Victorian Greenhouse Gas Emissions Report

2021

VICTORIA State Government | Energy, Environment and Climate Action

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community to progress their aspirations.

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Minister's foreword

In Victoria, we're not just talking about climate action. We're getting on with it.

In the last year we've set a new, ambitious and achievable 2035 target to reduce Victoria's emissions by 75-80% below 2005 levels and committed to reach net zero emissions by 2045 - five years earlier than previous planned. Our targets put Victoria among global climate leaders.

The *Victorian Greenhouse Gas Emissions Report 2021* measures Victoria's progress towards our targets. This report shows that Victoria is already in range for our 2025 target of 28-33% below 2005 levels, having slashed Victoria's emissions by 32.3% below 2005 levels. We have now set our sights on our next target of halving Victoria's emissions by 2030.

Victoria has firmly established a downward trajectory for emissions. The historical emissions data in this report shows a turning point in the last decade where emissions fell steeply, and the economy and population grew. This reflects the Victorian Government's clear plan to cut emissions, advances in renewable technologies and the efforts of all Victorians to take action on climate change.

The transition of Victoria's energy system to renewables has had a significant impact on our emissions. To continue to drive this transition we've set nation leading targets – with a renewable energy target of 95% by 2035, Australia's first offshore wind targets and the biggest renewable energy storage targets in Australia. Our revival of the State Electricity Commission will support our goal of delivering 95% renewable energy generation by 2035, and we've invested an initial $1 billion for the SEC to build the energy projects it needs to hit that target.

We'll continue to work hard to cut emissions, put downward pressure on power bills and create a more climate resilient state.

I trust this report will assist government, business and individuals to identify opportunities and take action for a net zero emissions and climate resilient future.

The Hon. Lily D'Ambrosio MP

Minister for Climate Action

Minister for Energy and Resources

Minister for the State Electricity Commission

Summary

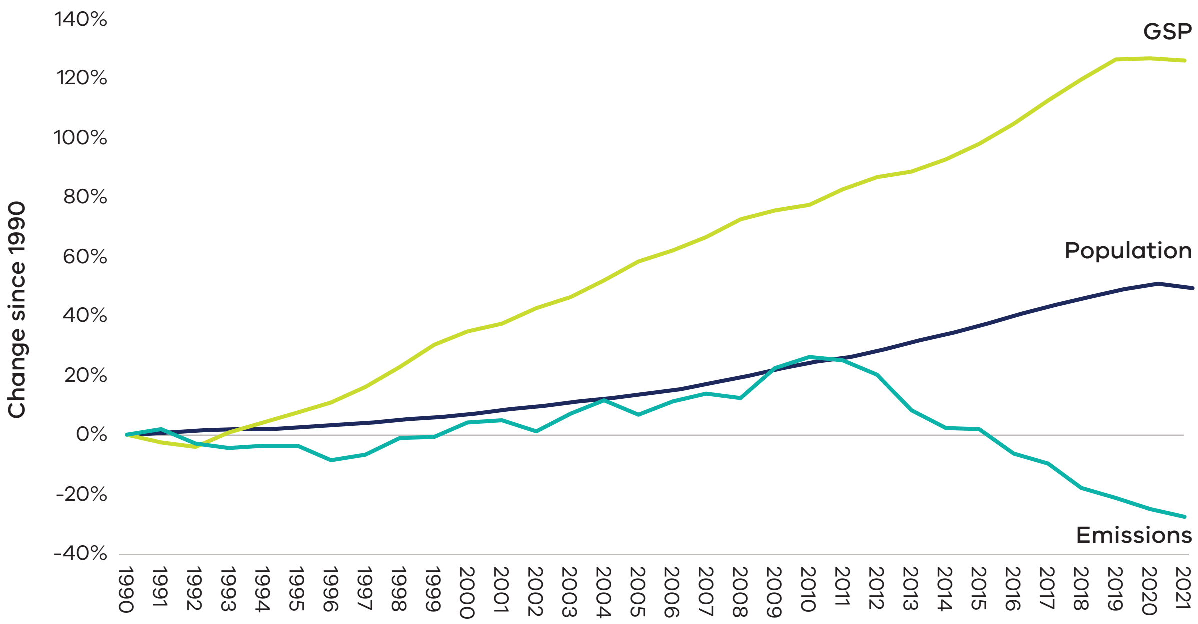
The *Victorian Greenhouse Gas Emissions Report 2021* (the report) is the sixth in a series of annual emissions reports required under Victoria's *Climate Change Act 2017* (the Act). The report provides an overview of the state's greenhouse gas emissions from 1990 to 2021[1] with a focus on trends since 2005 (the reference year for interim emissions reduction targets under the Act). It also explains emissions sources and trends over time, including the likely drivers of those trends.

The key findings in this report include:

Victoria's population and economy have grown, while emissions have declined

Victoria's emissions declined by 27.6% between 1990 and 2021, as the population increased by 49.5% and the economy grew by 126% (Figure 1). Victoria's per capita emissions in 2021 — a measure of the state's total net emissions divided by its population — were well below the national average, and lower than all states and territories' other than South Australia, Tasmania and the Australian Capital Territory (ACT).

Figure 1: Change in Gross State Product (GSP), population and emissions – Victoria, 1990 to 2021



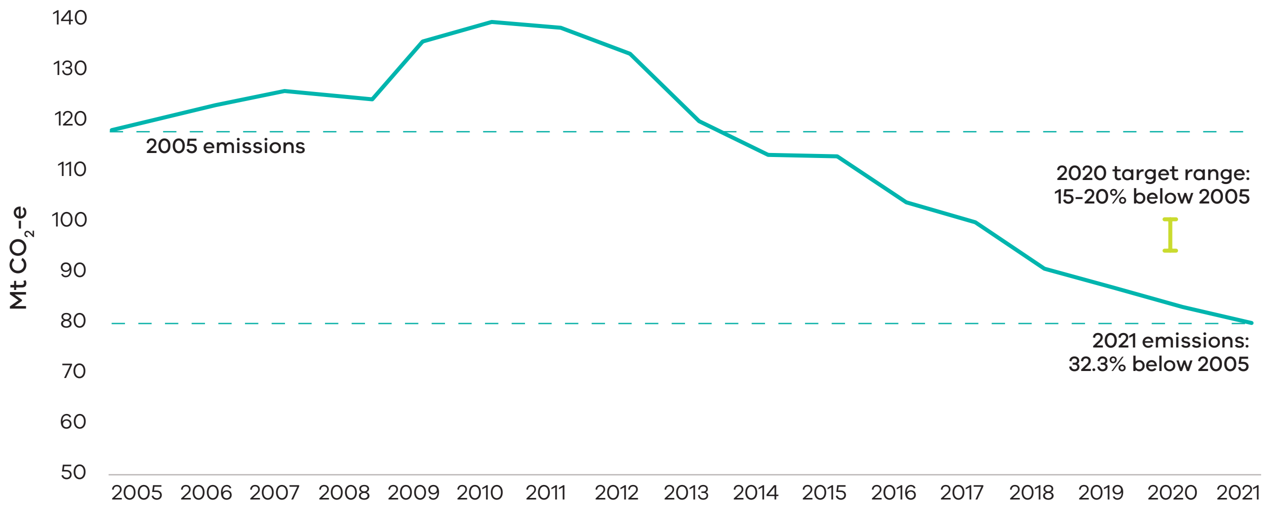
Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e), Australian National Accounts: State Accounts 2021-22 (ABS, 2022) and Australian Demographic Statistics 2022 (ABS, 2023)

[1] 2021 is the latest year for which official emissions data, published by the Commonwealth Government, are available.

Victoria has cut emissions by almost a third since 2005

Victoria's total net emissions fell by 32.3% between 2005 and 2021, to a total of 80.1 million tonnes (Mt) of carbon dioxide equivalent (CO_2-e) (Figure 2). This progress in reducing emissions compared to 2005 levels means that 2021 emissions are within the range of the 2025 target to reduce Victoria's emissions 28–33% below 2005 levels.

Figure 2: Victoria's total net emissions, 2005 to 2021

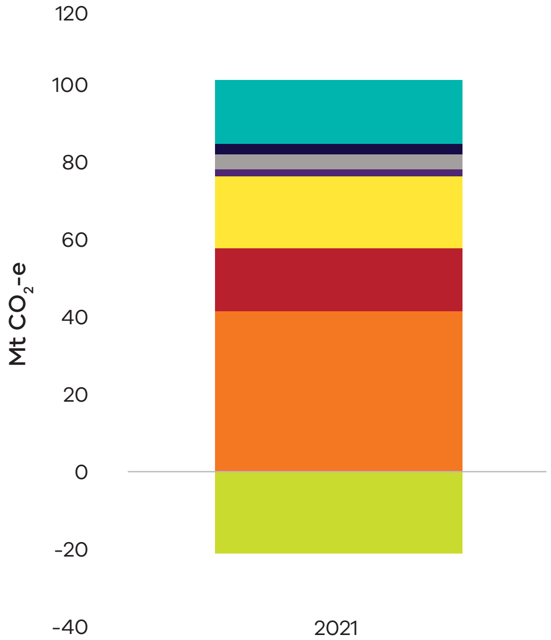


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

The electricity sector continues to be Victoria's largest source of emissions but also leads the state's emissions reduction efforts

The electricity sector was responsible for 51.8% of Victoria's total net emissions in 2021. Other sources of state emissions were transport (23.2%), agriculture (20.5%), fuel combustion[2] (20.4%), industrial processes and product use (IPPU) (4.9%), waste (3.4%) and fugitive emissions from fuels (2.2%) (Figure 3).

Figure 3: Victorian emissions by sector and energy subsector, 2021[3]



		Share	Mt CO_2-e
	Agriculture	20.5%	16.4
	Waste	3.4%	2.7
	Industrial processes and product use	4.9%	3.9
Energy	Fugitive emissions from fuels	2.2%	1.7
Energy	Transport	23.2%	18.6
Energy	Fuel combustion	20.4%	16.3
Energy	Electricity generation	51.8%	41.4
	LULUCF	-26.4%	-21.1
	Total	100%	80.1

Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)
Note: Numbers may not sum to 100% due to rounding.

[2] This sector has been renamed from direct combustion in previous reports to fuel combustion to be consistent with the naming convention used by the Commonwealth Government.

[3] Percentage contributions of each sector are calculated in terms of sectors' shares of total net emissions (that takes into account net removals (sequestration)by the LULUCF sector).

Between 2005 and 2021, the electricity generation sector was responsible for almost two thirds of the change (reduction) in Victoria's total net emissions. Electricity emissions fell 0.3 Mt CO_2-e between 2020 and 2021 due to growth in renewable electricity generation reducing demand for gas powered generation.

The transport sector continued to be impacted by reduced travel due to the COVID-19 pandemic

Transport remained the second largest contributor to Victoria's 2021 emissions, but transport emissions fell below 2005 levels for the first time (from 20.2 Mt CO_2-e in 2005 to 18.6 Mt CO_2-e in 2021). In 2021, transport emissions fell for the second year in a row, with these two years breaking a trend of emissions having steadily increased with population growth since 2005. The key driver of this change was COVID-19 pandemic-related changes to human movement. Reduced domestic aviation and road vehicle use meant emissions fell 2.2 Mt CO_2-e between 2020 and 2021.

The Victorian land sector's role in absorbing emissions continued to grow in 2021

Victoria's forests and natural systems, the Land Use, Land Use Change and Forestry (LULUCF) sector, absorbed over a quarter of Victoria's emissions in 2021. LULUCF emissions fell 1 Mt CO_2-e from 2020 levels to -21.1 Mt CO_2-e in 2021 as La Nina conditions contributed to good growing conditions that increased forest cover.

Emissions have declined for all sectors except industrial processes and product use since 2005

Emissions have declined in all sectors except IPPU since 2005 with the largest decline in the electricity sector, LULUCF sector and fuel combustion sectors. IPPU sector emissions increased between 2005 and 2021 (by 1.1 Mt CO_2-e), driven mainly by the growth in the stock of air conditioning and refrigeration systems.

Introduction

Section 52 of the *Climate Change Act 2017* (the Act) requires the Minister administering the Act to prepare annual greenhouse gas emissions reports for Victoria. The Act requires that the reports include an overview and collation of the best practicably available information about Victoria's greenhouse gas emissions; and the extent to which emissions have been reduced compared with 2005 levels (the reference year for interim emissions reduction targets under the Act).

The *Victorian Greenhouse Gas Emissions Report 2021* presents information on Victoria's emissions in two forms:

i. presentation of emissions data in accordance with sectors defined by the Intergovernmental Panel on Climate Change (IPCC) reporting framework for national greenhouse gas inventories, with disaggregation of data in the energy sector; and

ii. presentation of emissions data by sectors of the economy categorised according to the Australian and New Zealand Standard Industrial Classification (ANZSIC).

Data for the report are sourced from *State and Territory Greenhouse Gas Inventories* (DCCEEW, 2023e) released in June 2023 by the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW)[4]; and the *Australian Greenhouse Emissions Information System* online database. Both sources provide data at a state and territory level over the period 1990 to 2021. These are the most recent official data on annual greenhouse gas emissions.

The data relate to production-based rather than consumption-based emissions in Victoria, that is these account for emissions from goods and services produced in Victoria. This is in accordance with the United Nations Framework Convention on Climate Change's (UNFCCC) emissions accounting provisions.

Economic and population statistics for Victoria have been used to calculate emissions intensity measures and obtain insights into trends in the state's emissions.

Unless otherwise specified, data in this report follows DCCEEW's convention of being based on financial years[5]. Numbers may also not sum precisely to the totals due to rounding.

Updated historical data

DCCEEW reviews, and, where necessary, revises greenhouse gas data annually to ensure the data are produced in a manner consistent with international methodologies; and to reflect improved estimation methods and new sources of information as they become available.

This review process has resulted in updated historical emissions data for Victoria for 1990 to 2020. Consequently, data over this period in this year's report differ from that presented in the *Victorian Greenhouse Gas Emissions Report 2020*.

This is discussed further in Chapter 2 and Appendix A.

Victoria's emissions reduction targets

The Victorian Government has committed to reach net zero emissions by 2045 – five years earlier than previous planned. The *Climate Change Act 2017* requires the Government to set 5-yearly interim targets to establish the pathway to net zero.

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[4] DCCEEW prepares National Greenhouse Accounts that include a series of annual publications to meet Australia's international obligations under the UNFCCC. These include State and Territory Greenhouse Gas Inventories and the *National Inventory Report 2021* (DCCEEW, 2023d). UNFCCC reporting rules and guidelines are those adopted under decision 24/CP.19 – known as the Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention; and the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

[5] Financial years to June 30 – for example, the year 2012 refers to the Australian financial year from 1 July 2011 to 30 June 2012.

To date the government has set interim emissions reduction targets for:

- 2020 of 15 – 20% below 2005 levels
- 2025 of 28 – 33% below 2005 levels
- 2030 of 45 – 50% below 2005 levels
- 2035 of 75 – 80% below 2005 levels

The government will set the 2040 target in 2028.

This report is structured as follows:

Chapter 1: Presents the trend in Victoria's emissions from 1990 to 2021; its contribution to national emissions and emissions per capita and per unit of Gross State Product (GSP).

Chapter 2: Presents Victoria's emissions by sector based on IPCC sector categories. It describes historical trends in emissions in each sector and the key drivers of those trends.

Chapter 3: Presents Victoria's emissions by economic sector based on ANZSIC sector categories.

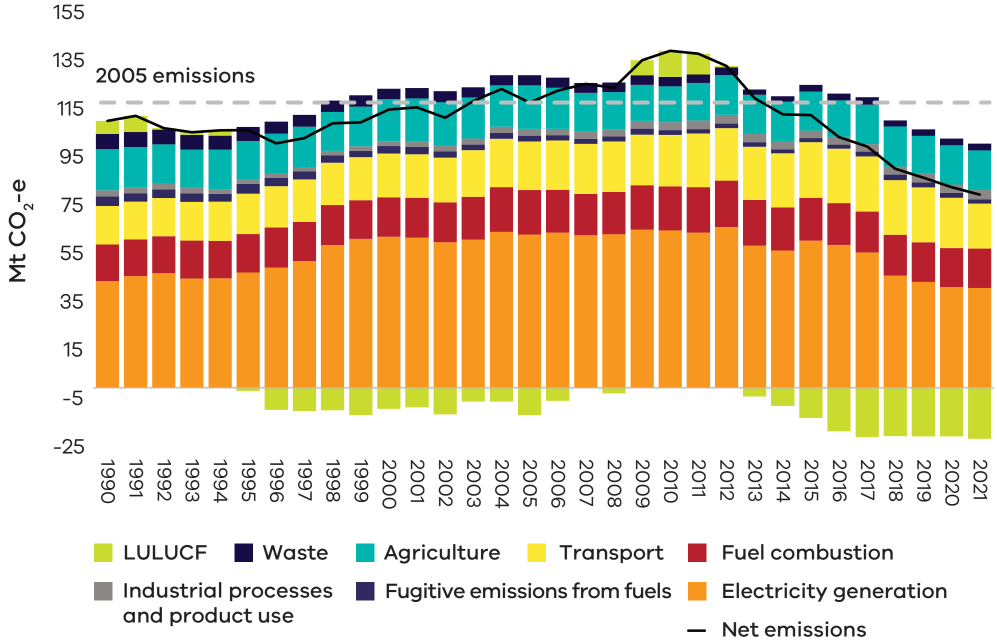
1 Victorian emissions and indicators – 1990 to 2021

1.1 Emissions 1990 to 2021

Victoria's total net emissions fluctuated from 1990 and 2000, before increasing to a peak in 2010 then falling over the period to 2021 (Figure 4). In 2021, total net greenhouse gas emissions were 80.1 Mt CO_2-e, or 27.6% below 1990 levels.

Chapter 2 discusses the trends in sectoral emissions and key factors driving these trends.

Figure 4: Total net emissions and emissions by sector – Victoria, 1990 to 2021

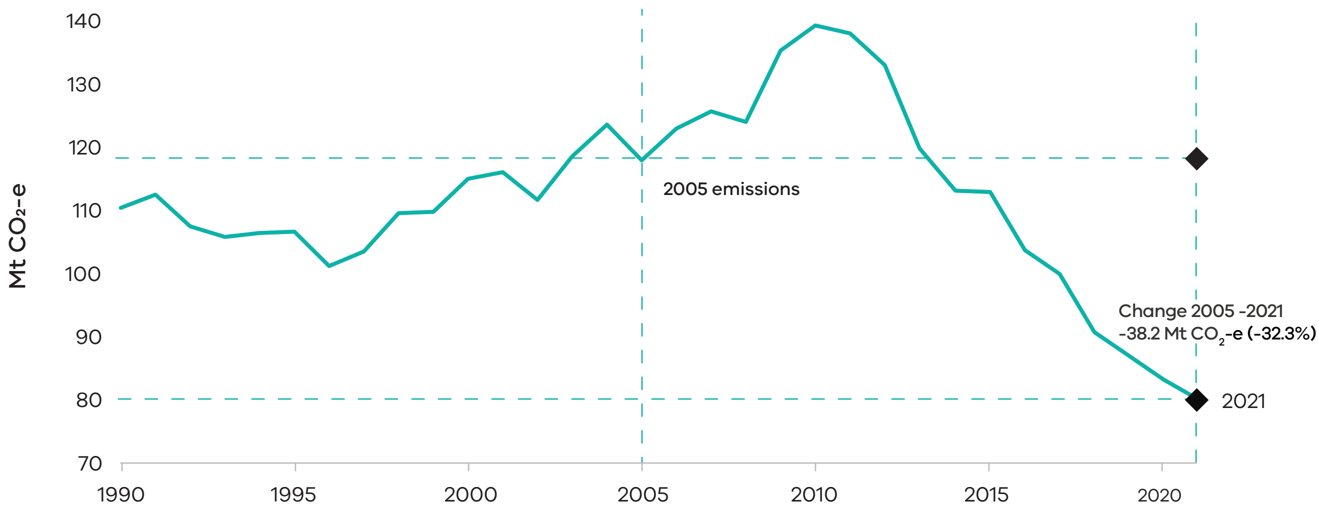


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

1.2 Change in emissions – 2005 to 2021

Victoria's greenhouse gas emissions reduction targets use 2005 as the baseline year as stipulated by the Act. In 2021, Victoria's total net emissions of 80.1 Mt CO_2-e were 38.2 Mt CO_2-e (32.3%) below the baseline level of 118.2 Mt CO_2-e in 2005 (Figure 5). The 32.3% reduction is within the 2025 target range of 28 – 33% below 2005 levels.

