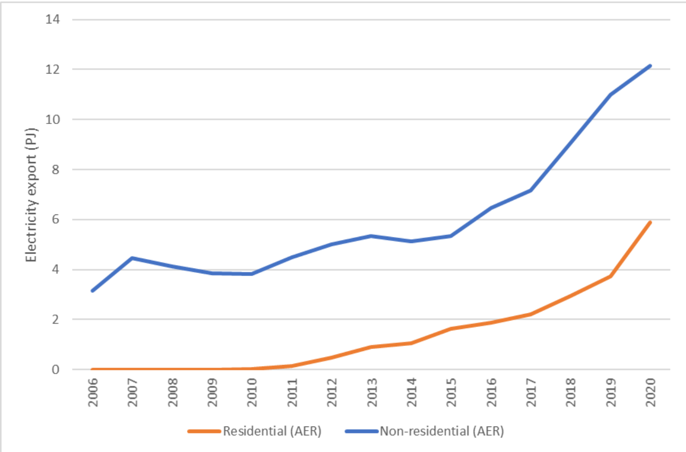
We have also compared the electricity consumption of the average *occupied* Victorian household derived from both the AES and AER data (Figure 49). Both sets of data suggest a significant reduction in average household electricity consumption between 2005-06 and 2018-19, and an increase in consumption between 2018-19 and 2019-20. The AER data provides insights into the impact that both rooftop PV systems and energy efficiency have had on household electricity consumption over the last fourteen years. Based on the AER data, average mains electricity consumption decreased by 1,331 kWh/yr (20.5%) between 2005-06 and 2018-19; of this, we estimate that PV self-consumption was responsible for 261 kWh/yr (19.6% of the total reduction) and energy efficiency was responsible for 1,070 kWh/yr (80.4% of the total). This suggests that energy efficiency has been the main driver of household mains electricity savings over this period, although the rooftop PV systems have also played an important role in boosting Victoria's renewable electricity supply.

Figure 50: Total Victorian non-residential electricity consumption, excluding electricity supply



The AER RIN responses also provide data on the annual electricity delivered (or mains electricity consumption) of all non-residential customers; it is not possible to break this down further into the economic sectors. As this data comes from electricity distributors, it does not include electricity consumption (or losses) within the electricity distribution network or during electricity generation and transmission. We understand that AES does include this in the electricity consumption of the Electricity supply sub-sector. Figure 50 above provides a comparison of the AES and AER data for total non-residential electricity consumption, excluding the electricity supply sub-sector. The estimate derived from the AER data is significantly lower than the AES estimate.

Figure 51: Total Victorian electricity exports from embedded generation



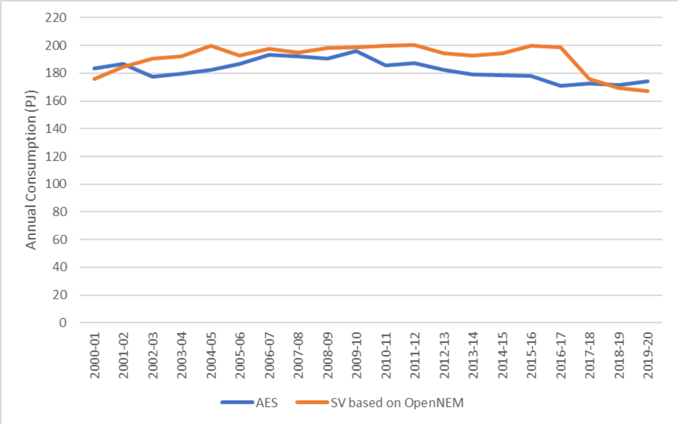
One reason that the AER consumption is somewhat lower than the AES consumption may be that the AER data is just for mains electricity consumption and does not include self-consumption of energy produced on-site from embedded generation. Adding the self-consumption of the embedded generation would give a more accurate estimate of total electricity consumption. In the non-residential sector, this could include both co-generation and rooftop PV systems. From Figure 51, it is evident that export from non-residential embedded generation is much higher than the export from residential rooftop PV systems. This suggests that the self-consumption could also be higher, but it is much more difficult to estimate as it comes from both co-generation and rooftop PV systems, and the magnitude of the non-residential electricity consumption can vary significantly from site-to-site.

Data provided by OpenNEM[116] enables an alternative estimate of total Victorian electricity consumption to be made. We have used the OpenNEM data on annual electricity generation from 2001 to 2020, combined with data on electricity imports into Victoria and exports of electricity to other states, to estimate the total net electricity consumption. This should equate to the total electricity consumption, including “behind the meter” consumption and losses in the transmission and supply system. In Figure 52, we compare this estimate with the AES total electricity consumption data. There is a much closer match between the AES and our estimate derived from the OpenNEM data. There are some differences in the data which might explain the discrepancies: the OpenNEM data is based on calendar years while the AES data is based on financial years; and, the OpenNEM data does not include co-generation at non-residential sites, although it does include estimated total generation from rooftop PV systems. The fact that the AES data and our estimate based on the OpenNEM data are fairly consistent, suggests that the AES data is reasonable at the highest level but that there may be some misallocation of electricity consumption between the economic

[116] https://opennem.org.au/energy/vic1/?range=1d&interval=30m

sectors, especially the residential and commercial sectors, as these rely heavily on econometric modelling.