Figure 5: Trend in net emissions – Victoria, 1990 to 2021 – highlighting change between 2005 and 2021

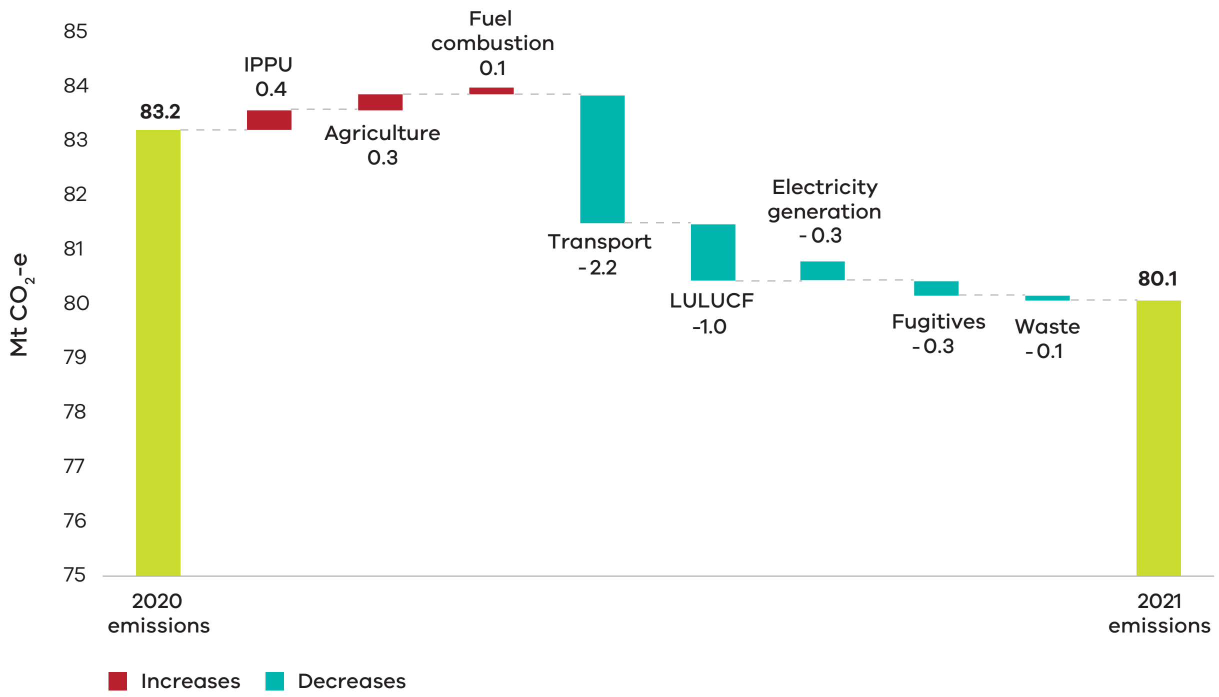


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e).

1.3 Change in emissions – 2020 to 2021

Between 2020 and 2021, Victoria's emissions declined by 3.8%. This was mainly driven by falling emissions in transport (2.2 Mt CO_2-e), increased removals from the LULUCF sector (1.0 Mt CO_2-e) and falling emissions from electricity generation (0.3 Mt CO_2-e), fugitive emissions from fuels (0.3 Mt CO_2-e), and waste (0.1 Mt CO_2-e) (Figure 6). The main drivers behind these reductions were pandemic-related reductions in passenger vehicle use and domestic aviation, increasing forest cover as La Nina contributed to good growing conditions and growth in renewable electricity generation reducing demand for gas powered generation.

Figure 6: Change in emissions by sector - Victoria, 2020 to 2021



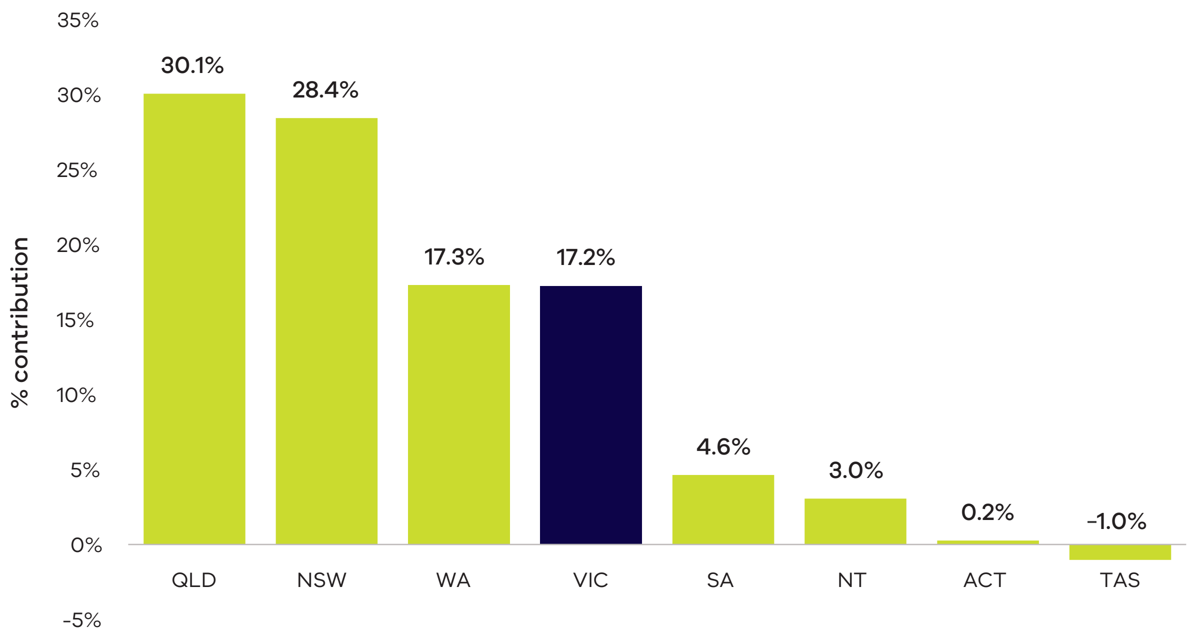
Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e).

1.4 Victoria's contribution to national emissions

In 2021, Victoria was the fourth largest contributor to Australia's total net emissions (17.2%) behind Queensland (30.1%), New South Wales (28.4%) and Western Australia (17.3%) (Figure 7). Between 2020 and 2021, Victoria moved from being the third to the fourth largest contributor to national emissions, as Western Australia's net emissions surpassed Victoria's share by 0.1%.

In 2021, Victoria's share of Australia's total net emissions increased from 16.7% in 2020, the lowest level on record, to 17.2% in 2021. Victoria's share of national emission remains significantly lower than the peak of 23.3% in 2011 (Figure 8).

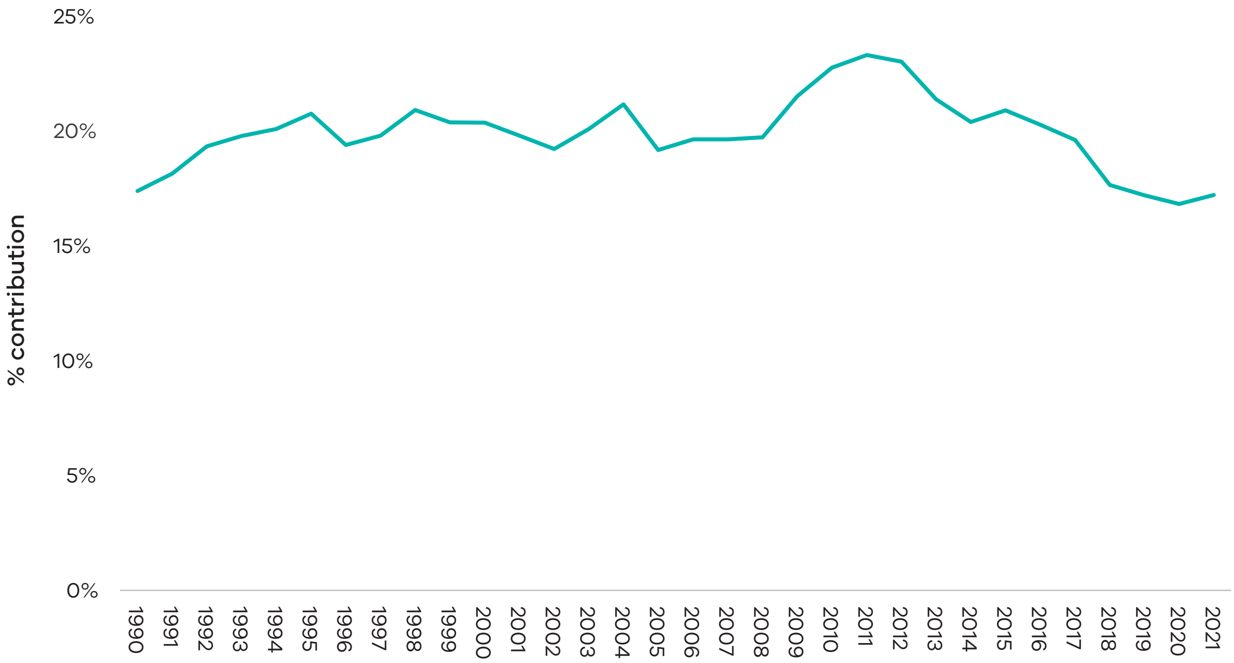
Figure 7: Contribution to national emissions by state and territory, 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Note: Tasmania's share of -1.0% reflects the fact that net removals in the LULUCF sector in that state exceeded emissions in other sectors resulting in Tasmania recording negative total net emissions in 2021

Figure 8: Contribution to national emissions – Victoria, 1990 to 2021

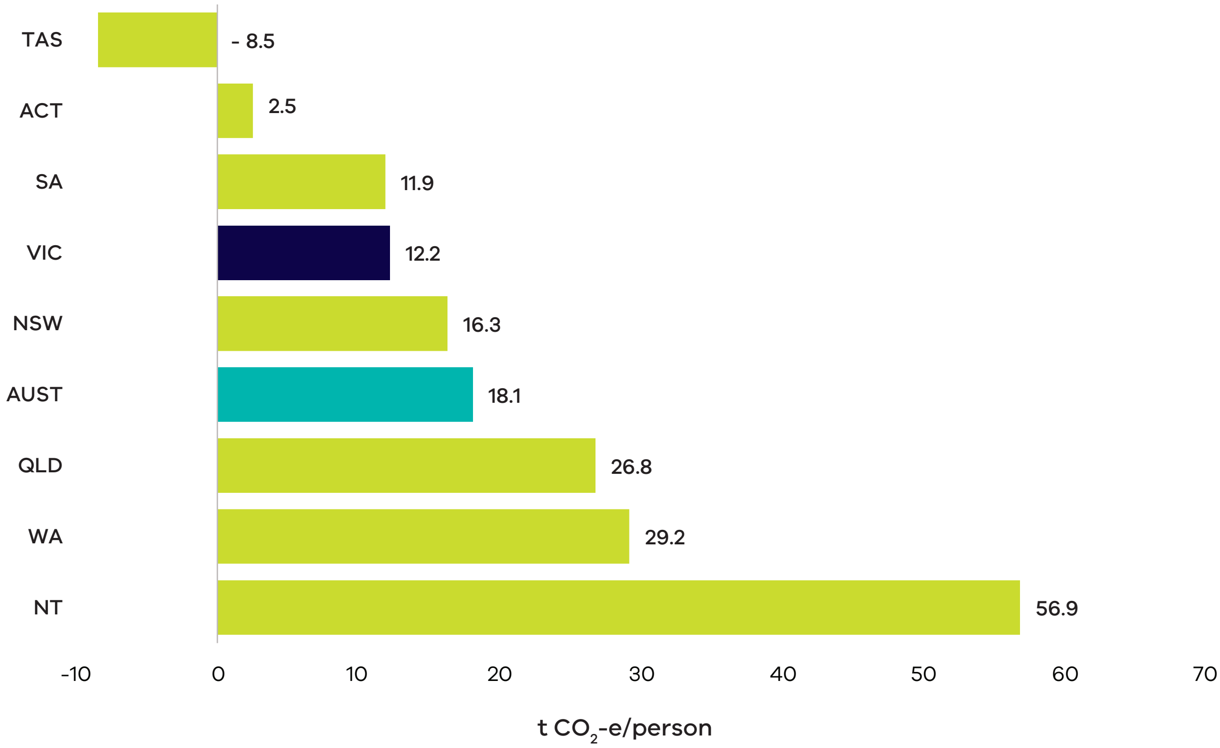


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

1.5 Per capita emissions

Victoria's per capita emissions – a measure of the state's total net emissions divided by its population – were 12.2 tonnes (t) CO_2-e/person in 2021. This was less than the national average (18.1 t CO_2-e) and lower than all states and territories other than Tasmania, the Australian Capital Territory (ACT) and South Australia (SA) (Figure 9).

Figure 9: Per capita emissions in Australia by state and territory, 2021

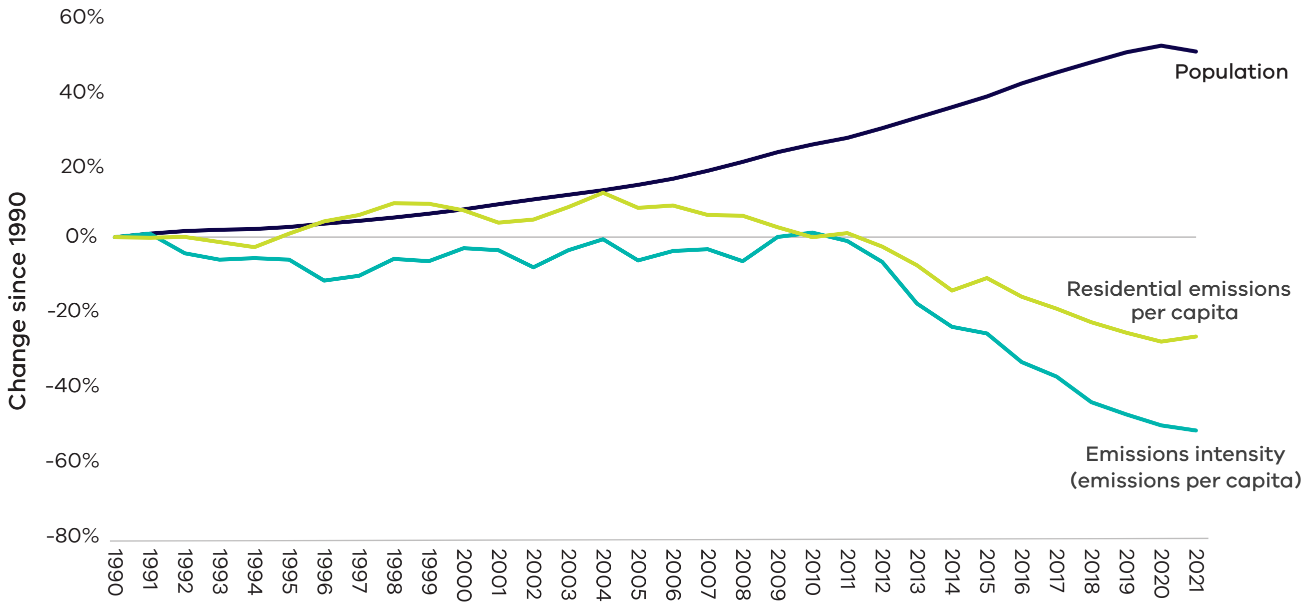


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Australian Demographic Statistics 2022 (ABS, 2023)

Note: Tasmania's value of -8.5 t CO_2-e per capita reflects the fact that net removals in the LULUCF sector exceeded emissions in other sectors, resulting in Tasmania recording negative total net emissions in 2021.

Victoria's per capita emissions have declined steadily since 2010 (Figure 10, green line), and are now less than half the level in 1990. Per capita emissions from household-related activities[6] have also decreased since peaking in 1998, and by 2021 had fallen 26.6% below 1990 levels (Figure 10, yellow line).

Figure 10: Changes in per capita emissions, residential per capita emissions and population growth – Victoria, 1990 to 2021

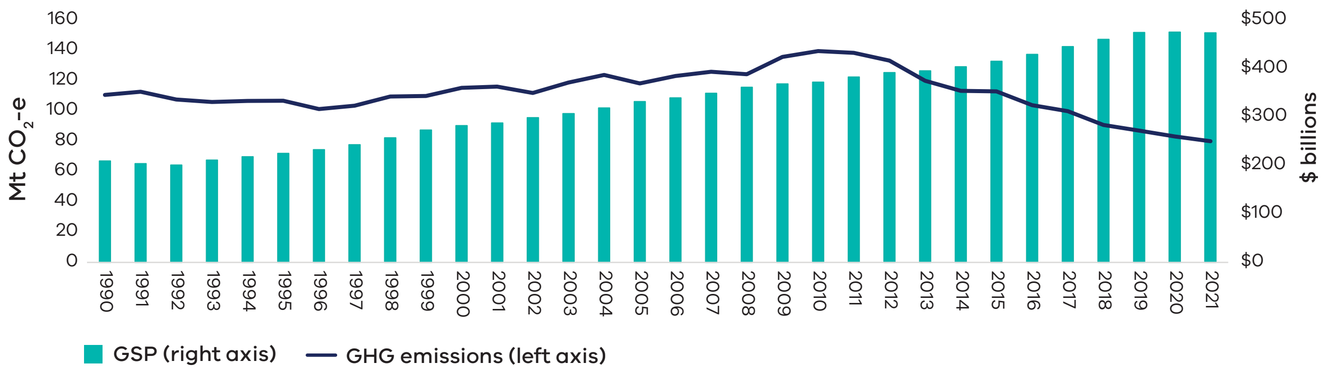


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Australian Demographic Statistics 2022 (ABS, 2023)

1.6 Emissions and Gross State Product

Between 1990 and 2021, real Gross State Product (GSP) increased by 126% while emissions fell by 27.6% (Figure 11). This means the emissions intensity of the Victorian economy – measured as total net emissions divided by GSP – declined by 68%, from 0.53 to 0.17 kg CO_2-e per $GSP (Figure 12).