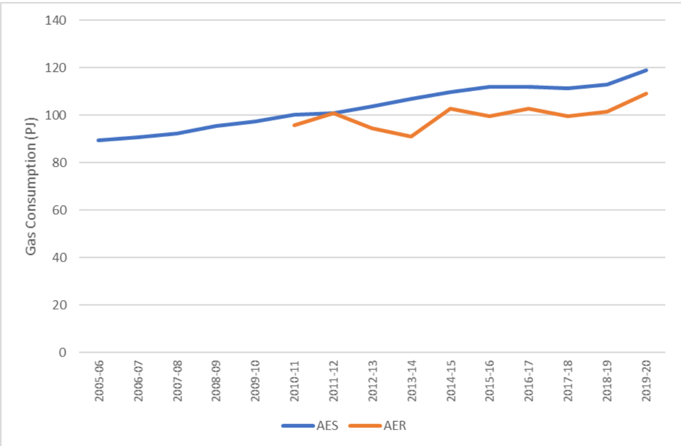
Figure 52: Total Victorian electricity consumption – AES vs SV estimate using OpenNEM



10.3 Natural gas consumption

In their RIN responses, the Victorian gas distributors[117] provide data for the total volume of gas delivered (in GJ) to residential, commercial and industrial customers. Figure 52 compares AES data on residential natural gas consumption to the aggregated data from the AER RIN responses. In general, the 2021 AES estimate is somewhat higher than the total residential gas consumption calculated from the AER RIN responses. Over the period 2010-11 to 2019-20 the AES estimate of total gas consumption is 91.3 PJ (9.1%) higher than the total gas consumption over this period calculated from the distributor data.

Figure 52: Comparison of Victorian Residential natural gas consumption estimates



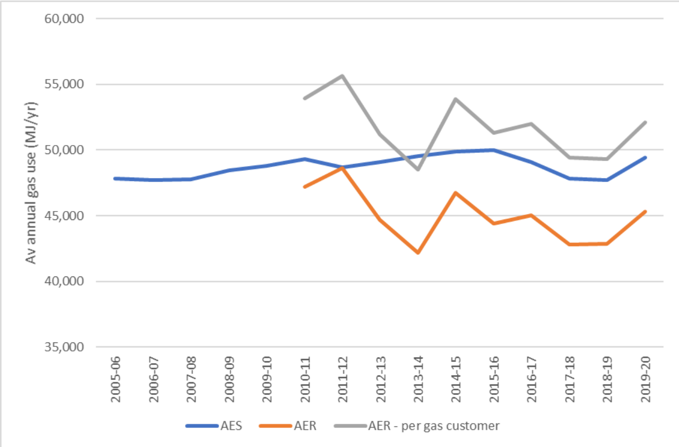
In Figure 53, we compare the natural gas consumption of the average *occupied* Victorian household (MJ/yr) calculated from both the 2021 AES and AER data, as well as the average gas use per residential natural gas customer calculated from the AER data[118]. Again, the AER data shows a gas consumption that is lower than the AES. The AES data suggests that

[117] AusNet Gas Services, Australian Gas Networks, Multinet

[118] The AER RIN responses contain data on the total number of residential customers at the start and end of each year. We have used the average of this to calculate the average number of customers in each year and used this to calculate the average annual gas consumption per customer. This is higher than the average for occupied households, as not all households have a natural gas connection.

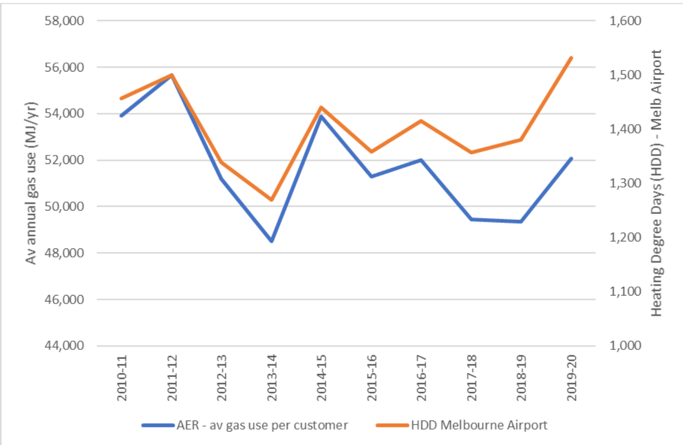
average household gas use trended upwards from 2005-06 to 2015-16 and then started to trend down, only increasing between 2018-19 and 2019-20 due to the onset of COVID19 restrictions. However, the AER data suggests that average consumption showed a downward trend between 2011-12 and 2018-19. This is likely to have been driven by increases to the minimum efficiency of new dwellings in 2005 (Five Star Standard) and 2013 (Six Star Standard), Victoria's variation to the water heating requirements in the building code that required new gas reticulated houses to install gas-boosted solar water heaters, an increasing market share for the more efficient gas instantaneous water heaters compared to gas storage systems, a declining market share for gas room heaters, and some general efficiency improvements to new gas ducted heaters.

Figure 53: Comparison of annual gas use of the average occupied household



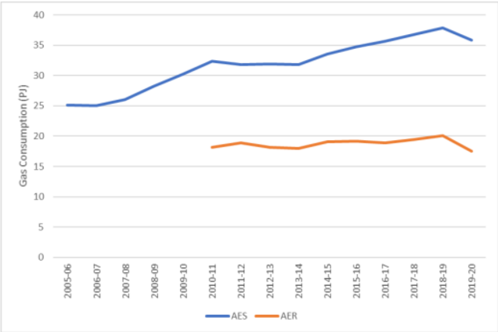
Another difference between the AES and AER, is that the AES data shows much less annual variation. In Victorian homes, natural gas is used mainly for heating, and this means that the amount of gas used each year is highly dependent on the severity of the heating season; in cold years, the gas consumption can be significantly higher than in warmer years. Figure 54 shows the average annual natural gas use per Victorian gas customer plotted against the annual Heating Degree Days (HDD) at Melbourne Airport. It is evident that there is a strong correlation between the total annual residential gas consumption and the total HDD in each year. From this graph, it is also evident that there was a large increase in HDD between 2018-19 and 2019-20 and this, combined with the onset of the COVID19 restrictions and greater working from home, was responsible for the large increase in average household gas consumption.