Figure 11: Greenhouse gas emissions and real GSP – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Australian National Accounts: State Accounts 2021-22 (ABS, 2022)

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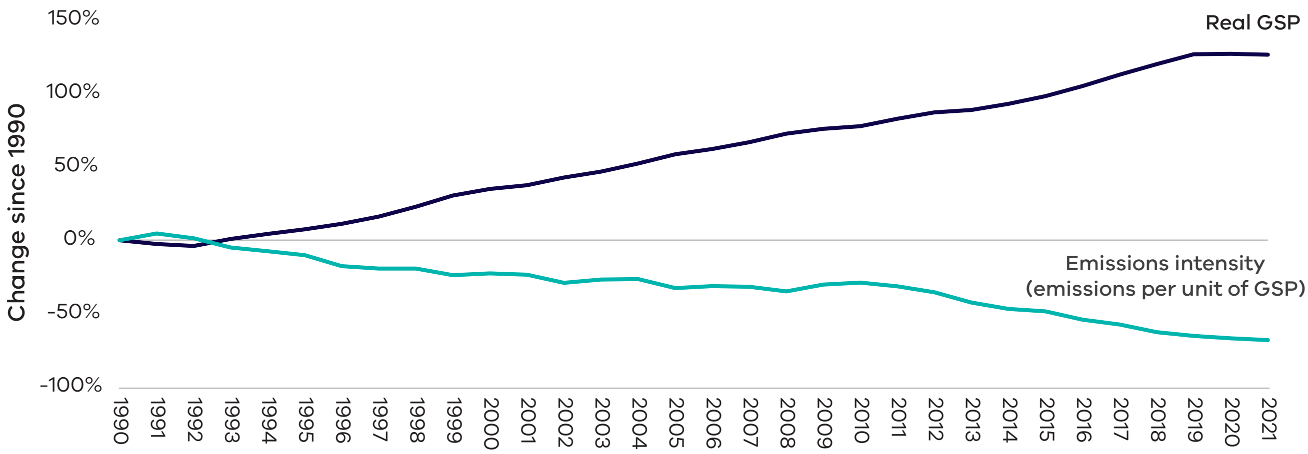
6 Residential sector per capita emissions are residential sector emissions divided by population. Residential sector emissions are emissions arising from activities in households involving the consumption of electricity, the consumption of gas for heating and/or cooking, transport activities, the use of refrigeration and air conditioning units and the use of waste and wastewater services. To allocate emissions associated with residential sector use of transport fuels and refrigerants, DCCEEW has used either information from the National Greenhouse and Energy Reporting (NGER) scheme, or economic modelling utilising the most recent version of the Supply-Use Tables, their corresponding Input-Output Tables for product details and the Energy Account published by the Australian Bureau of Statistics (ABS).

Figure 12: Change in real GSP and emissions intensity (emissions per unit of GSP) – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Australian National Accounts: State Accounts, 2021-22 (ABS, 2022).

1.7 Emissions by greenhouse gas type

Carbon dioxide (CO_2) was the largest contributor to Victoria's greenhouse gas emissions in 2021 at 56.1 Mt CO_2-e (70%), followed by methane (CH_4) at 17.1 Mt CO_2-e (21.3%), nitrous oxide (N_2O) at 3.9 Mt CO_2-e (4.9%) and hydrofluorocarbons (HFCs) at 2.9 Mt CO_2-e (3.6%). Other gases included perfluorocarbons (PFCs) at 0.1 Mt CO_2-e (0.12%) and sulphur hexafluorides (SF_6) at 0.04 Mt CO_2-e (0.05%) (Figure 13).

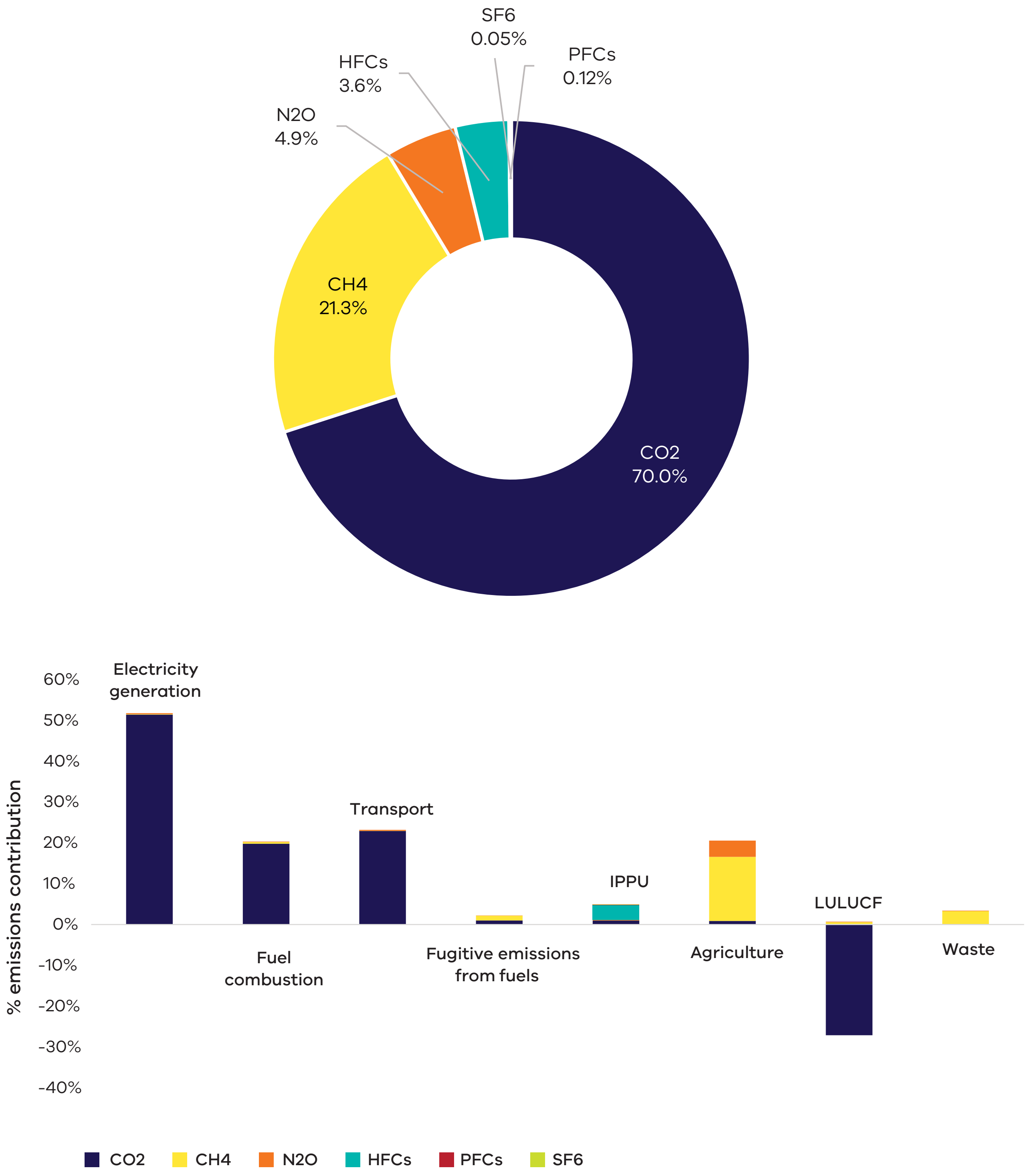
The largest source of CO_2 emissions was use of fossil fuels in electricity generation, transport and the fuel combustion. LULUCF continued to be a CO_2 emissions sink (due to removals from the sector).

Agriculture was the main source of CH_4 emissions, predominantly from livestock digestive processes. There were also smaller contributions of CH_4 emissions from the waste (mainly from solid waste disposal) and fugitive emissions (mainly from the distribution of fossil gas) sectors.

Agriculture was also the main source of N_2O emissions, which arise from agricultural soils due to microbial and chemical transformations associated with nitrogen fertiliser application.

HFCs, PFCs and SF_6 emissions arise from the industrial processes and product use (IPPU) sector, including, for example, leakage of HFCs from air conditioning and refrigeration units, PFC emissions from aluminium smelting and SF_6 emissions from electricity supply and distribution networks.

Figure 13: Victoria's greenhouse gas emissions by gas type and sector, 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

2 Emissions by sector (IPCC categories)

This chapter presents information on Victoria's greenhouse gas emissions by sector, the activities that drive these emissions and the key factors influencing emissions trends. Sectors are based on the five categories identified in the Intergovernmental Panel on Climate Change's International Guidelines (IPCC, 2006), namely:

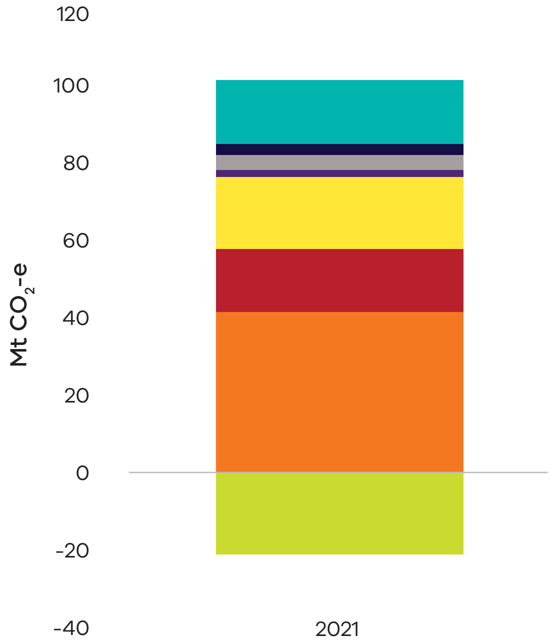
- Energy
- Industrial processes and product use (IPPU)
- Agriculture
- Land use, land use change and forestry (LULUCF)
- Waste.

The energy sector is disaggregated into four subsectors: electricity generation, fuel combustion from stationary sources, transport and fugitive emissions from fuels.

This report relies on the *National Inventory Report 2021* (DCCEEW, 2023d) as the primary source of information on activities that drive sectoral emissions. It also draws on Commonwealth Government statistics for Victoria, academic and Victorian Government publications and consultation with experts to obtain additional insights into the factors that influenced sectoral emissions trends over the period 1990 to 2021.

Figure 14 presents the share of Victoria's net emissions in 2021 by sector and energy subsectors. The energy sector remains the largest contributor to Victoria's emissions, with 51.8% of state-wide net emissions coming from the electricity subsector (41.4 Mt CO_2-e). The next largest subsectors are transport, agriculture and fuel combustion, contributing roughly one fifth of Victoria's net emissions each in 2021.

Figure 14: Victorian emissions by sector and energy subsectors, 2021[7]

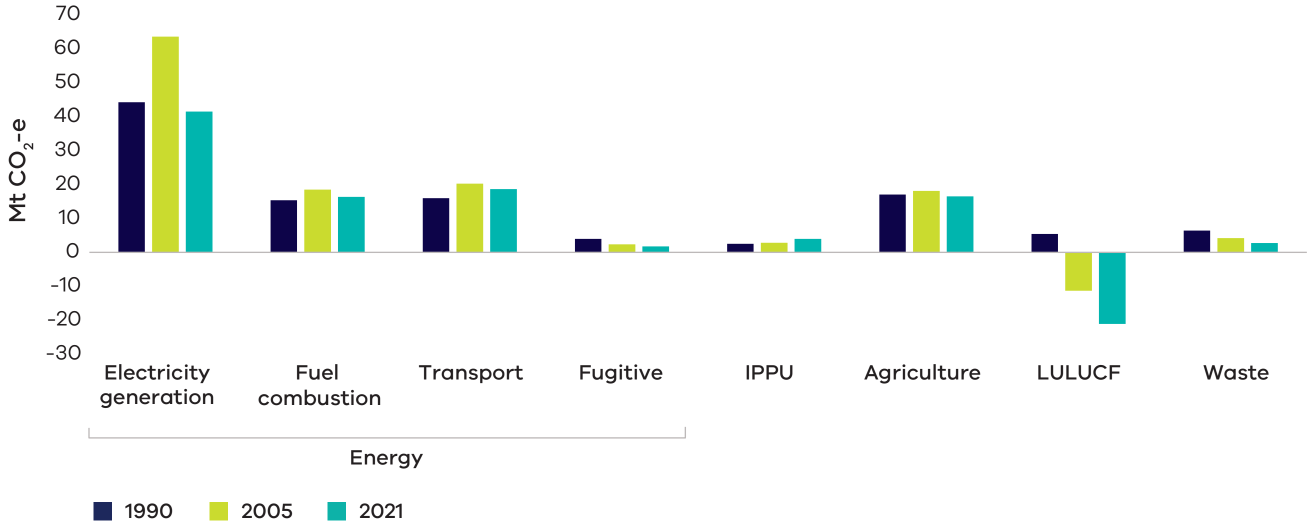


		Share	Mt CO_2-e
	Agriculture	20.5%	16.4
	Waste	3.4%	2.7
	Industrial processes and product use	4.9%	3.9
Energy	Fugitive emissions from fuels	2.2%	1.7
Energy	Transport	23.2%	18.6
Energy	Fuel combustion	20.4%	16.3
Energy	Electricity generation	51.8%	41.4
	LULUCF	-26.4%	-21.1
	Total	100%	80.1

Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)
Note: Numbers may not sum to 100% due to rounding.

[7] Percentage contributions of each sector are presented as a share of total net emissions (i.e. they take into account removals (sequestration) in the LULUCF sector).

Figure 15: Emissions by sector and energy subsectors – 1990, 2005 and 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Figure 15 presents emissions by sector in 1990, 2005 and 2021. Key points to note include:

- emissions from electricity generation, fuel combustion, transport and agriculture increased between 1990 and 2005, but declined between 2005 and 2021;
- emissions from IPPU increased between 1990 and 2005 and continued to increase to 2021;
- LULUCF was a net source of emissions in 1990 but sequestered more emissions than it generated in both 2005 and 2021 (i.e. the sector provided net removals in both years); and
- emissions from waste and fugitive emissions from fuels declined between 1990 and 2005 and continued to do so to 2021.

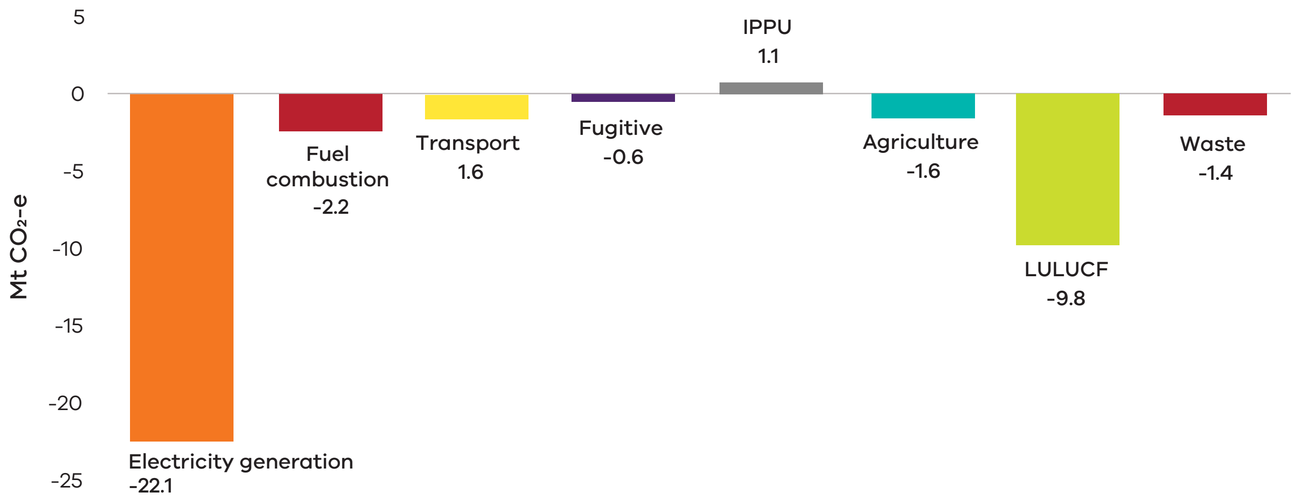
Table 1 and Figure 16 provide further details on the scale of changes in sectoral emissions between 2005 and 2021. The electricity generation subsector experienced the largest absolute reduction in net emissions, followed by LULUCF, fuel combustion, agriculture, transport, waste and fugitive emissions from fuels.

Table 1: Change in emissions by sector and energy subsector between 2005 and 2021, Victoria

Sector	2005 Mt CO_2-e	2021 Mt CO_2-e	Change 2005 to 2021 Mt CO_2-e
Electricity generation	63.5	41.4	-22.1↓
Fuel combustion	18.5	16.3	-2.2 ↓
Transport	20.2	18.6	-1.6 ↓
Fugitive emissions	2.4	1.7	-0.6 ↓
IPPU	2.8	3.9	1.1 ↑
Agriculture	18.1	16.4	-1.6 ↓
LULUCF	-11.3	-21.1	-9.8 ↓
Waste	4.2	2.7	-1.4 ↓
Total (net emissions)	**118.2**	**80.1**	**-38.2 ↓**

Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e).
Note: Numbers may not sum due to rounding.

Figure 16: Change in emissions between 2005 and 2021 by sector and energy subsector, Victoria

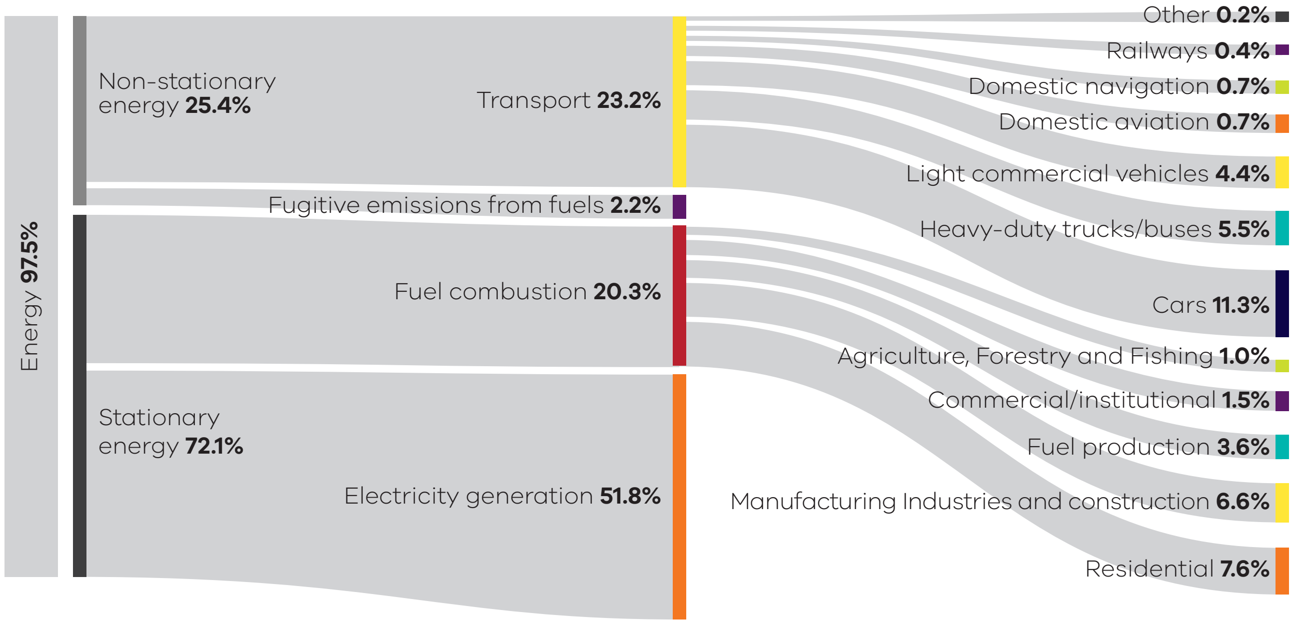


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

2.1 Energy

The energy sector comprises the following subsectors: electricity generation, fuel combustion, transport and fugitive emissions from fuels. Figure 17 shows the contribution of each subsector to Victoria's total net emissions in 2021 – collectively, the energy sector was responsible for 97.5%[8] of Victoria's total net emissions in that year.

Figure 17: Energy subsectors and their contributions to total net emissions in Victoria, 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)
Note: Numbers may not sum to 100% due to rounding.

[8] In this report, shares of emissions from each sector are compared with Victoria's total net emissions, which includes negative emissions from removals in the LULUCF sector. Using this approach, the shares of emissions from non-LULUCF sectors add up to more than 100%. When removals from the LULUCF sector are excluded, energy emissions were 77% of total emissions from Victoria's non-LULUCF sectors in 2021.

2.1.1 Electricity generation

Sources of emissions

Emissions from electricity generation arise from the combustion of fuels to generate power supplied to the electricity grid.

International emissions accounting requires that emissions data are recorded for production rather than consumption of good and services, including electricity. In accordance with these accounting requirements, the electricity emissions subsector includes all emissions released from electricity generated in Victoria (some of which is exported for consumption in other states). Emissions associated with electricity imported by Victoria from other states or territories are not included as part of Victoria's net emissions but are included in the emissions inventories of the jurisdictions in which the electricity is generated.

Electricity generation in Victoria

In 2021, emissions from fossil fuel-fired electricity generation accounted for approximately half (51.8%) of Victoria's total net emissions. The great majority of these electricity emissions were from Victoria's brown coal-fired power stations, with the remaining emissions largely from gas-powered electricity generation and a small amount from other fossil fuels.

Three brown coal-fired power stations were operating in 2021, all located in the Latrobe Valley: Yallourn, Loy Yang A and Loy Yang B. Approximately 66% (34,000 GWh) of the state's electricity was generated by these power stations, producing 39.9 Mt CO_2-e or 50% of Victoria's total net emissions in 2021 (CER, 2022). The brown coal generation share of 66% in 2021 was a fall in share from around 69% (33,700 GWh) in 2020. While absolute brown coal-fired generation and emissions increased slightly from 2020 to 2021, this was outweighed by a fall in gas powered electricity generation.

Large and medium gas-fired power stations were responsible for emitting 0.8 Mt CO_2-e or 1.0% of Victoria's total net emissions in 2021 (CER, 2022). There was a decrease in the overall share of electricity generation from gas from 6.4% in 2020 to 3.8% in 2021 (DCCEEW, 2023e). This decrease largely reflected strong growth in the output of renewable generation, which displaced higher cost gas generation in Victoria's electricity mix in 2021, as well as milder weather over summer 2020/21 than the previous summer.

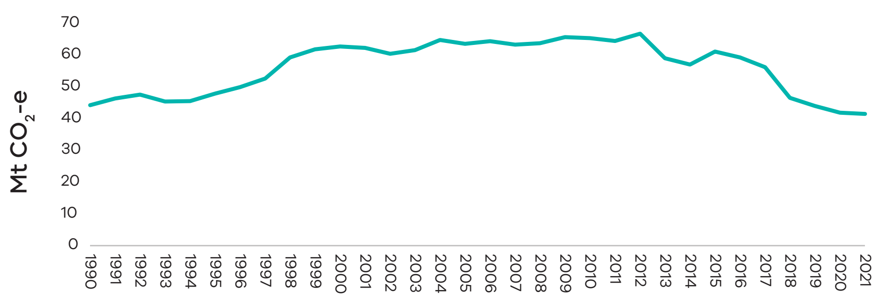
Renewable electricity generation produced no emissions and generated around 30% of Victoria's electricity in 2021 (DCCEEW, 2023e). This was around a quarter higher than the share of 24.3% in 2020, reflecting increased wind and solar generation, including from rooftop solar systems, as well as a higher output from Victoria's hydroelectricity generators in 2021.

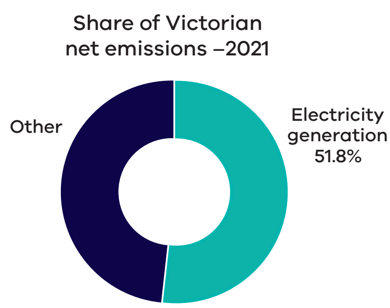
Emissions trends and drivers

Figure 18 shows the trend in emissions from electricity generation since 1990.

Emissions from electricity generation increased from 1990 to a peak in 2012. Emissions then fell significantly through to 2021, excepting a brief increase in 2015.

Figure 18: Emissions from electricity generation – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)

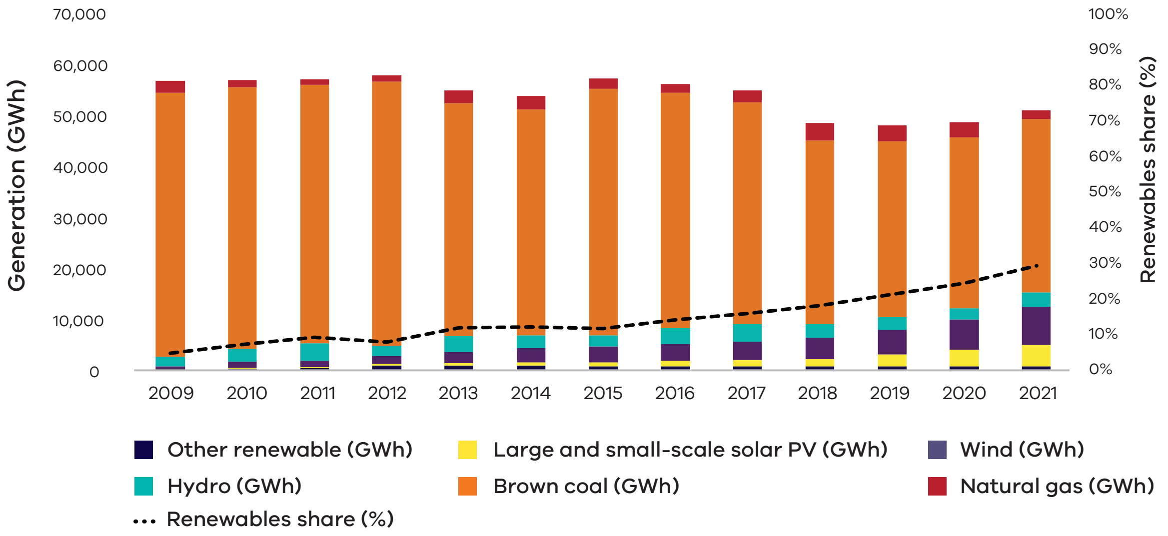




Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Underlying the decline in emissions is a transformation of the state's electricity system. A large factor in the decline is the reduction of coal-fired electricity generation, mostly related to the closure of Hazelwood Power Station in March 2017. There have also been continued improvements in energy efficiency, through programs such as Victorian Energy Upgrades (VEU) Program, and renewable energy installation and use increased both absolutely and as a share of Victoria's total generation. Renewable electricity generation's share increased from around 12% in financial year 2014 to 29% in 2021 (Figure 19) (DEECA, 2023b), underpinned by Victoria's Renewable Energy Targets of 40% by 2025, 65% by 2030 and 95% by 2035.

Figure 19: Victoria's changing electricity system – renewable energy is accelerating



Source: Department of Energy, Environment and Climate Action internal analysis based on NEOpoint (DEECA 2023b)

2.1.2 Fuel combustion

Sources of emissions

Fuel combustion emissions arise from burning fuels for activities such as the production of fuels (for example oil and fossil gas extraction, oil refining and coal mining); generating heat, steam or pressure for manufacturing operations; and burning fossil gas for heating, hot water and cooking in households and businesses.

Fuel combustion does not include emissions from fuel combustion for electricity generation or transport – emissions from these activities are accounted for in the electricity generation and transport subsectors respectively.

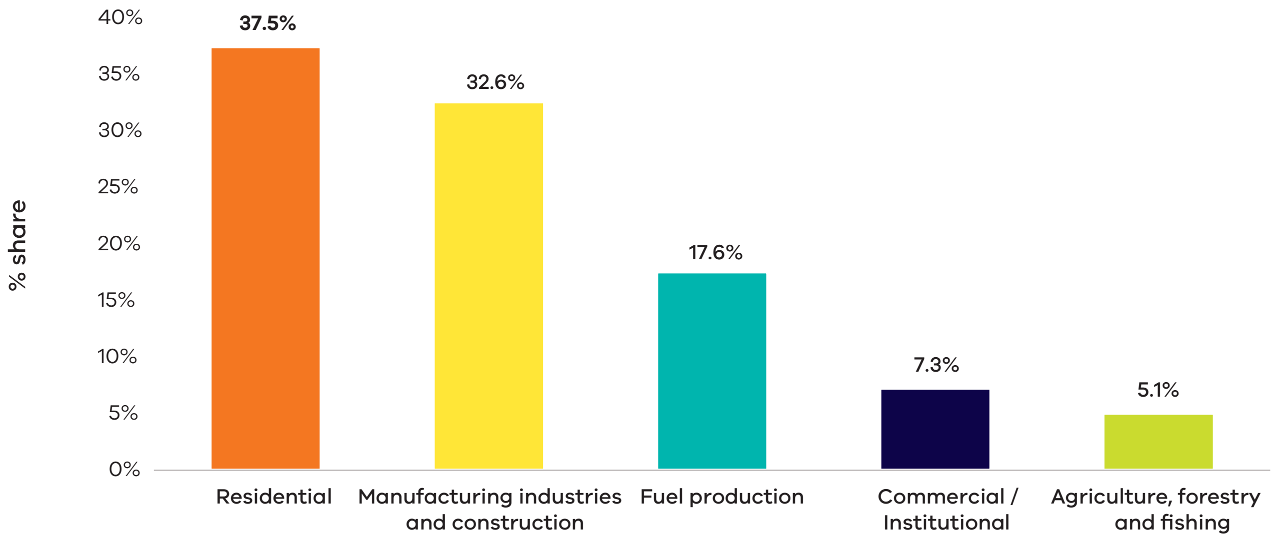
Fuel combustion in Victoria

Residential activities are the largest source of emissions from fuel combustion in Victoria, followed by manufacturing industries and construction and fuel production (Figure 20).

Fossil gas is the major fuel used for fuel combustion in Victoria, representing 57% of the total fuels used in 2021. In that year, Victoria consumed a total of 212 petajoules (PJ) of fossil gas in fuel combustion activities, with the highest consumption in the residential (50%), manufacturing (27%) and commercial (9%) activity sub-categories (DCCEEW, 2022b).

Other fuels contributing to fuel combustion include onsite use of diesel, liquified petroleum gas (LPG) and various petroleum-based oils.

Figure 20: Fuel combustion emissions by activity sub-categories – Victoria, 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

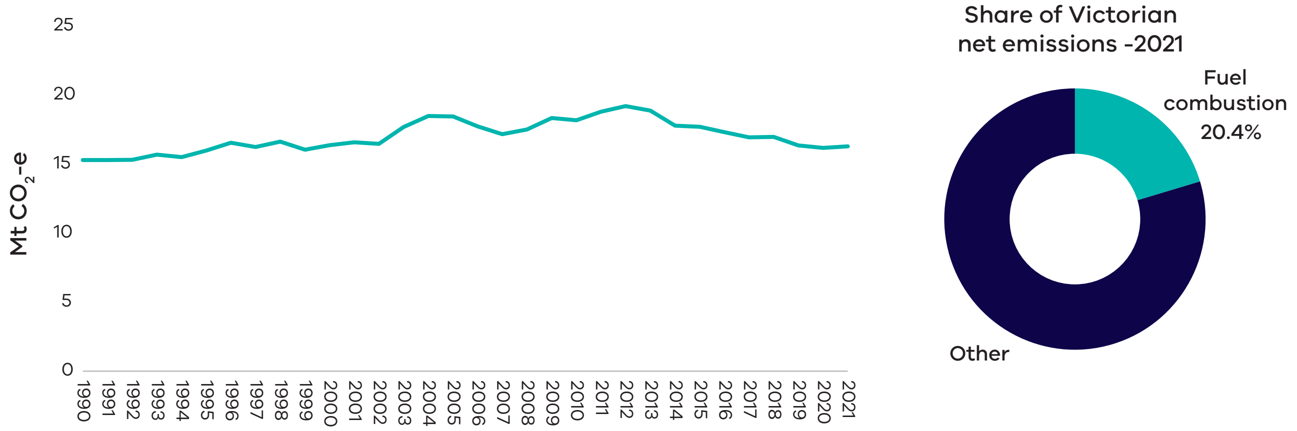
Emissions trends and drivers

Fuel combustion accounted for 20.4% of Victoria's total net emissions in 2021 – the fourth largest share of total net emissions behind electricity generation, transport and agriculture.

Fuel combustion emissions were 15.3 Mt CO_2-e in 1990 – reaching their peak at 19.2 Mt CO_2-e in 2012 – before declining slightly to 16.3 Mt CO_2-e in 2021 (Figure 21). Population growth and increased economic activity in Victoria contributed to higher fuel combustion emissions in 2021 than 1990 (with emissions predominately from the residential and manufacturing and construction sectors). However, in the last decade, emissions growth has flattened, most likely caused by a reduction in industrial fossil gas use, as well as ongoing improvements in appliance efficiency and building performance.

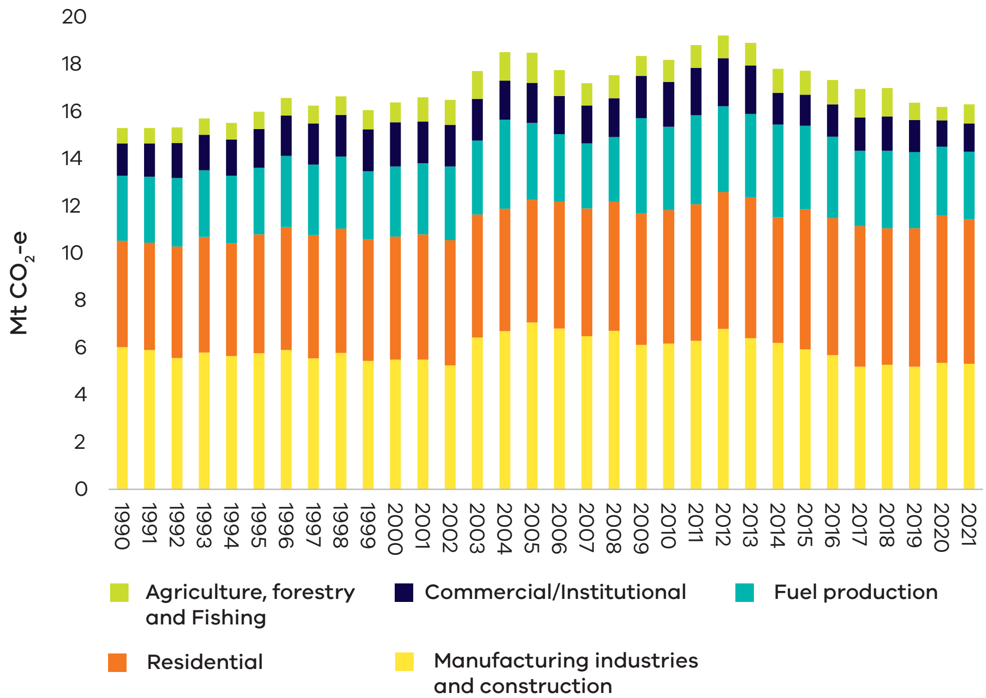
Interannual variability in emissions over the 31-year period is associated with differences in the rate of economic growth and seasonal variations driving residential heating demand (i.e. colder versus milder winters).

Figure 21: Emissions from fuel combustion – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Figure 22: Emissions by fuel combustion sub-categories – Victoria, 1990 to 2021



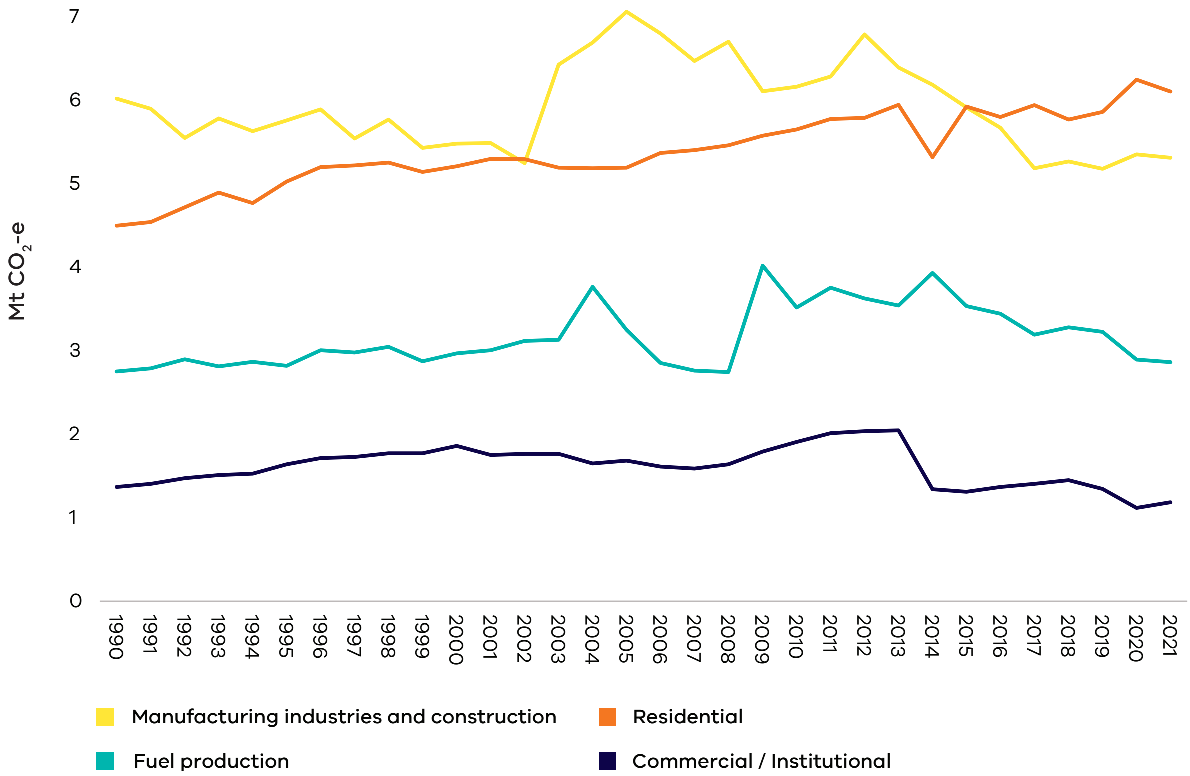
Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

The residential sector was the largest contributor to fuel combustion emissions in 2021 at nearly 37.5% – up from 29.4% in 1990 (Figure 22).