Figure 54: Av annual gas use per customer vs Heating Degree Days at Melbourne Airport

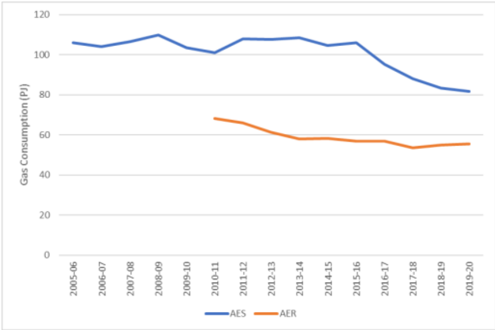


In Figure 55, we provide a comparison between the annual gas consumption estimates in the Commercial and Industrial sectors from the 2021 AES[119] and AER data. The AES estimate of natural gas consumption is much higher than the aggregated gas consumption calculated from the distributor data. Over the period 2010-11 to 2019-20, the AES total consumption is 82.6% higher than the AER total consumption in the Commercial sector, and 66.9% higher than the AER total consumption in the Industrial sector. It is not clear why there is such a large difference between the two data sources.

Figure 55: Comparison of Victorian commercial and industrial gas consumption estimates

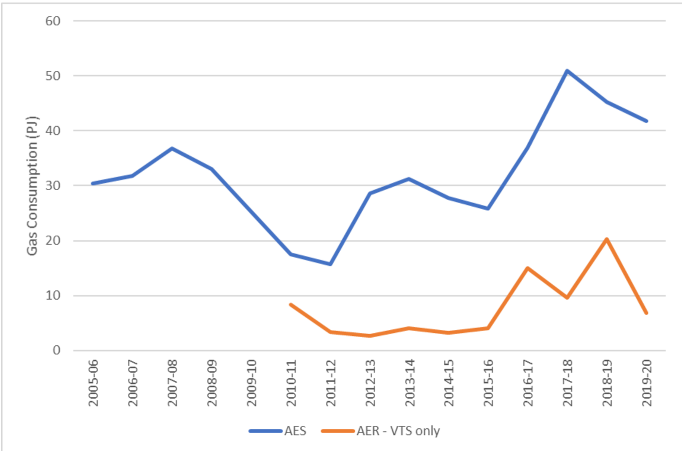


Commercial



Industrial

Figure 56: Comparison of gas consumption for electricity generation



The organisation that is responsible for Victoria's gas transmission system – APA GasNet Australia - also provides an annual RIN response to the Australian Energy Regulator, and this provides an annual record of the natural gas flowing through the Victorian Transmission System. Their RIN response includes data on the gas volume (GJ) supplied to electricity generation customers, the gas volume (GJ) for the tariffed transmission service, and the gas volume (GJ) that passes through the different injection points[120]. Figure 56 provides a comparison of the AES and AER data on gas consumption in the 'electricity supply' sector. The AES consumption is significantly higher than the consumption obtained from APA GasNet's RIN response. This may be because the AER data is just the gas generation consumption for the VTS (or DTS) system. The 2022 update to the *Victorian Gas Planning*

[119] For the AES data, the industrial estimate includes the following sectors: manufacturing, mining, agriculture, electricity, gas and water (excluding electricity supply), transport and construction.
[120] Longford, Culcairn, Dandenong, Iona, VicHub, SEAGas, Pakenham, TasHub.

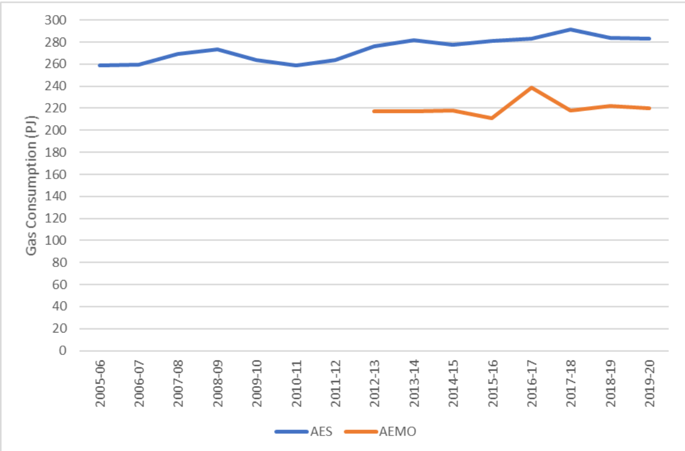
Report forecasts 7.77 PJ of consumption for DTS gas generation consumption and 9.66 PJ of consumption for non-DTS gas generation consumption in 2022[121].

The Victorian Transmission System, also known as the Declared Transmission System (DTS), supplies gas to Melbourne and regional Victoria. It also supplies gas to NSW via an interconnection to the Moomba-Sydney Pipeline at Culcairn, to South Australia via the SEA Gas Pipeline at Port Campbell. A description of the operation of the VTS is provided by the Australian Energy Market Commission[122]:

> *Gas can enter or exit the system from the Longford gas plant and the VicHub in the east, Culcairn in NSW, the western underground gas storage (WUGS) facility at Iona, the SEA Gas Pipeline, Otway Gas Plant and Mortlake Pipeline through their connection to the SEA Gas Pipeline at Port Campbell, the Pakenham facility and the Dandenong LNG facility. Gas can also be injected from the Tasmanian Gas Pipeline (TasHub) into the VTS at Longford. Gas is principally sourced from offshore gas fields in the Gippsland, Bass and Otway basins.*

Data provided in APA GasNet's RIN responses seems to provide a complete record of gas consumption in the VTS (or DTS), although further information is required to fully understand the gas flows and therefore the total natural gas consumption in Victoria. This would require an understanding of the net annual import (or export) of gas from/to NSW and South Australia, and of the net annual import of gas from the storage facilities located at Iona and Dandenong. From the 2022 update to the *Victorian Gas Planning Report,* it is evident that there is also consumption in the non-DTS network, both for gas generation and in the residential and business sectors[123], and this data is necessary to understand total natural gas consumption in Victoria. We are yet to locate a separate historical source for this data.

Figure 57: Comparison of total Victorian natural gas consumption



The various Victorian Gas Planning Reports[124] prepared by the Australian Energy Market Operator (AEMO) provide historical and projected data on total gas consumption in the DTS

[121] *Victorian Gas Planning Report – Update*, Australian Energy Market Operator, March 2022. This notes that the non-DTS gas generation at Bairnsdale and Mortlake.

[122] https://www.aemc.gov.au/energy-rules/national-gas-rules/gas-scheme-register/vic-victorian-transmission-system

[123] Non-DTS gas generation occurs at Bairnsdale and Mortlake. In addition to this, there is some residential and commercial (tariff V) and industrial (tariff D) gas consumption at Bairnsdale, Lang Lang and off the South Gippsland pipeline. *Victorian Gas Planning Report – Update*, Australian Energy Market Operator, March 2022

[124] *Victorian Gas Planning Report*, AEMO, March 2019; *Victorian Gas Planning Report*, AEMO, March 2021; *Victorian Gas Planning Report – Update*, AEMO, March 2022

(or VTS) and non-DTS gas transmission networks in Victoria, for both residential and business (Tariff V and D) customers and for gas generation from 2013 to 2020. Figure 57 compares the AES data for total Victorian natural gas consumption with the AEMO data. The AES estimate is significantly higher than the AEMO estimate – between 2012-13 and 2019-20, the total AES estimate is 496 (28.2%) higher than the AEMO estimate. The reason for this large difference is not clear.

10.4 Conclusions

In this section we have compared the Victorian electricity and natural gas consumption data from the 2021 edition of AES Table F with alternative data obtained by aggregating data contained in the RIN responses provided by electricity and gas distributors to the Australian Energy Regulator. This has been supplemented by an estimate of total Victorian electricity consumption derived from OpenNEM data, and data on total Victorian natural gas consumption obtained from various Victorian Gas Planning Reports published by AEMO. There are significant differences between the AES data – with relies on a combination of NGERS data and econometric estimates – and the AER/AEMO data which uses *metered* energy consumption.

While at the state level, the AES electricity consumption estimate is in reasonable agreement with the estimate derived from OpenNEM, the AES data seems to underestimate residential electricity consumption. This suggests that estimates for the commercial and industrial sectors may also not be accurate. This may be due to differences in the way in which the electricity self-consumption of rooftop PV and other onsite (embedded) generation is calculated, and to the econometric estimates misallocating electricity consumption between the different economic sectors.

There are very significant differences between the AES and the AER/AEMO gas consumption data, both at the state level, and for the residential, commercial and industrial sectors. The reasons for these differences are not clear, although they are likely to stem partly from the AES use of econometric estimates rather than metered data. The large difference between the AEMO and AES data on total Victorian natural gas consumption suggests that there may also be misallocation of gas consumption between states and territories.

As “the authoritative and official source of energy statistics for Australia”, the AES data is used by governments to track energy consumption at the national, state and territory level, to help understand the impact of past energy policy and program interventions, and to plan and target future ones. It is concerning that there seem to be inaccuracies in the AES historical consumption estimates for electricity and natural gas, key sources of energy in most economic sectors. Investigations undertaken by Paul Ryan for the *Residential Baseline Study* on residential energy consumption, and investigations undertaken for this study on commercial and industrial energy consumption, suggest that better, *metered*, electricity and gas consumption data is now readily available through the RIN responses provided by distribution and transmission service providers to the Australian Energy Regulator. We have raised these issues with the Energy Statistics and Analysis section of the Department of Industry, Science and Energy, to see if the AER/AEMO data can be used as an input to the AES, to facilitate more accurate estimates using the best available current data.

Prior to the publication of this report, the 2022 edition of the AES data was released, and this has responded, in part, to the issues raised in this report.

11 Appendix 5 – Comparison of Victoria's emission sources with other jurisdictions

11.1 Introduction

In Section 5.3 we compared Victoria's total net greenhouse gas emissions with those of the other states and territories. In this Appendix, we provide a more detailed insight into how Victoria's greenhouse gas emissions from the different sources – Energy, Agriculture, Industrial processes, Waste, and Land Use, Land Use Change and Forestry (LULUCF) - compare to other states and territories. We look at how the emissions have changed over the period 1989-90 to 2019-20, as well as each jurisdiction's share of both emissions and population in 2019-20.