In 1990 manufacturing and construction contributed the largest share of fuel combustion emissions at 39.4% (6.0 Mt CO_2-e). The manufacturing and construction sector's share has been gradually declining and was overtaken by the residential sector as the largest source of fuel combustion emissions in 2015 (Figure 23).

Fuel combustion emissions from manufacturing and construction generally declined between 1990 and 2002, with a sharp increase in 2003 due to growth in the output of metal and mineral production and food processing. Following a peak in 2005, and a temporary spike in 2012, emissions from this sub-category reduced in line with the overall decline in heavy manufacturing activity in the state (Figure 23).

Figure 23: Trends in emissions in the four major fuel combustion sub-categories – Victoria, 1990 to 2021



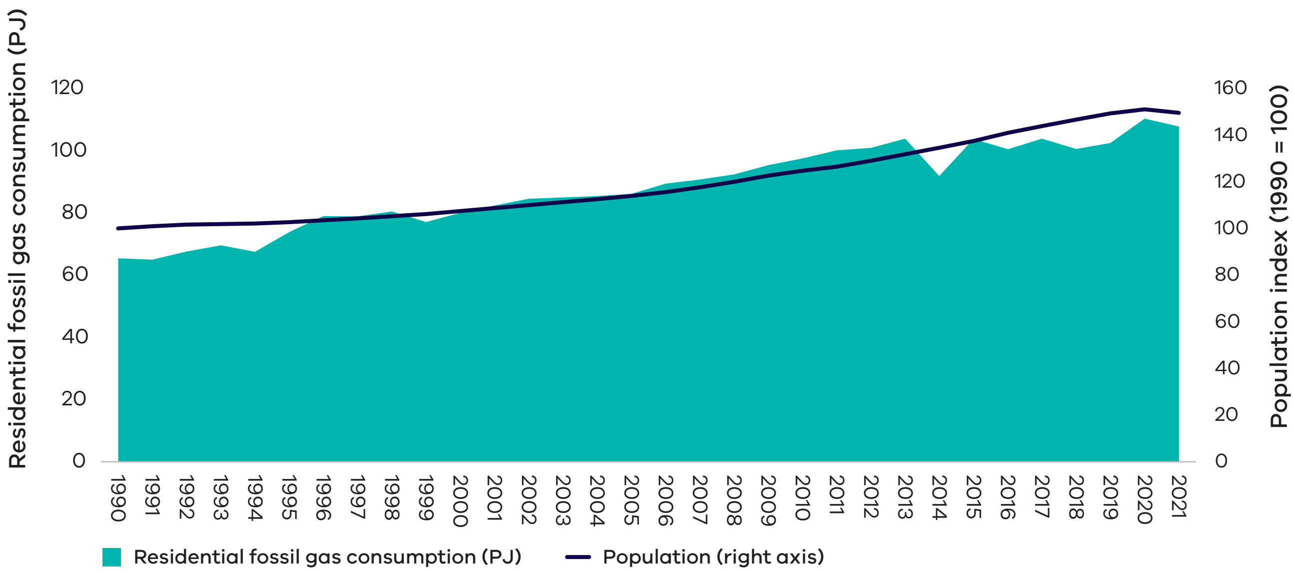
Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Fuel combustion emissions from fuel production were at similar levels in 1990 (2.8 Mt CO_2-e) and 2021 (2.9 Mt CO_2-e) with variation in between, including a peak of 4.0 Mt CO_2-e in 2009 (Figure 23). Between 2019 and 2020, emissions decreased by 10% (0.33 Mt CO_2-e), and continued at 2020 levels through 2021, as transport fuel demand declined following pandemic-related reductions in transport activity.

From 1990 to 2013, a gradual shift towards a services-based economy increased commercial sector fuel combustion emissions by almost 50%. The Australian Energy Statistics accounting revisions [9] contributed the step change in emissions in 2014. Since 2018, a declining trend is observed in the sector due to reduction in diesel consumption.

Residential sector emissions have mostly grown since 1990 (Figure 23) in line with population and the associated fossil gas demand for water and space heating (Figure 24). The residential sub-category surpassed manufacturing as the major user of fossil gas in Victoria in 2006 (DCCEEW, 2022b).

Figure 24: Trends in residential fossil gas consumption and population – Victoria, 1990 to 2021



Source: Australian Energy Statistics, Table F (DCCEEW, 2022b) and Australian Demographic Statistics 2022 (ABS, 2023)

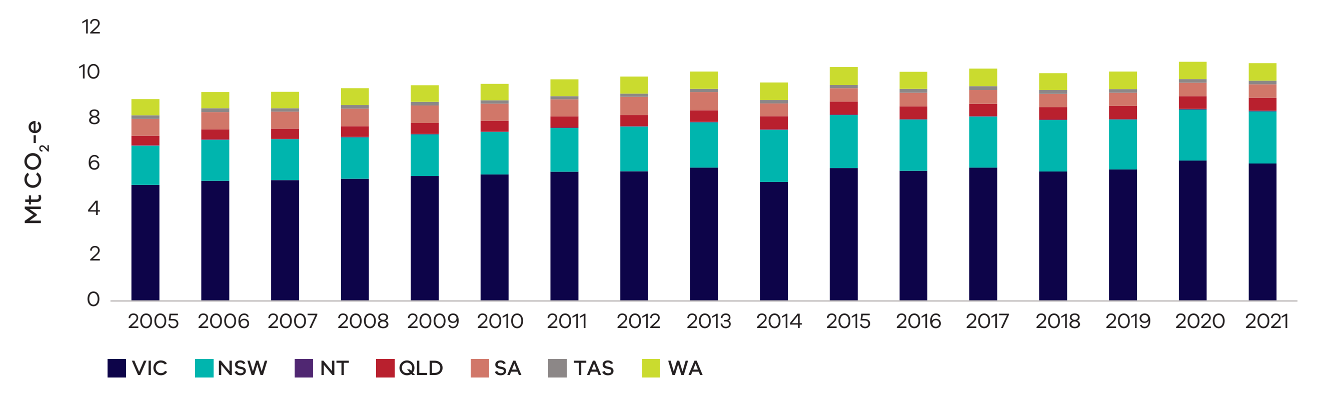
[9] Accounting revisions to the 2022 Australian Energy Statistics energy data have flowed through to the 2021 State and Territory Greenhouse Gas Inventories (STGGI). For the commercial/institutional and residential sub-categories, the accounting revisions resulted in step-change drops in emissions from approximately 2014 onwards.

Box 1: The role of fossil gas in residential fuel combustion emissions

Residential fuel combustion in Victoria

Residential fuel combustion emissions are caused by households burning fuels to cook, heat their homes, and heat water. Over 90% of residential fuel combustion emissions come from burning fossil gas, with the remainder from burning wood or LPG. Victoria's residential fuel combustion emissions in 2021 exceeded those of every other state and territory in Australia combined and have done so since 2005 (Figure 25).

Figure 25: Residential fuel combustion emissions of Australian states and territories, 2005 and 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Victoria's residential fuel combustion emissions are so high because Victoria has a large number of households that use fossil gas at home and the levels of gas usage per Victorian household are much higher than in other states.

Approximately 76% of Victorian households were connected to fossil gas in 2021 (Energy Networks Australia, 2021), and Victoria's cooler temperatures and the widespread use of ducted gas heating – which is uncommon in other states – leads to greater use of gas than elsewhere. At almost 1 t CO_2-e per person annually, Victoria's per capita fuel combustion emissions in 2021 were more than double the national average and three times as high as the next closest state, South Australia (Figure 26)[10].

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[10] The Australian Capital Territory also has high per-capita usage of gas by households, due to cold winters and a high penetration rate of ducted gas heaters (CUAC, 2014), but separate residential fuel combustion data for the territory are not available.

Figure 26: Residential fuel combustion emissions of Australian states and territories per capita (t CO_2-e per capita) in 2021

Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

In 2021, residential fuel combustion in Victoria produced 6.1 Mt CO_2-e. Over 90% of these emissions came from burning fossil gas, with the remainder from burning wood or LPG. Emissions from residential gas use accounted for 34.2% of fuel combustion emissions in Victoria and 7.0% of the state's total net GHG emissions.

Note: Fuel combustion emissions from fossil gas shown here are limited to direct emissions from consumption. More emissions are produced in the fossil gas supply chain, including leakages during the exploration, production, transmission, storage and distribution of fossil gas. These are reported in the fugitive emissions from fuels sector (refer to section 2.1.4).

The opportunity for Victoria to reduce residential fuel combustion emissions

The biggest opportunity to reduce emissions from residential fuel combustion is reducing the use of fossil gas in Victorian households. Through the Gas Substitution Roadmap, the Victorian Government is helping more Victorians make the switch to modern, efficient electric appliances. Going all-electric can save a new home around $1000 each and every year on their energy bills, and up to $2200 if paired with rooftop solar. All-electric homes are not only cheaper to run, they are healthier to live in and help reduce Victoria's emissions.

Actions under the Roadmap build on existing programs such as the Victoria Energy Upgrades program, Solar Homes program and the Big Housing Build program that promote the use of efficient electric heating, cooling and cooking appliances. The government will release an update to the Roadmap in late 2023.

To further support the transition away from fossil gas, the Victorian Government has introduced new incentives through the Victorian Energy Upgrades program to help replace gas appliances with modern, efficient, electric equipment. And from 1 January 2024, all new homes and residential subdivisions requiring a planning permit will be prohibited from connecting to the gas network, helping more households take advantage of the energy bill savings of all-electric homes.

2.1.3 Transport

Sources of emissions

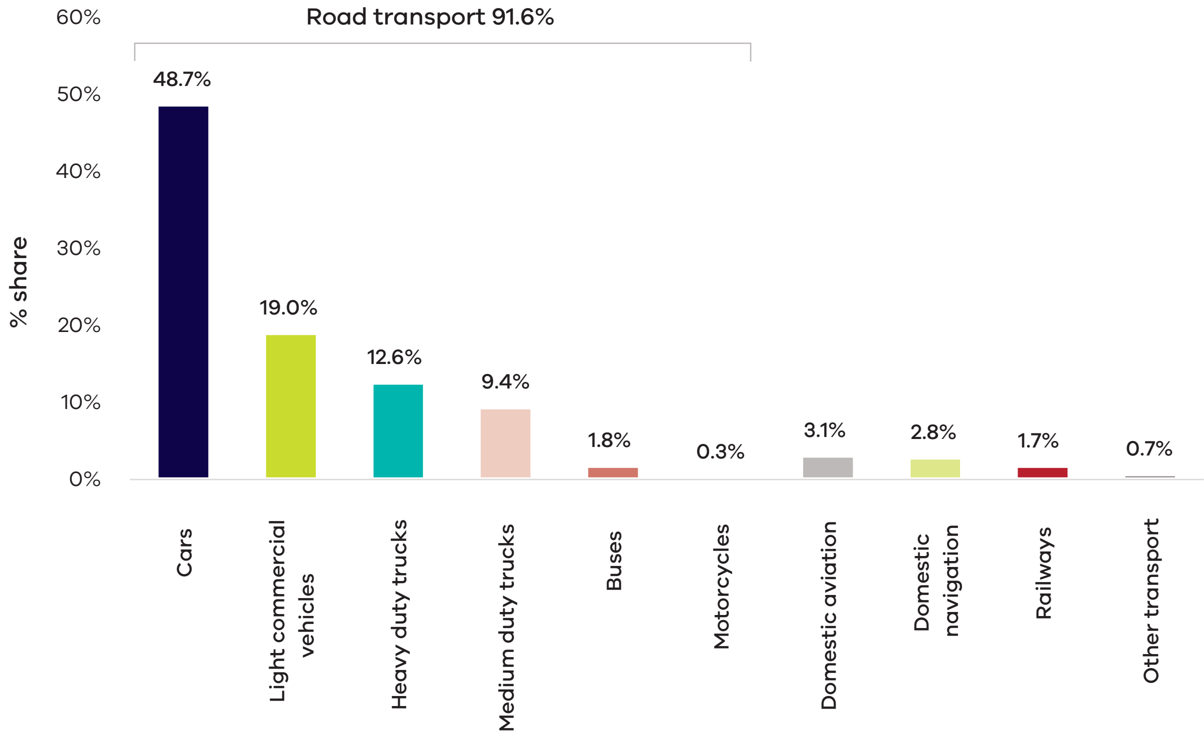
Emissions from transport arise from the combustion of fuels such as petrol, diesel and LPG in passenger and commercial motor vehicles, railways, domestic aviation and domestic navigation (i.e. shipping).

Emissions from electricity used to power public transport (i.e. metropolitan trains and trams) and charge electric vehicles are not included, as these are accounted for in the electricity generation emissions.

Transport in Victoria

In 2021, road transportation was responsible for the vast majority (91.6%) of transport emissions, with the major contributors being cars (48.7%), trucks and buses (23.7%) and light commercial vehicles (19%) (Figure 27).

Figure 27: Transport emissions by sub-categories – Victoria, 2021

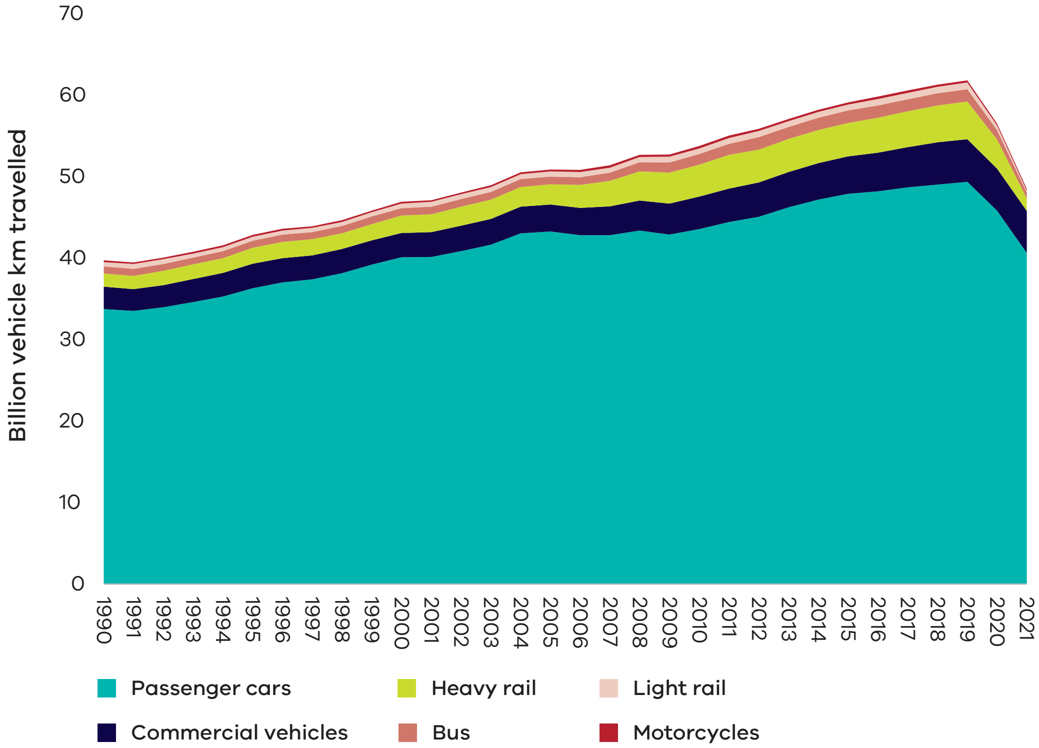


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Despite an increase in public transport use (heavy rail, light rail and buses) since 1990, cars have remained the dominant mode of transport in Melbourne (Figure 28).

Passenger transport activity – the total distance travelled – has tended to increase steadily with population growth over time but, in 2021, passenger transport activity decreased for the second year running. This was due to pandemic-related reductions in travelling (BITRE, 2021).

Figure 28: Total passenger kilometres travelled – Melbourne, 1990 to 2021



Source: Australian Energy Statistics, Table F (DCCEEW, 2022b) and Australian Infrastructure Statistics (BITRE, 2021)

The transport sector consumed 276 petajoules (PJ) of energy in 2021, with the main fuels being diesel (48%), petrol (43%), domestic aviation turbine fuel (3%) and LPG (2%) (DCCEEW, 2022b)[11].

In 2020, diesel overtook petrol as the main transport fuel being consumed by energy content. This continued to be the case in 2021, with 133 PJ of diesel and 119 PJ of petrol being consumed. In both 2020 and 2021, travel restrictions reduced passenger vehicle use, resulting in a noticeable decrease in petrol sales, while freight activity levels and truck movements were much less affected, reflected in diesel sales remaining relatively stable over the period (BITRE, 2021), (DCCEEW, 2022b).

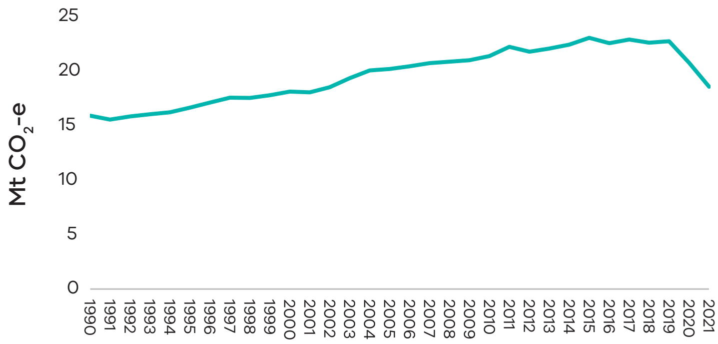
Emissions trends and drivers

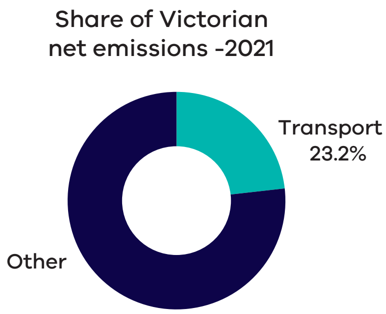
Transport emissions in 2021 were 18.6 Mt CO_2-e Despite a significant fall in the last two years, this is 2.7 Mt CO_2-e (16.8%) higher than in 1990.

Transport emissions increased steadily from 1990 to 2015, from 15.9 Mt CO_2-e in 1990 to 20.2 Mt CO_2-e in 2005 then peaking at 23.1 Mt CO_2-e in 2015. After 2015, transport emissions were roughly stable until 2019, falling in 2020 and 2021 as a result of reduced travel during the COVID-19 pandemic. Together, this produced a decrease in transport emissions of 1.6 Mt CO_2-e between 2005 and 2021 (Figure 29).

Despite the fall in transport emissions in 2020 and 2021, the overall growth from 1990 to 2021 represents the largest growth in absolute emissions from any sector over the period. Transport contributed 23.2% of Victoria's net emissions in 2021, the second largest share after electricity generation.