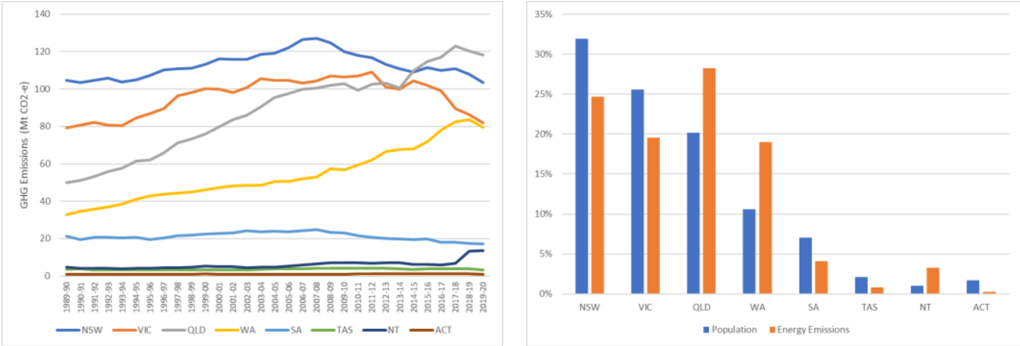
More detailed information on Victoria's greenhouse gas emission sources is available in the *Victorian Greenhouse Gas Inventory 2020*, including more detailed breakdowns of the emission source categories[125].

11.2 Energy emissions

Energy related emissions dominate the total net greenhouse gas emissions in all states and territories. In all jurisdictions, these emissions (Figure 58) increased from 1989-90 to the mid-2000s. They have since started to decline in most jurisdictions: in New South Wales and South Australia from the mid-2000s; in Victoria and Tasmania from the early 2010s; and in Queensland and Western Australia from the late 2010s. However, the emissions have continued to increase in the Northern Territory. In 2019-20, Victoria had the third highest Energy emissions (81.6 Mt CO_2-e), just ahead of Western Australia (79.6 Mt CO_2-e), but well behind New South Wales (103.6 Mt CO_2-e) and Queensland (118.3 Mt $CO_{2\text{-e}}$). Energy emissions were growing rapidly in Western Australia and Queensland but have recently started to decline. However, this apparent turn around may be largely due to the COVID-19 restrictions and may not last. New South Wales, Victoria, South Australia, Tasmania and the ACT's share of energy emissions are lower than their population share. Queensland, Western Australia and Northern Territory's share of emissions are much higher than their population share.

[125] Energy is segmented into electricity generation, fuel combustion, transport and fugitive emissions. Transport is segmented further into cars, heavy duty trucks and busses, light commercial vehicles, domestic aviation, domestic navigation, railways and other. Agriculture is segmented into enteric fermentation, agricultural soils, manure management, urea application, liming, and field burning of agricultural residues. Waste is segmented into solid waste disposal, biological treatment of solid waste, incineration/burning of waste, and wastewater treatment and discharge. The complex LULUCF category is segmented into several categories relating to forest, grassland, cropland and wetland management and changes.

Figure 58: Comparison of Energy related greenhouse gas emissions

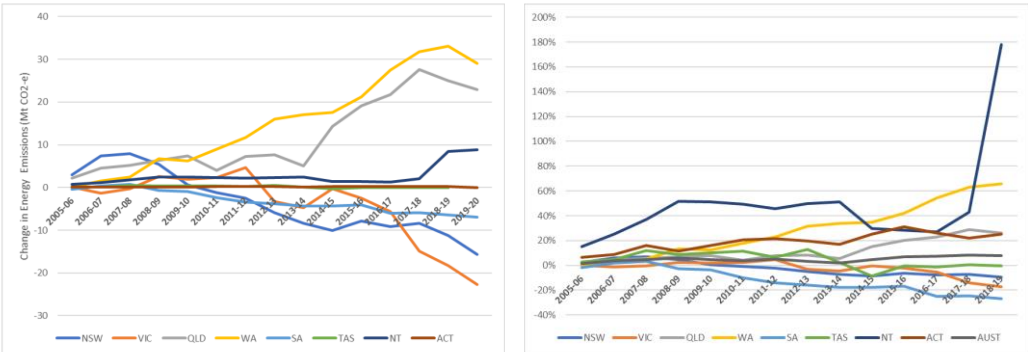


Total state and territory energy emissions

Share of population and energy emissions

Figure 59 shows the change in the Energy related emissions in the states and territories since 2004-05. In absolute terms, the largest reductions have occurred in Victoria (22.7 Mt CO_2-e), New South Wales (15.6 Mt CO_2-e), and South Australia (7.0 Mt CO_2-e). In percentage terms, the largest reductions have occurred in South Australia (29.0%), Victoria (21.7%), and NSW (13.1%). Energy emissions have increased in Western Australia (29.0 Mt CO_2-e, 57.5%), Queensland (22.9 Mt CO_2-e, 24.0%), Northern Territory (8.9 Mt CO_2-e, 186.6%), and the ACT (0.04 Mt CO_2-e, 4.3%). As can be seen in Figure 25 above, these increased emissions more than offset the reductions in Victoria, NSW and South Australia, meaning that Australia's total energy related emissions increased over this period by 15.5 Mt CO_2-e (3.8%).

Figure 59: Change in Energy related greenhouse gas emissions since 2004-05



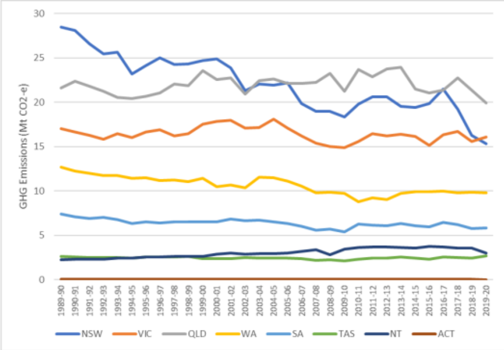
Absolute change in energy emissions

Percentage change in energy emissions

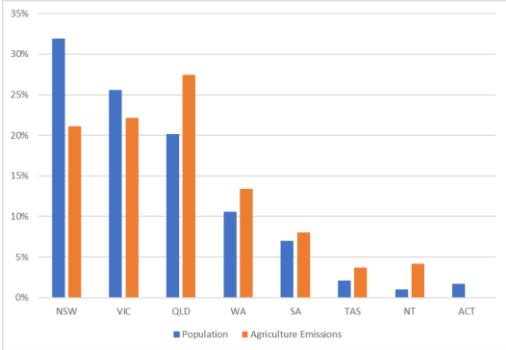
11.3 Agricultural emissions

Agricultural emissions make the second largest contribution to net greenhouse emissions. Figure 60 shows how these emissions have changed in the states and territories from 1989-90 to 2019-20. In New South Wales, Western Australia and South Australia they have declined over this period. The emissions in Queensland, Tasmania and Victoria have remained fairly constant (with some annual fluctuation), and in the Northern Territory the emissions have increased. In 2019-20, Victoria had the second highest emissions from agriculture (16.1 Mt CO_2-e), behind Queensland (19.9 Mt CO_2-e) and just ahead of New South Wales (15.3 Mt CO_2-e). Agricultural emissions in Western Australia (9.8 Mt CO_2-e) and South Australia (5.8 Mt CO_2-e) are also significant. New South Wales, Victoria and the ACT's share of agricultural emissions are lower than their population share. Queensland, Western Australia, South Australia, Tasmania and the Northern Territory's share of agricultural emissions are higher than their population share.

Figure 60: Comparison of Agricultural greenhouse gas emissions



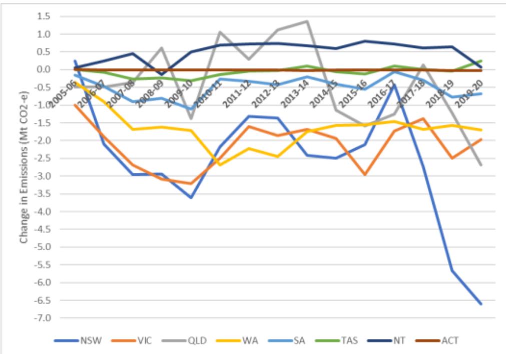
Total state & territory agricultural emissions



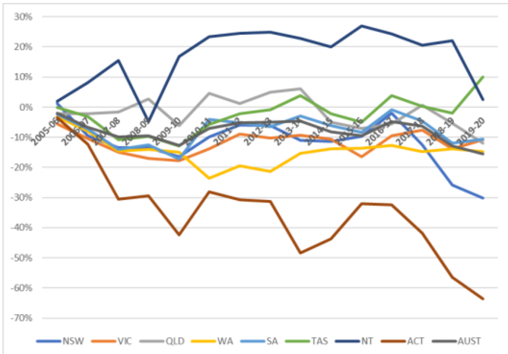
Share of population and agricultural emissions

Figure 61 shows the change in the Agricultural emissions in the states and territories since 2004-05. In absolute terms, the largest reductions have occurred in NSW (6.6 Mt CO_2-e), Queensland (2.7 Mt CO_2-e), Victoria (2.0 Mt CO_2-e), Western Australia (1.7 Mt CO_2-e), and South Australia (0.7 Mt CO_2-e). In percentage terms, the largest reductions have been in the ACT (63.6%), New South Wales (30.1%), Western Australia (14.8%), Queensland (11.9%), Victoria (10.9%) and South Australia (10.5%). Emissions have increased in Tasmania (0.2 Mt CO_2-e, 10.0%) and the Northern Territory (0.1 Mt CO_2-e, 2.5%).

Figure 61: Change in Agricultural greenhouse gas emissions since 2004-05



Absolute change in agricultural emissions

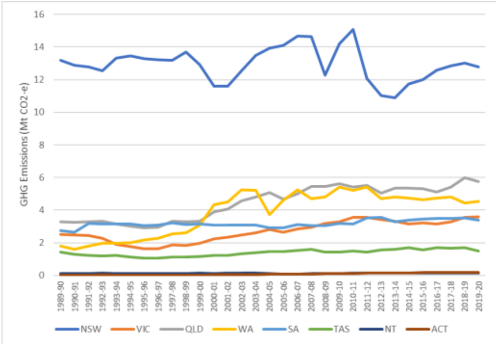


Percentage change in agricultural emissions

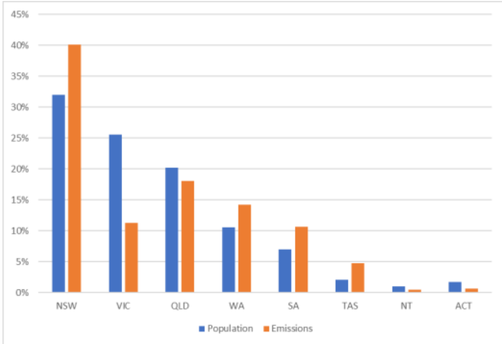
11.4 Industrial process emissions

The total Industrial process emissions in the different states and territories over the period 1989-90 to 2019-20 are shown in Figure 62. Over this period, the emissions have increased in Queensland, Western Australia, Victoria and Tasmania. They have stayed fairly constant in South Australia and shown a general downward trend in NSW (with fluctuation). At 12.8 Mt CO_2-e, NSW's industrial process emissions in 2019-20 are by far the largest. Victoria had the fourth highest emissions (3.6 Mt CO_2-e), behind Western Australia (4.5 Mt CO_2-e), Queensland (5.8 Mt CO_2-e), and New South Wales. For a small state, Tasmania's emissions are also significant (1.5 Mt CO_2-e). Victoria, Queensland, Northern Territory and the ACT's share of industrial process emissions are lower than their population share. New South Wales, Western Australia, South Australia and Tasmania's share of industrial process emissions are higher than their population share.