Figure 29: Emissions from transport – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)



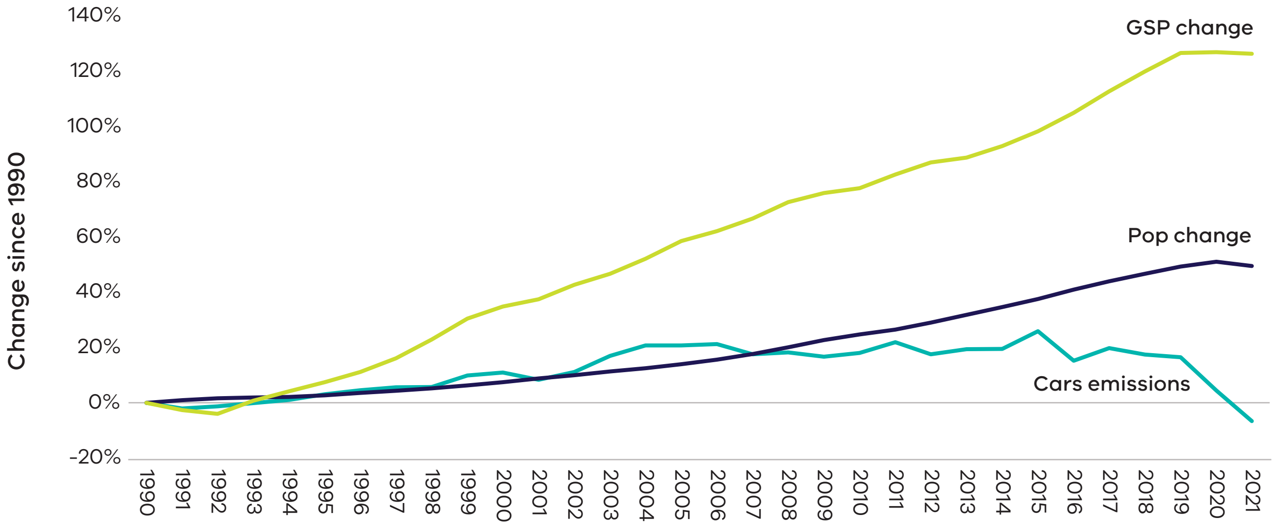


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

[11] Fuel consumption data sourced from Australian Energy Statistics and adjusted to exclude international aviation fuel. This is consistent with the UNFCCC accounting framework that excludes international aviation and shipping for national inventories.

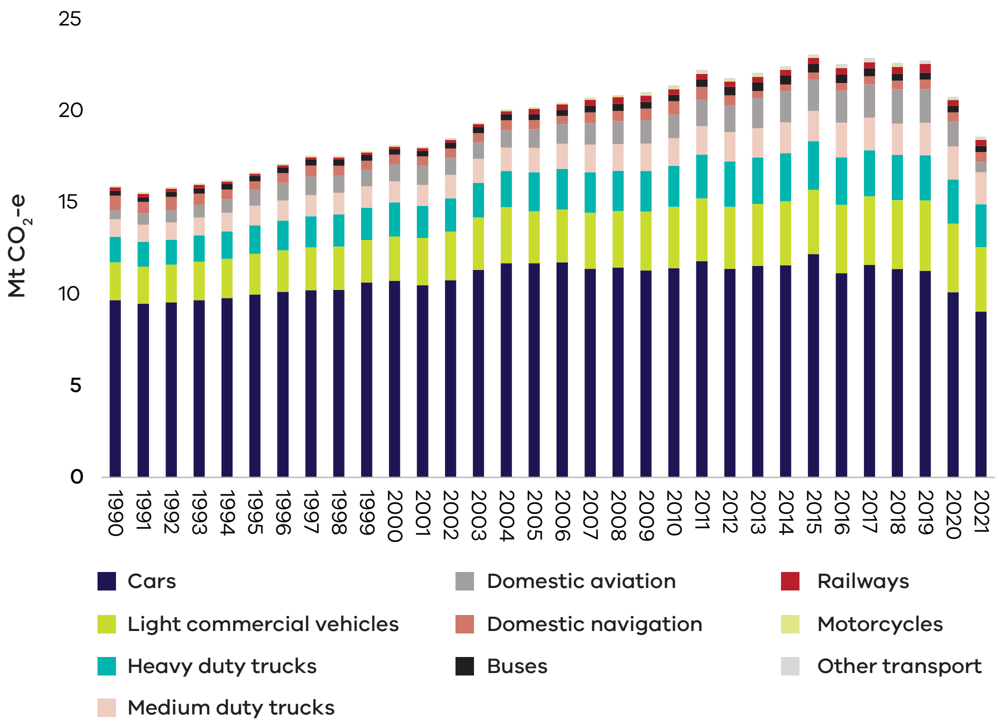
Between 1990 and 2005, passenger car emissions grew at an average annual rate of 1.6%, following trends of population and economy growth (0.9% and 3.1% average annual growth respectively). However, the trends then decoupled: between 2005 and 2021, emissions from cars decreased by an annual average of 1.5%, despite average annual population growth of 1.7% and average annual economic growth of 2.3% over that period (Figure 30).

Figure 30: Trends in passenger motor vehicle emissions against population and GSP – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Australian Demographic Statistics 2022 (ABS, 2023)

Figure 31: Emissions by transport sub-categories – Victoria, 1990 to 2021

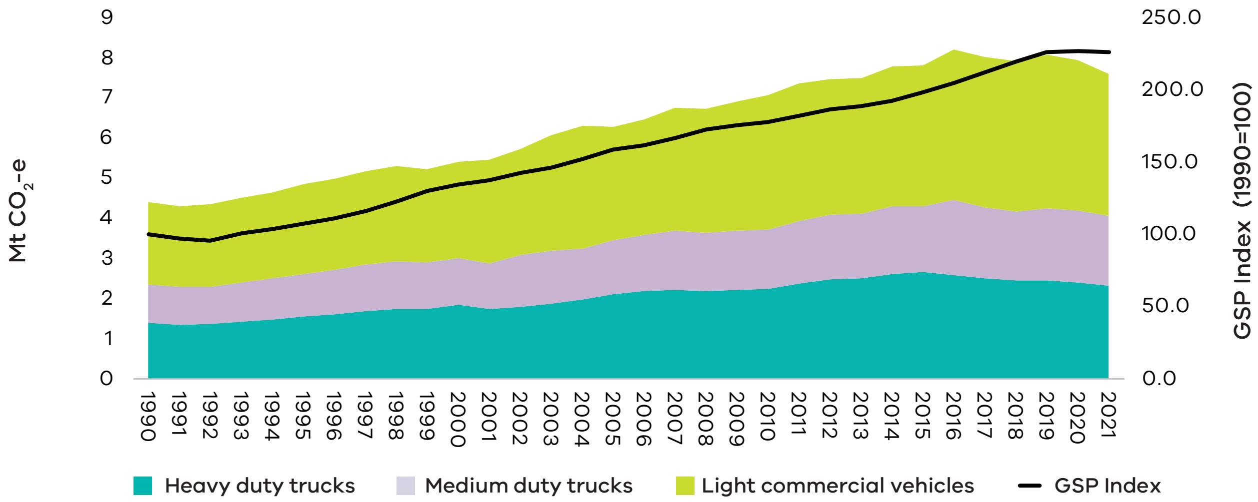


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Along with light commercial vehicles, the share of transport emissions attributable to other freight vehicles has grown. Combined, freight vehicles – heavy-duty trucks, medium-duty trucks and light commercial vehicles – increased their share of Victoria's transport emissions from 31% in 2005 to 41% in 2021.

While freight vehicle emissions fell in 2020 and 2021, this has not outweighed their steady increased from 1990 to 2019 (Figure 32). Though freight emissions are driven, in general, by economic growth, light commercial vehicles have experienced the highest growth since 2005, due to growth in online retail and e-commerce as well as the increasing consumer preference for larger vehicles (see Box 2).

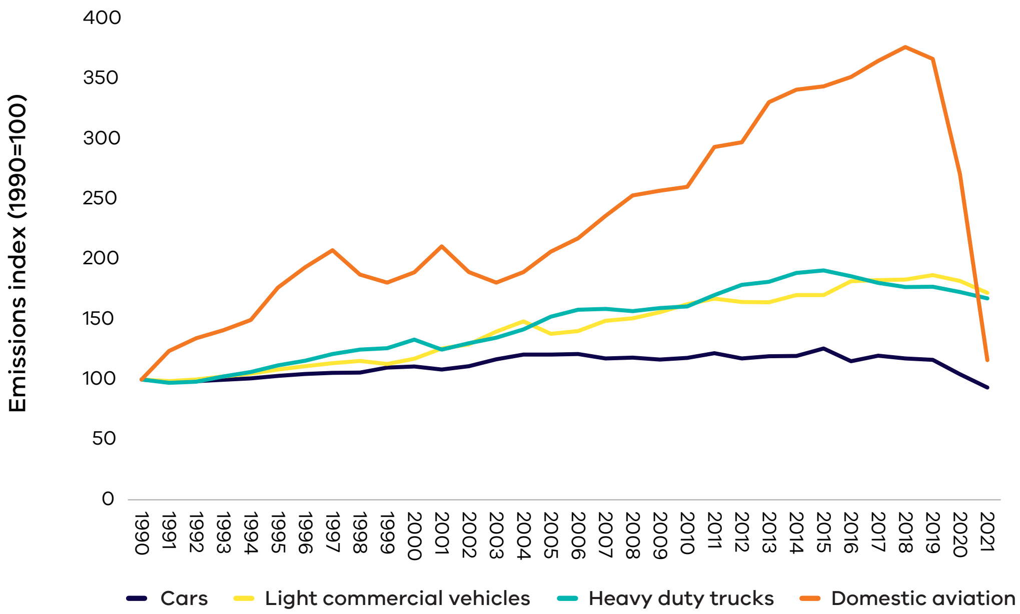
Figure 32: Trends in freight vehicle emissions and GSP – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Australian National Accounts: State Accounts, 2021–22 (ABS, 2022)

Domestic aviation emissions increased more rapidly than those from any of the other transport sub-categories between 2005 and 2019 (4.3% average annual increase), reflecting growth in air travel related to business and tourism (Figure 33). The sharp decrease of 42% from 2019 to 2021 was associated with the decline in air travel due to the COVID-19 pandemic; emissions are expected to increase again in following years.

Figure 33: Trends in emissions from the four major transport sub-categories – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Box 2: Changes in Victoria's road vehicle fleet

Excluding temporary changes caused by the COVID-19 pandemic, the dominant driver of changes to Victoria's transport emissions has been changes to Victoria' road vehicle fleet; chiefly in cars and light commercial vehicles.

Zero emissions vehicles entering the market

Victorians are purchasing more zero emissions vehicles (ZEVs). Sales of light vehicle ZEVs increased from 0.5% of new sales in 2018 to 1.8% in 2021, then to 8.0% in 2023 (year-to-date until June 2023) (NTC, 2018) (EV Council, 2019) (DEECA, 2023a) (DEECA 2023).

While ZEV sales have grown, ZEVs still make up a low proportion of Victoria's road fleet: around 0.4% as of January 2023 (BITRE, 2023b). This is because the bulk of the road fleet is made up of vehicles purchased in previous years, with Victorians typically holding onto their vehicles for 11 years before replacing them (BITRE, 2023a).

Because vehicles sold in the remainder of the 2020s are likely to continue operating past 2035, influencing consumer choices of vehicle purchases in the short term – i.e. increasing ZEVs' proportion of sales – will be important for reducing Victoria's long term road transport emissions. The Victorian Government has a ZEV sales target of 50% light vehicles by 2030, and a ZEV Roadmap that sets out actions in the coming decade to prepare for and promote a stronger uptake of ZEVs. To further support the growth in ZEVs, the Victorian Government has invested $19 million to roll out hundreds of public and fleet chargers across the state, ensuring that motorists are never more than an hour away from a charger.

Preference for larger vehicles

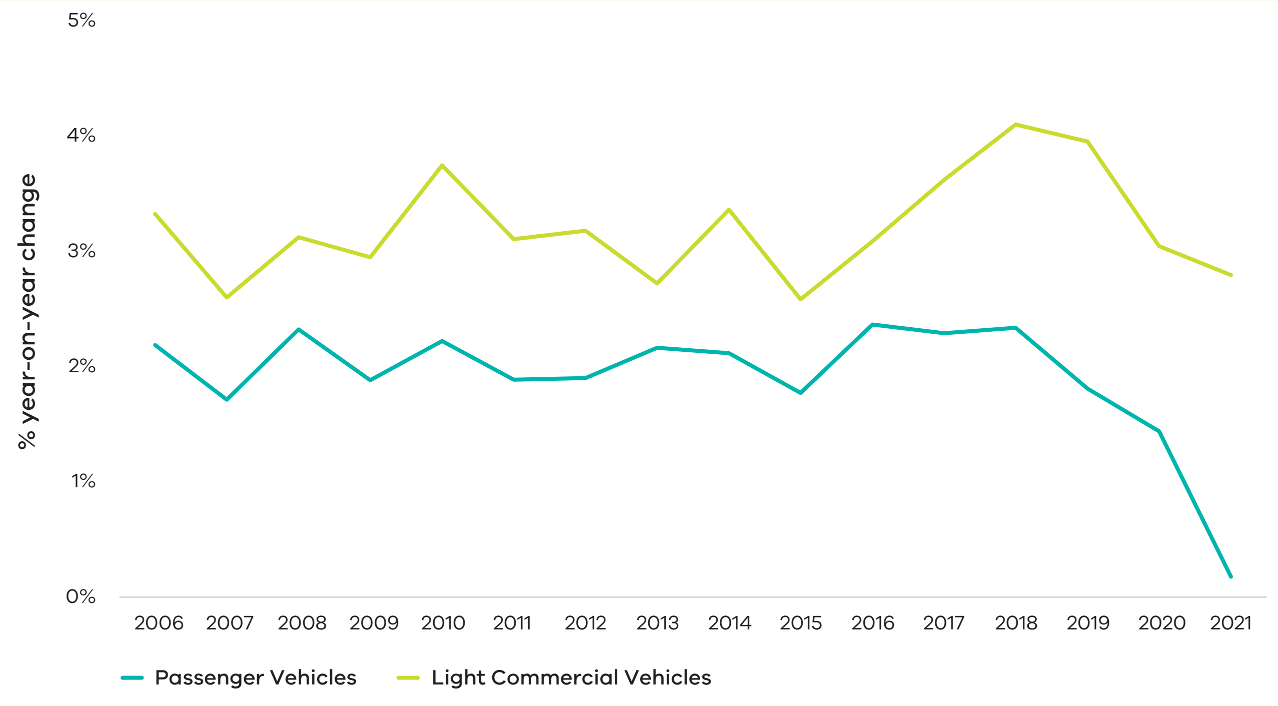
In recent years, Victorian consumers have shown an increasing preference for larger vehicles. There has been strong growth in sport utility vehicles (SUVs) sales in the last decade, with SUV sales more than tripling from around 55,000 in 2010 to 170,000 in 2023. This represents an increase from a quarter of passenger vehicle sales in 2010 to three quarters in 2023[12] (ABS 2018, FCAI 2023).

In addition to buying bigger cars, Victorians are increasingly buying light commercial vehicles (utility vehicles, panel vans, dual cab chassis vehicles and goods vans) rather than cars. Light commercial vehicles such as the Toyota Hilux and Ford Ranger consistently rank in the top 5 most popular models sold in Victoria (RACV, 2023), and light commercial vehicles have experienced higher annual growth than passenger vehicles each year since 2005 (Figure 34).

Larger vehicles – whether passenger vehicles, like SUVs, or light commercial vehicles – are typically heavier than smaller cars and have greater wind resistance, requiring more fuel to drive and therefore producing more emissions per kilometre travelled. Australian passenger cars and light SUVs are estimated to have an average emissions intensity of 146.5g/km, whereas the average emissions intensity of a heavy SUV or light commercial vehicle is 45% higher, at 212.5g/km (NTC, 2022).

[12] % sales of passenger vehicle is based on the sales of non-SUV passenger vehicles and all SUVs. The % sales is not based on total vehicle sales in Victoria (i.e. exclude sales data on light commercial vehicles and other heavy vehicles).

Figure 34: Annual growth in registrations of passenger vehicles and light commercial vehicles (%) in Victoria, 2005 to 2021



Source: ABS Motor Vehicle Census from 2005 to 2021 (ABS, 2005 to 2021)

Tax incentives for larger vehicles

The shift towards larger vehicles is not limited to Victoria, with this trend observed globally (Cozzi et al., 2023). However, a contributing factor in Australia has been federal government incentives to reduce the cost of light commercial vehicles.

In 2020, the federal government offered an instant asset tax write-off for light commercial and other work vehicles valued up to $150,000. In turn, Australian sales of light commercial vehicles increased by around a quarter after the policy was introduced (FCAI, 2021). From July 2023, the write-off value was reduced to $20,000 per annum and applied over three years instead of one year (ATO, 2023).

Commonwealth policies

In 2023, the Commonwealth released its National Electric Vehicle Strategy (NEVS) to drive cleaner, cheaper to run vehicles that work towards Australia's emissions goals (DCCEEW, 2023f). The NEVS sets out actions to increase the supply of affordable ZEVs, provide financial incentives to drive ZEV demand and implement supporting infrastructure.

The NEVS included a commitment to develop a fuel efficiency standard (FES) for light vehicles to incentivise the supply of fuel efficient vehicles and ensure that low and zero emissions vehicles are brought into the Australian market. This would bring Australia in line with other countries with a FES that account for around 80% of global car sales (Quicke, 2022).

2.1.4 Fugitive emissions from fuels

Sources of emissions

Fugitive emissions result from the release or leaks of gases from the venting and flaring of gases during the exploration, extraction, production, processing, storage, transmission and distribution of fossil fuels including coal, oil and fossil gas. Emissions from decommissioned coal mines are also included in this subsector.

Fugitive emissions do not include emissions from the combustion of fuels in activities such as electricity generation, the operation of mining plants and equipment or the transportation of fossil fuels by road, rail or sea. These are accounted for in the electricity generation, fuel combustion and transport subsectors respectively.

Fugitive emissions from fuels in Victoria

In 2021, 49.2% of fugitive emissions in Victoria resulted from leakages during the exploration, production, transmission, storage and distribution of fossil gas[13].

Most of the remaining fugitive emissions were associated with flaring and venting as part of oil and fossil gas production and processing[14]. Additional emissions came from leakage during the exploration, production, storage and distribution of oil and flaring in Victoria's petroleum industry, which is concentrated in the offshore regions of the Otway and Gippsland basins.

A small contribution to Victoria's total fugitive emissions (less than 1%) occurs from the extraction of solid fuels, particularly from brown coal mines.

Victoria's fugitive emissions (1.7 Mt CO_2-e in 2021) are significantly lower than those of New South Wales (11.0 Mt CO_2-e), Western Australia (8.5 Mt CO_2-e) and Queensland (20.4 Mt CO_2-e) due to the greater volumes and types of coal and fossil gas production in those states.

Emissions trends and drivers

Victoria's fugitive emissions rose from 4 Mt CO_2-e in 1990 to a peak of 4.1 Mt CO_2-e in 1995. Emissions then declined to a low of 1.6 Mt CO_2-e in 2014 before increasing again – with interannual variability – to reach 1.7 Mt CO_2-e in 2021 (Figure 35). In 2021, this subsector accounted for 2.2% (Figure 35) of Victoria's total net emissions.