Figure 62: Comparison of Industrial process greenhouse gas emissions



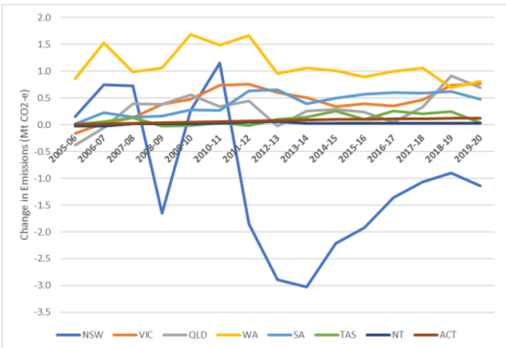
Total state & territory industrial process emissions



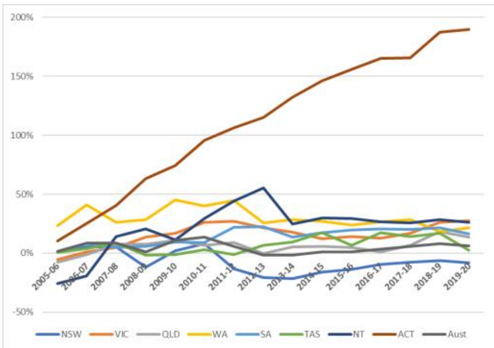
Share of population and industrial process emissions

Figure 63 shows the change in Industrial process emissions in the states and territories since 2004-05. Since this time, Industrial process emissions have reduced only in NSW (1.1 Mt CO_2-e, 8.2%). The emissions have increased in all other jurisdictions. The largest increases have occurred in Western Australia (0.80 Mt CO_2-e, 21.5%), Victoria (0.77 Mt CO_2-e, 27.4%), Queensland (0.69 Mt CO_2-e, 13.7%), and South Australia (0.48 Mt CO_2-e, 16.4%).

Figure 63: Change in Industrial process greenhouse gas emissions since 2004-05



Absolute change in industrial process emissions

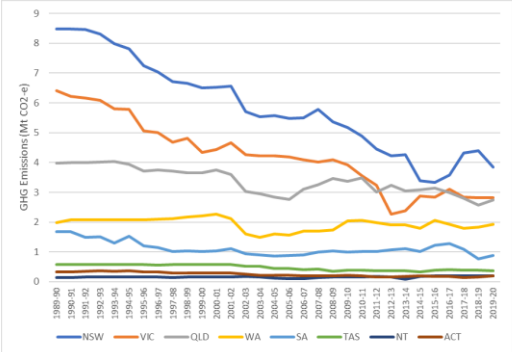


Percentage change in industrial process emissions

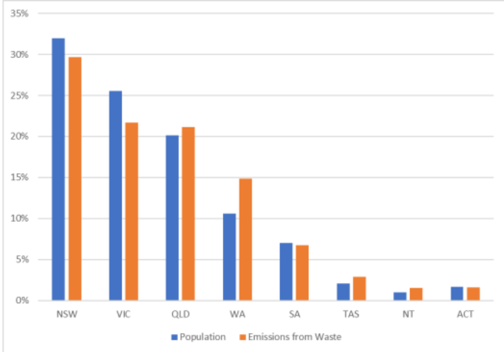
11.5 Waste emissions

The total Waste emissions in the different states and territories over the period 1989-90 to 2019-20 are shown in Figure 64. Over this period, the Waste emissions in most jurisdictions displayed a downward trend, most noticeably in NSW and Victoria. In 2019-20, Victoria had the second highest emissions from waste (2.8 Mt CO_2-e), behind NSW (3.8 Mt CO_2-e). The Victorian emissions showed a strong reduction from 2008-09 to 2012-13 but have since increased and overtaken Queensland (2.7 Mt CO_2-e). New South Wales, Victoria, South Australia and the ACT's share of waste emissions are lower than their population share. Queensland, Western Australia, Tasmania and the Northern Territory's share of emissions are higher than their population share.

Figure 64: Comparison of Waste related greenhouse gas emissions

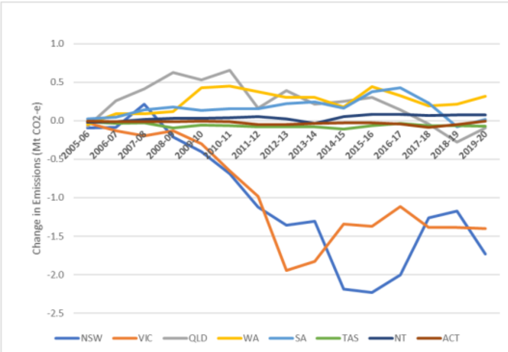


Total state & territory waste emissions

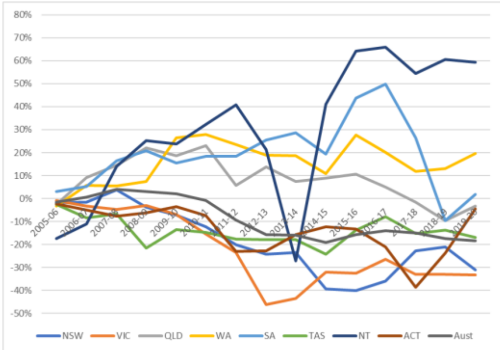


Share of population and waste emissions

Figure 65: Change in Waste related greenhouse gas emissions since 2005



Absolute change in waste emissions



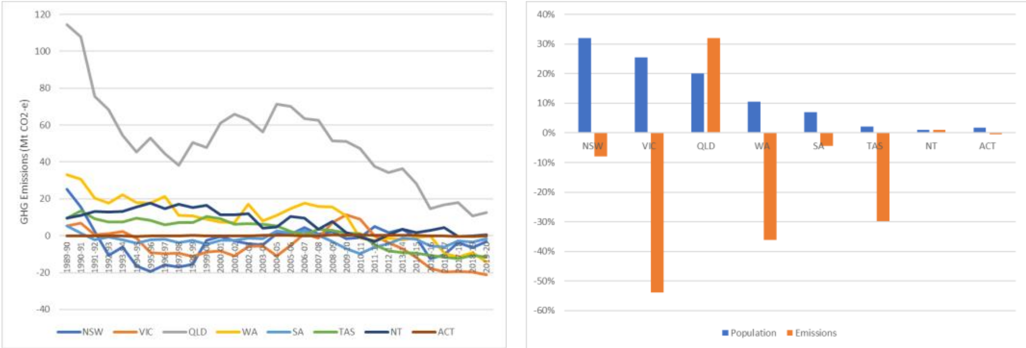
Percentage change in waste emissions

Figure 65 shows the change in waste emissions in the states and territories since 2004-05. In absolute terms, the largest reductions in waste emissions have been in NSW (1.7 Mt CO_2-e) and Victoria (1.4 Mt CO_2-e). In percentage terms, the largest reductions have been in Victoria (33.2%), New South Wales (31.0%) and Tasmania (16.9%). Emissions have increased in Western Australia (0.3 Mt CO_2-e, 19.7%), the Northern Territory (0.07 Mt CO_2-e, 59.3%) and South Australia (0.02 Mt CO_2-e, 1.8%).

11.6 Land use emissions

Total net emissions from Land Use, Land Use Change and Forestry (LULUCF) in the different states and territories over the period 1989-90 to 2019-20 are shown in Figure 66. In most cases, the net emissions have decreased over this period, and this is especially the case in Queensland. In New South Wales, Victoria, Western Australia, South Australia and Tasmania, LULUCF now provides a net sink for emissions (or negative emissions). In 2019-20, it provided the largest emissions sink in Victoria (21.1 Mt CO_2-e), Western Australia (14.1 Mt CO_2-e), Tasmania (11.6 Mt CO_2-e), NSW (3.1 Mt CO_2-e) and South Australia (1.7 Mt CO_2-e). In both Queensland (12.5 Mt CO_2-e), and Northern Territory (0.4 Mt CO_2-e) LULUCF results in net positive greenhouse gas emissions. The reduction in LULUCF emissions in Queensland, most of which was achieved before the Kyoto Protocol was agreed in 1997, is a key reason that Australia has been able to meet its very unambitious international abatement targets. Between 1989-90 and 2019-20, emissions from LULUCF in Queensland reduced by 102.0 Mt CO_2-e. This accounts for much the reduction in Australia’s total net emissions of 142.9 Mt CO_2-e that occurred over this period.

Figure 66: Comparison of net emissions from Land Use, Land Use Change and Forestry

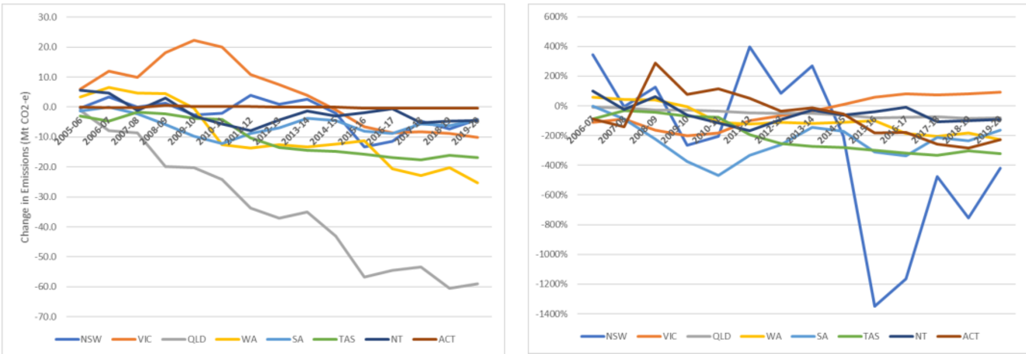


Net total state & territory land use emissions

Share of population and land use emissions

Figure 67 shows the change in LULUCF emissions in the states and territories since 2004-05. During this period, Land use emissions have reduced in all jurisdictions. The largest reductions have been in Queensland (58.9 Mt CO_2-e), Western Australia (25.3 Mt CO_2-e), Tasmania (16.9 Mt CO_2-e), Victoria (10.0 Mt CO_2-e) and South Australia (4.3 Mt CO_2-e).

Figure 67: Change in net emissions from land use, land use change and forestry since 2004-05



Absolute change in net land use emissions

Percentage change in net land use emissions