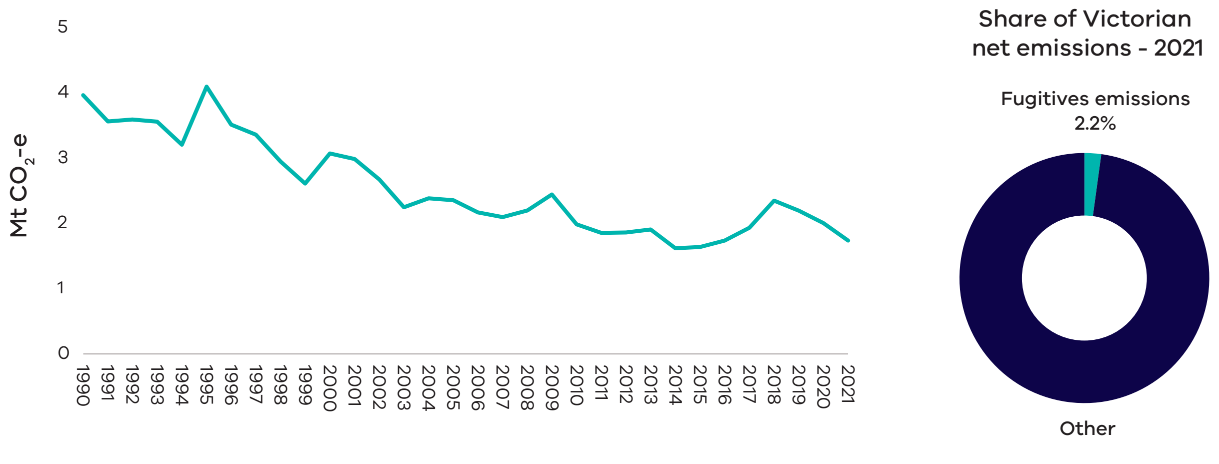
Crude oil production in Victoria fell by 94% between 1990 and 2021 (DCCEEW, 2022a). This contributed to the general downward trend from 1990 to 2015 (Figure 35). Increased emissions from flaring during oil and fossil gas production and processing contributed to increased fugitive emissions after 2016.

The annual volume of fossil gas consumption remained relatively stable between 1990 and 2005, , with some interannual variability. From 234 PJ in 2005, fossil gas consumption generally increased to a peak of 249 PJ in 2013 and) before declining to 212 PJ in 2021 (DCCEEW, 2022b). Key factors behind changes in fossil gas demand after 2005 include population that grew by an annual average of 1.7% from 2005 to 2021, seasonal variation in the demand for fossil gas for heating, and variation in annual levels of gas-powered generation (GPG) to help meet electricity demand.

The level of fugitive emissions associated with fossil gas consumption has moderated over time due to improvements in transmission, storage and distribution resulting in reduced fossil gas leakages.

Fossil gas production was generally stable between 1990 and 2002, after which production increased significantly to cater both for expanding Victorian residential demand and increasing exports to other states. In 2021, production levels were around double those in 1990 (DCCEEW, 2022a).

Figure 35: Fugitive emissions from fuels – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

[13] Also includes emissions from flaring during exploration.

[14] These emissions are from equipment operating as designed, as opposed to leakages.

2.2 Industrial processes and product use (IPPU)

Sources of emissions

Industrial processes include emissions generated from a range of production processes involving, for example:

- the use of carbonates (e.g. limestone, dolomite, magnesite, etc.);
- carbon when used as a chemical reductant (e.g. iron and steel or aluminium production); and
- chemical industry processes (e.g. ammonia and nitric acid production).

Product use includes emissions associated with the use of synthetic gases such as:

- hydrofluorocarbons (HFCs) in refrigeration and air conditioning, foam blowing, fire extinguishers, aerosols/metered dose inhalers and solvents;
- sulphur hexafluoride (SF_6) in electrical equipment; and
- perfluorocarbons (PFCs) arising from primary aluminium production.

Emissions associated with the consumption of electricity or combustion of fuels in industrial production are accounted for in the electricity generation and fuel combustion subsectors.

IPPU emissions in Victoria

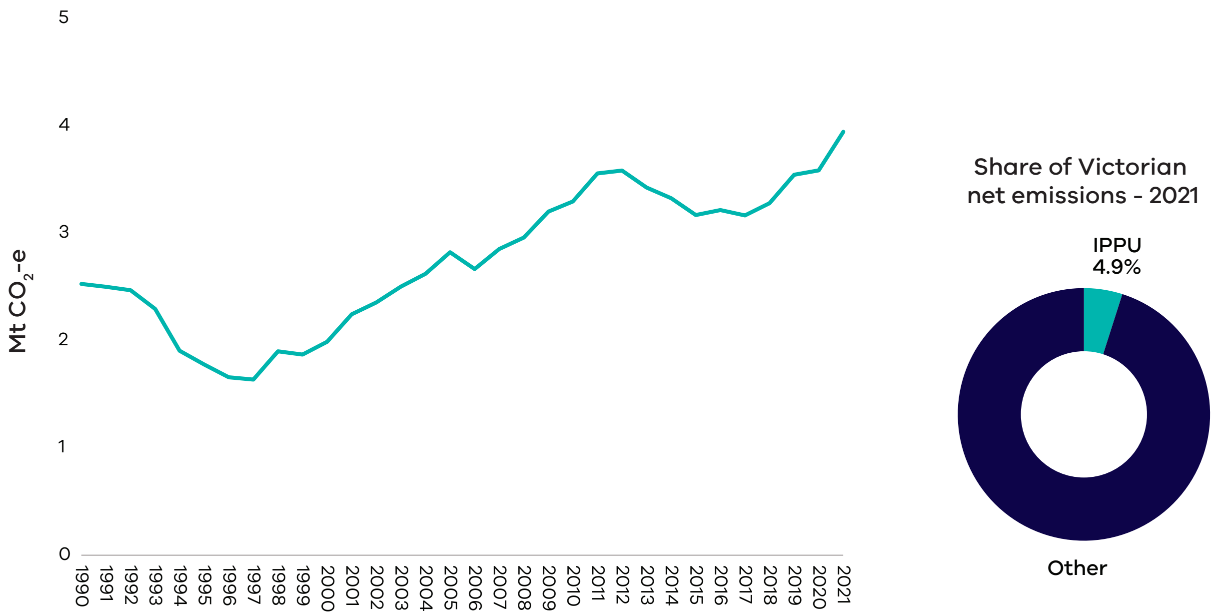
In 2021, 73.6% of Victoria's IPPU emissions resulted from the use of synthetic greenhouse gases (mainly HFCs), primarily for refrigeration and air conditioning in commercial, residential and transport activities.

The remaining 26.4% of IPPU emissions resulted from activities such as minerals, metals and chemicals production.

Emissions trends and drivers

Victoria's IPPU emissions fell between 1990 and 1997, before rising steadily to 2012. Emissions declined from 2013 to 2018, before resuming their rise from 2019 to 2021 (Figure 36). In 2021, this sector accounted for 4.9% of Victoria's total net emissions.

Figure 36: Emissions from industrial processes and product use (IPPU) – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)

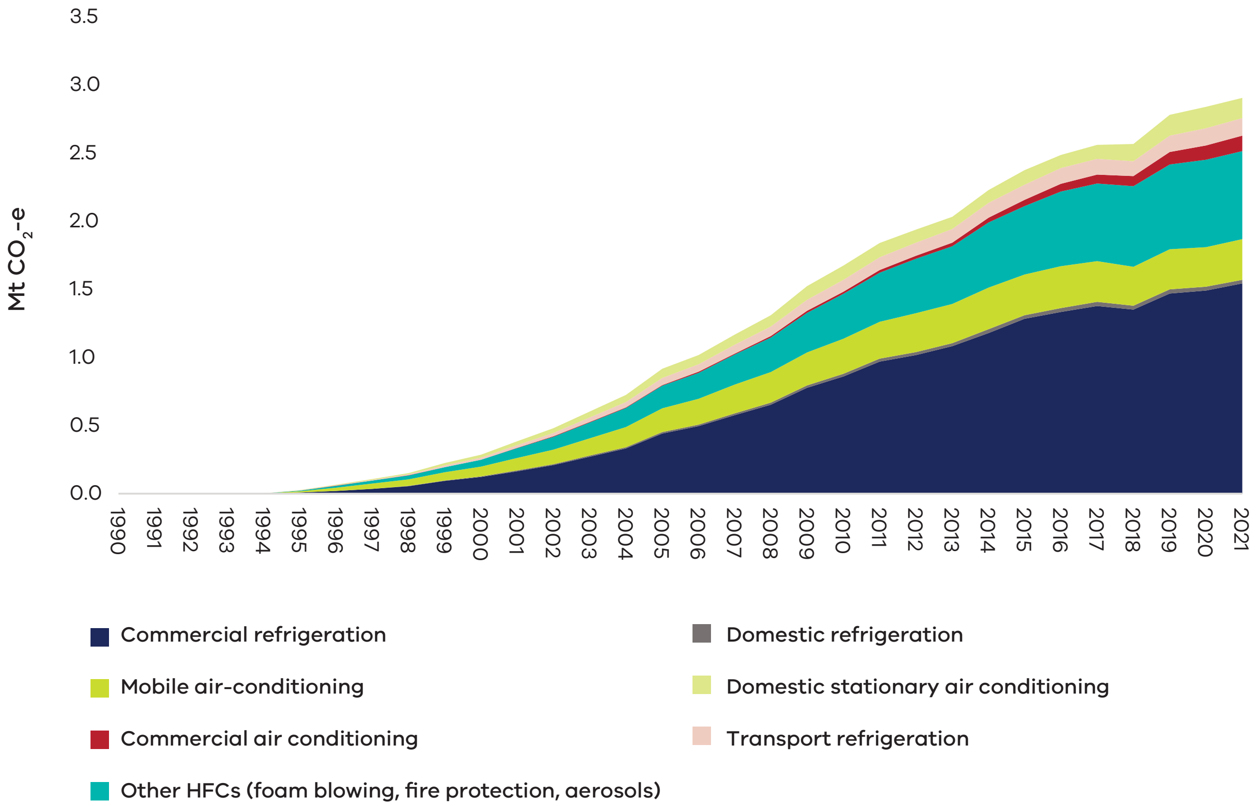


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Increasing use of HFCs, primarily for air conditioning and refrigeration, but also in aerosol propellants, fire protection and insulating foams, was the major driver of growth in IPPU emissions. From 1995[15] to 2021, HFCs grew from 1.4% to 73.6% of total IPPU emissions[16] (Figure 37). This growth in emissions is largely due to HFCs replacing ozone-depleting hydrochlorofluorocarbons (HCFCs) in response to a phase out of HCFCs which commenced in the mid-1990s. Population growth also led to increased demand for equipment and appliances that use HFCs.

The phase out of HCFCs in Australia was largely completed by 2016 . HFCs themselves are now subject to a phase-out and are being replaced by alternative substances with lower climate impacts (Brodribb & McCann, 2020). Both phase-outs are driven by the Montreal Protocol on Substances that Deplete the Ozone Layer[17].

Figure 37: Emissions from HFC use by activity – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Growth in the regulated bank of refrigerants[18] in Australia slowed from 2016 to 2020 but increased again in 2021 (Brodribb et al., 2022). The factors contributing to the growth in the regulated bank (Brodribb et al., 2022)

- rapid growth in deployment of refrigerant heat pumps, partially resulting from government policies aimed at accelerating a shift away from gas and less efficient electrical appliances ; and
- delays in transitioning to lower GWP refrigerants for mobile air conditioners in motor vehicles and commercial refrigeration units.

The main reasons behind the delay in transition including costs and availability[19] associated with the transition to lower GWP refrigerants (Brodribb et al., 2022)

IPPU emissions trends are also reflective of changes in economic activity. The growth in IPPU emissions from the mid-1990s would have been higher were it not for changes in industrial activity in Victoria, which partially offset the rise of HFC emissions from refrigeration and air conditioning units. For instance, after 1995, emissions from the chemicals industry dropped substantially due to the closure of several chemical production facilities and from 2011 to 2020, the closure of facilities producing clinker and lime also moderated growth in IPPU emissions.

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15 Data not available for most HFC emissions sources prior to 1995.

16 Estimates of Victorian HFC-related emissions are subject to uncertainty and are based on data from DCCEEW. DCCEEW estimates State and Territory product use emissions from ozone-depleting substances (ODS) substitutes (primarily HFCs) by dividing national emissions from ODS substitutes by the population of each state/territory.

17 The Montreal Protocol is an international agreement made in 1987, which set binding obligations for countries to phase out import and production of ozone depleting substances (HCFCs) and phase-down obligations for HFCs.

18 The regulated bank of refrigerants in Australia is the largest part of the overall bank, that is subject to regulation and controls under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. The regulated bank is comprised of HCFCs and HFCs

19 Supply chain issues related to the COVID-19 pandemic that may have played a role in the availability of low GWP units.

2.3 Waste

Sources of emissions

Emissions from the waste sector arise from the decomposition of organic waste in landfills and from the direct release of greenhouse gases during wastewater treatment. Emissions include:

- methane from the anaerobic decomposition of organic matter from solid waste in landfills and wastewater treatment plants; and
- nitrous oxide from the nitrification and denitrification of urea and ammonia in wastewater treatment plants.

Carbon dioxide (CO_2) emissions from the combustion of methane captured from landfills and wastewater treatment plants, and the combustion of biomass for electricity generation, are reported in the energy sector[20]. Emissions associated with energy used for managing and transporting waste are accounted for in the electricity generation, fuel combustion and transport subsectors.

CO_2 emissions from carbon stock transfers of harvested wood products (e.g. paper, wood) to landfill are reported in the LULUCF sector. However, methane emissions from the decomposition of wood and paper in landfill are reported in the waste sector [21].

Waste emissions in Victoria

The main sources of waste sector emissions in 2021 were the disposal of solid waste to landfill (65.8% of total waste sector emissions) and the treatment of domestic, commercial and industrial wastewater (30.9%). Waste decomposes in landfills over decades which means emissions from landfill in a given year are from a combination of older as well as more recently deposited waste. Most landfills in Victoria operate in accordance with best practice in greenhouse gas management, such as capturing and combusting landfill gas. This significantly reduces greenhouse gas emissions from this sector.

Wastewater emissions result from wastewater treatment by Victoria's 18 public water corporations, private wastewater treatment facilities managed by large-scale industrial facilities andon-site septic tanks . Factors influencing interannual variability in wastewater emissions include changing volumes of wastewater discharged by large industry and changes in the operational management and efficiencies of wastewater treatment plants. Many larger wastewater treatment plants in Victoria already capture the methane produced from the treatment process to use as renewable biogas, generating renewable electricity. Victoria's public water corporations, representing a significant proportion of the wastewater emissions, are actively exploring opportunities to further increase its capture and use of renewable biogas, and minimise greenhouse gas emissions from wastewater treatment at the source, as part of the industry's broader efforts to achieve net-zero emissions from its own operations by no later than 2035.

Emissions trends and drivers

Victoria's waste sector emissions declined between 1990 and 2013 before increasing through to 2017. Waste emissions have remained relatively stable to 2021, with some interannual variability (Figure 38).

In 2021, the waste sector was responsible for 3.4% of Victoria's total net emissions – emissions from the sector in 2021 were 2.7 Mt CO_2-e, significantly below the 6.4 Mt CO_2-e emitted in 1990 (Figure 38).

Notwithstanding some annual variation, the solid waste subsector's share has remained at around 71% on average and wastewater subsector's share has been around 27% between 1990 and 2021. Additionally, there has been a small but growing share of waste emissions associated with biological treatment of solid waste – from 0.1% of waste emissions in 1990 to 2.7% in 2021 (Figure 39).

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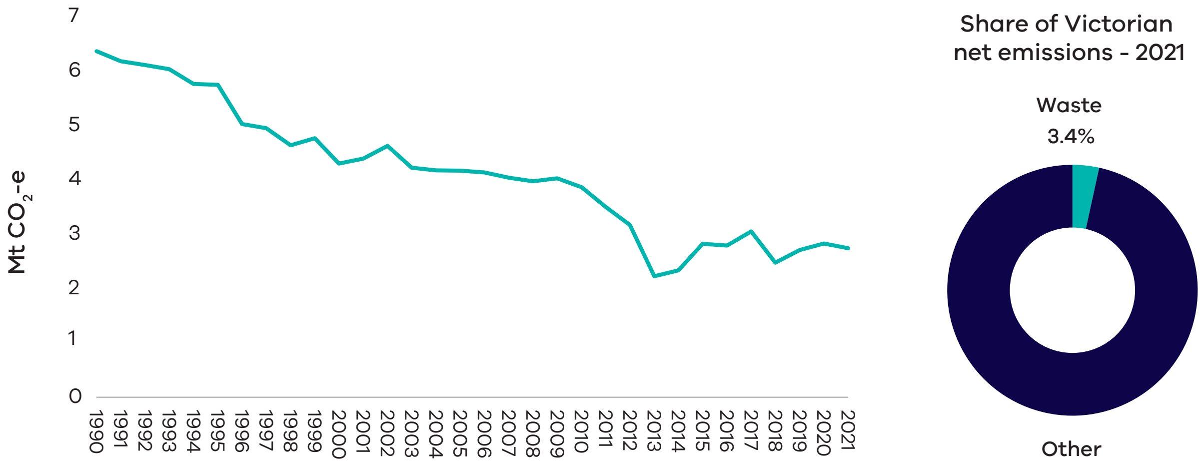
[20] Biogenic carbon dioxide from paper, wood, garden, food or other biomass is assumed to experience uptake and release within 100 years through photosynthesis. As per IPCC Guidelines (IPCC, 2006), biogenic carbon dioxide is assumed to have a neutral global warming potential and, as such, is reported as a memo item in the National Inventory Report 2021 (DCCEEW, 2023d).

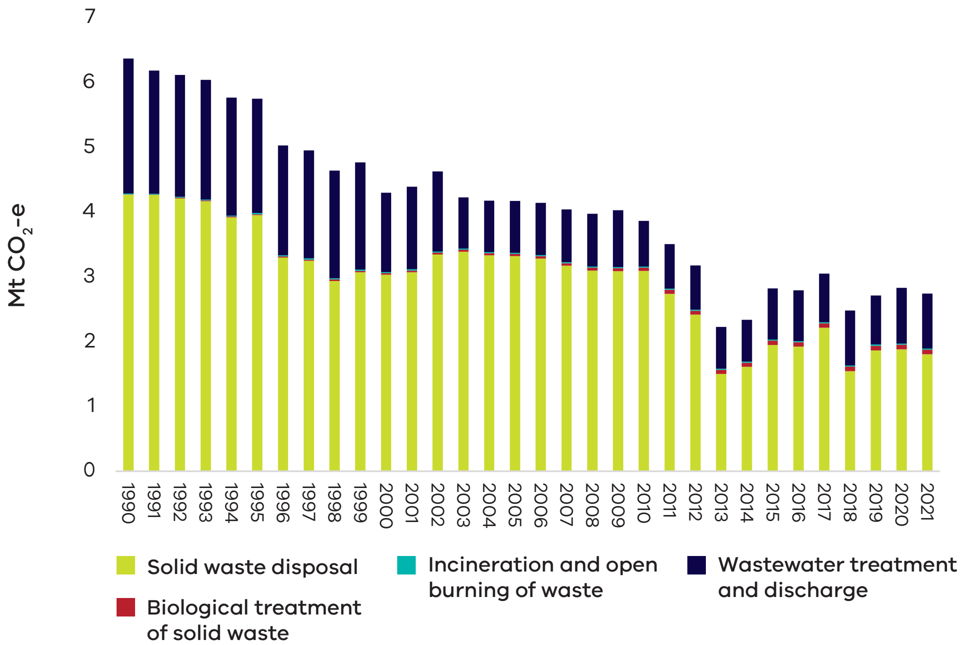
[21] Principles of conversion of carbon and mass are respected when estimating rates of decomposition therefore double counting of carbon does not occur.

Figure 38: Emissions from waste – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Figure 39: Emissions by waste sector sub-categories – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Despite steady population growth, waste emissions from the two major subsectors of solid waste management and wastewater treatment have both more than halved since 1990.

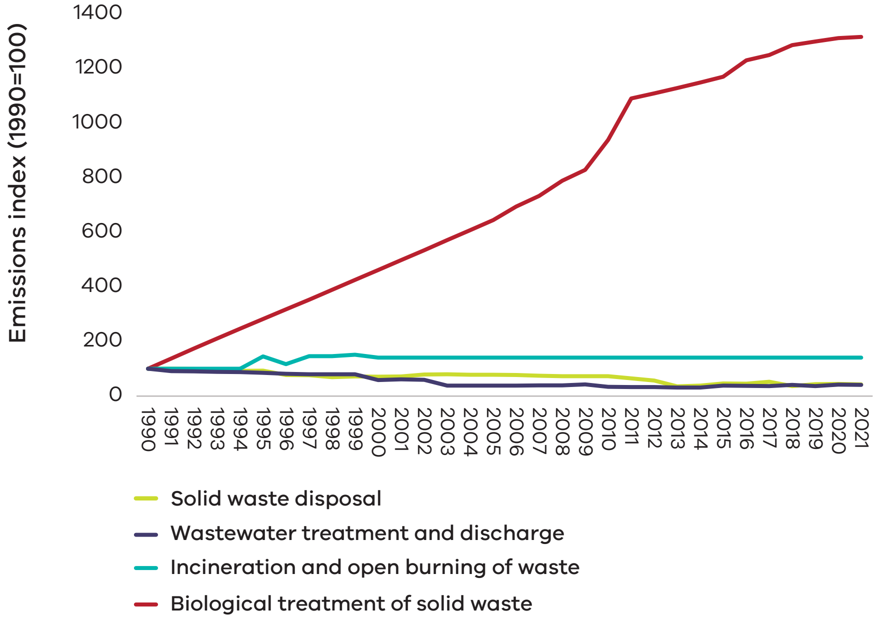
Emissions associated with management of solid waste fell by 57.7% between 1990 and 2021 despite increased volumes of solid waste produced by Victoria's expanding population. This was due to increased landfill gas capture and combustion; improved landfill management practices reducing methane leakage; greater levels of materials recycling; and increased diversion of organics from the waste stream to composting and electricity generation. These changes have contributed to a flattening trend in solid waste disposal emissions since 2013, even as the population has increased by 13% (Figure 40).

Similarly, emissions from wastewater decreased by 59.4% between 1990 and 2021, remaining stable for most of the last two decades, with changes due to more efficient wastewater treatment processes and increased methane capture from larger wastewater treatment plants.

Although emissions from biological treatment of solid waste only accounted for 2.7% of total waste emissions in 2021, they have grown significantly since 1990. This waste sub-category includes processes such as windrow composting and enclosed anaerobic digestion – which is considered an emerging waste treatment pathway in Australia. There are now several waste-to-energy facilities operating in Victoria utilising anaerobic digestion process to produce biogas as a fuel for energy production including at Wollert, Melton and Colac, with many more facilities now in the planning phase.

Emissions from incineration and open burning of solid waste have remained stable over the last two decades and contributed only 0.6% to waste emissions in 2021. Some of the main sources of emissions included in this sub-category are the incineration of solvents and municipal and clinical waste.

Figure 40: Trends in emissions by the major waste sub-categories – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

2.4 Agriculture

Sources of emissions

Agriculture sector emissions result from:

- enteric fermentation that occurs due to the digestive processes of ruminants (e.g. cattle and sheep) through which microbes decompose and ferment food in the animals' digestive tracts producing methane emissions;
- the anaerobic decomposition of organic matter contained in manure from animals;
- the release of nitrous oxide from cropping and pastureland from processes in the soil following the application of fertilisers, crop residues and animal waste; and
- burning agricultural residues.

Emissions associated with the use of electricity, fuel consumption to operate equipment and transport are accounted for in the energy sector. Removals associated with tree planting and vegetation or agroforestry activities is accounted for in the LULUCF sector.

Agriculture emissions in Victoria

Enteric fermentation from livestock was the main source of agriculture sector emissions in Victoria in 2021 (67.8%), followed by the release of nitrous oxide from fertilisers (18.5%) and manure management (8.7%). Emissions from urea application and liming (both for soil conditioning) were 4.4% of agriculture emissions.

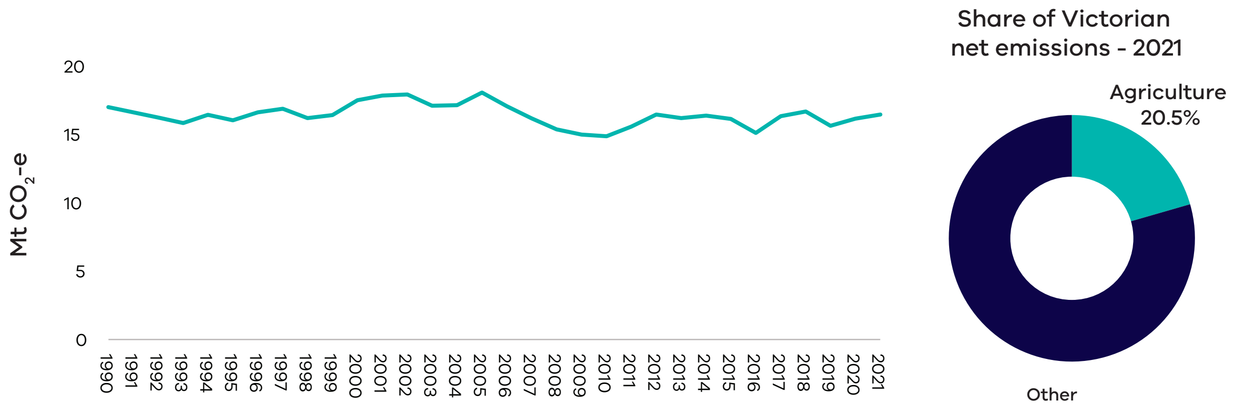
Under enteric fermentation emissions, dairy and beef cattle ,in roughly equal portions, contributed to almost half of total agriculture emissions.

Emissions trends and drivers

Between 1990 and 2021, emissions from agricultural activities have fluctuated between 15 and 18 Mt CO_2-e. In 2021, the sector accounted for 20.5% of Victoria's net emissions – the third largest share of total emissions behind electricity generation and transport (Figure 41).

The interannual variation in total agriculture emissions was driven mainly by seasonal conditions as well as food and fibre production and demand.

Figure 41: Emissions from agriculture – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)

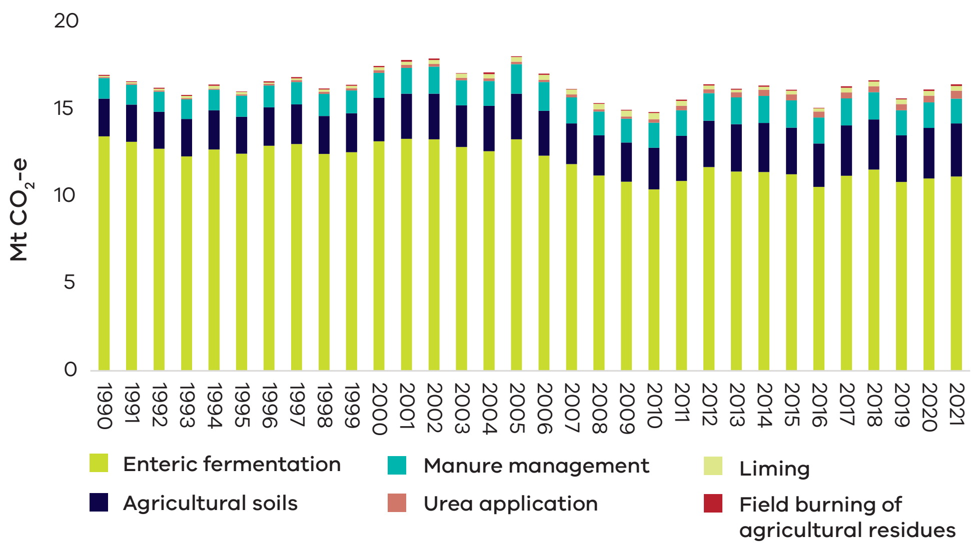


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Figure 42 presents the trend in agriculture emissions by activity sub-categories. Enteric fermentation has been responsible for the largest share of agriculture emissions for three decades but its share of emissions has declined from 79.2% in 1990 to 67.8% in 2021. The share of other sub-categories has increased over the same period, including agricultural soils (from 12.8% to 18.5%), manure management (from 6.9% to 8.7%) and urea application (from 0.3% to 2.8%).

Reduced enteric fermentation emissions from grazing sheep was the main contributor to the 3.2% decline in agriculture sector emissions from 1990 to 2021, primarily due to a decline in the sheep population since 1990 – likely driven by seasonal and market conditions. Emissions from cattle were higher in 2021 than in 1990, however interannual fluctuations occurred throughout the period reflecting variation in cattle numbers.

Figure 42: Emissions by agriculture sector sub-category – Victoria, 1990 to 2021

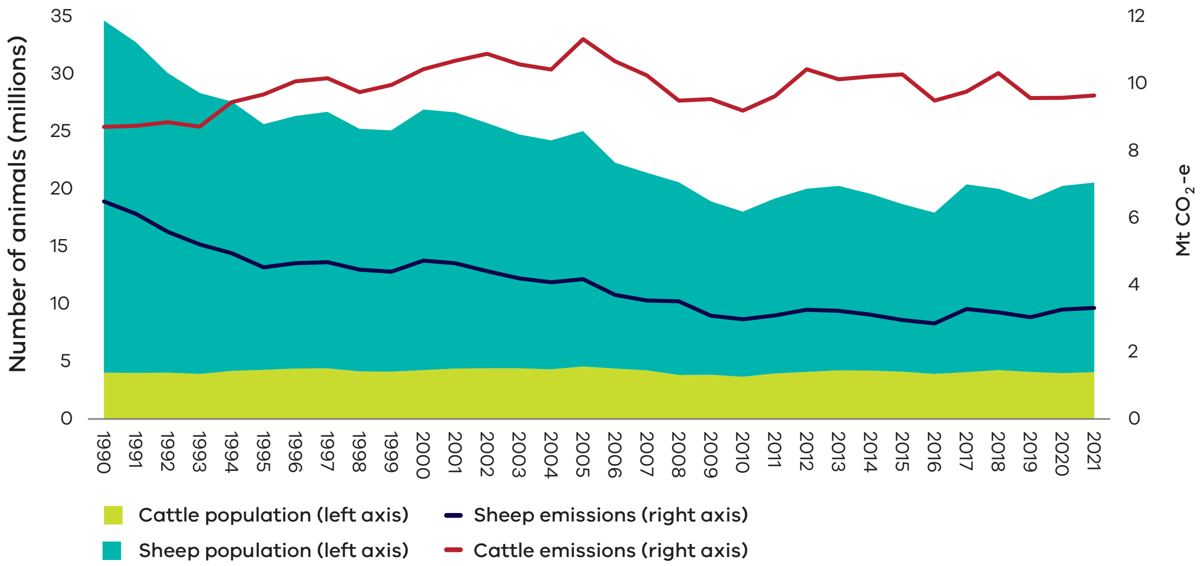


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Figure 43 presents trends in sheep and cattle populations and emissions from 1990 to 2021. Despite the decline in the sheep population since 1990, there were just over four times as many sheep as cattle in Victoria in 2021.

Victoria's cattle population was particularly influenced by the millennium drought that affected Victoria from 1997 to 2009. Cattle numbers initially remained steady, then declined towards the end of the drought in the late 2000s. Numbers increased with the return to more favourable conditions in 2010 and 2011.

Figure 43: Sheep and cattle populations and emissions – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and Agriculture Livestock Activity Tables 2021 (DCCEEW, 2023b)

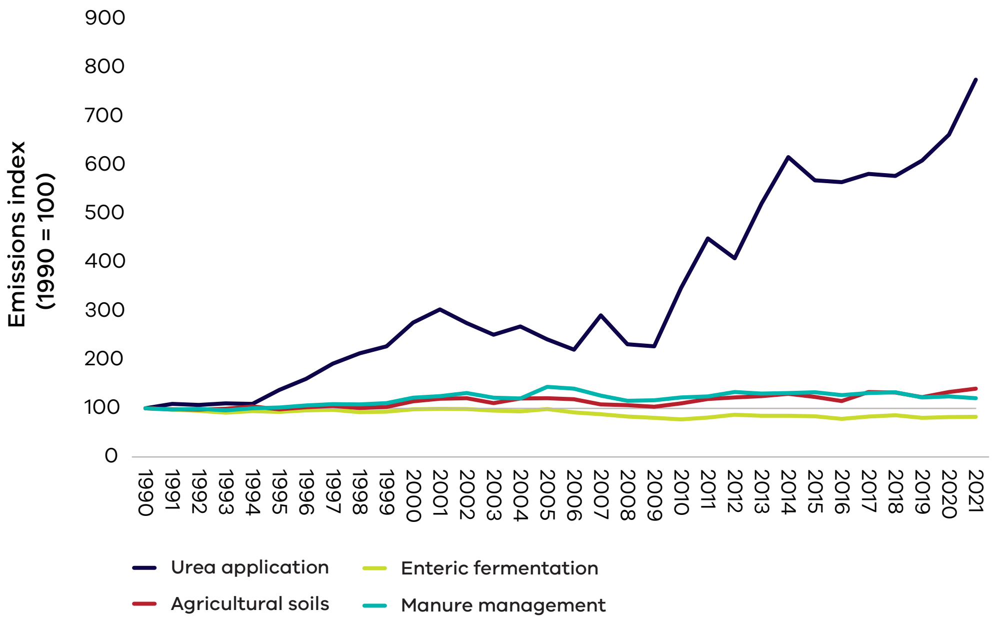
Note: Includes all the mechanisms that give rise to emissions from livestock, including enteric fermentation, manure management, urine and faeces on grazing land and atmospheric deposition of nitrous oxide.

Figure 44 presents trends in the four sub-categories with the greatest contributions to emissions from agriculture.

Emissions from enteric fermentation decreased by 17.2% between 1990 and 2021 due to the factors outlined above. Emissions from the other three major sub-categories (manure management, agricultural soils and urea application) increased from 1990 to 2021, although no clear trend has emerged in manure management emissions that vary depending on livestock numbers, manure management practices and climate factors.

Emissions from agricultural soils grew by 0.9 Mt CO_2-e (40.7%) between 1990 and 2021. The significant increase in total winter crop production (with wheat, barley and canola being the main products) – and associated increases in the application of fertilisers – were responsible for this growth. The total production of winter crop tripled, from 3.3 to 10.0 million tonnes between 1990 and 2021 (DCCEEW, 2023a). In the same period, urea application emissions also grew nearly seven-fold (Figure 44), with particularly strong growth in the last decade (DCCEEW, 2023e).

Figure 44: Trends in emissions for the four major agriculture sub-categories – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

2.5 Land Use, Land Use Change and Forestry

Sources of emissions

The land use, land use change and forestry (LULUCF) sector includes emissions and the removal (sequestration) of greenhouse gases resulting from direct human-induced land use, land use change and forestry activities. This includes emissions and removals from the clearance of forested land and conversion to other land uses; from new forests planted on previously unforested land; and from other practices that create emissions and removals (forest management, cropland management and grazing land management). Emissions and removals associated with infrequent, extreme bushfire events are reported based on long run trends in carbon stock change and have a limited impact on annual emissions.

Fossil fuel combustion associated with forestry and land management activities – such as diesel used in logging machinery – is accounted for in the fuel combustion subsector. Emissions from burning agricultural residues, and non-CO_2 emissions associated with land use such as the application of fertilisers, are accounted for in the agriculture sector.

Emissions in Victoria

The main sources of Victoria's LULUCF emissions and removals are forest lands and grasslands, specifically from land classified as:

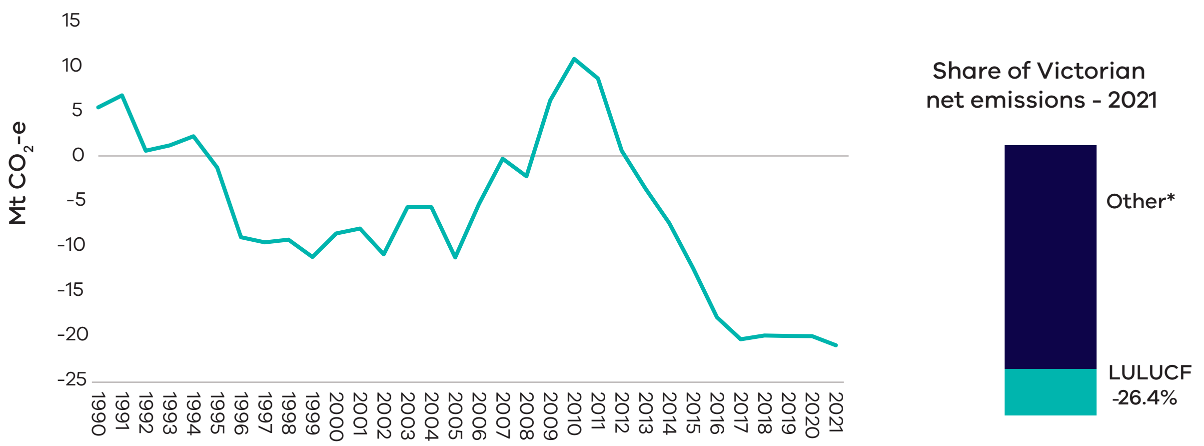
a. **Forest land remaining forest** – comprising changes in the native forest estate including fires[22] and harvesting from that estate and pre-1990 plantations.

b. **Land converted to forest land** – comprising plantations established since 1990 and regeneration of previously cleared land.

c. **Grassland remaining grassland** – includes all areas of grassland not reported under land converted to grassland, comprising grasslands and shrublands (woody areas that do not meet the definition of forest)[23].

d. **Forest land converted to cropland, grasslands, wetlands and settlements** – comprising primary and secondary clearing of forest land since 1972 to enable a change in land use and changes in soil carbon and other emissions resulting from land use change[24].

Figure 45: LULUCF net emissions – Victoria, 1990 to 2021 (left) and share of 2021 net emissions (right)



*The shares of all other sectors are 126.4%.

Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Emissions trends and drivers

Victoria's LULUCF emissions fluctuated significantly between 1990 and 2021 (Figure 45). LULUCF was a net sink (removals exceeded emissions) from 1995 to 2008 and from 2013 to 2021, and a net source of emissions (emissions exceeded removals) from 1990 to 1994 and from 2009 to 2012. Over the period 1990 to 2021, LULUCF provided a cumulative net sink of approximately –200.2 Mt CO_2-e. In 2021, in net terms, the LULUCF sector sequestered 21.1 Mt CO_2-e of emissions, equivalent to 26.4% of total Victorian emissions.

Figure 46 presents net emissions across all LULUCF sub-categories.

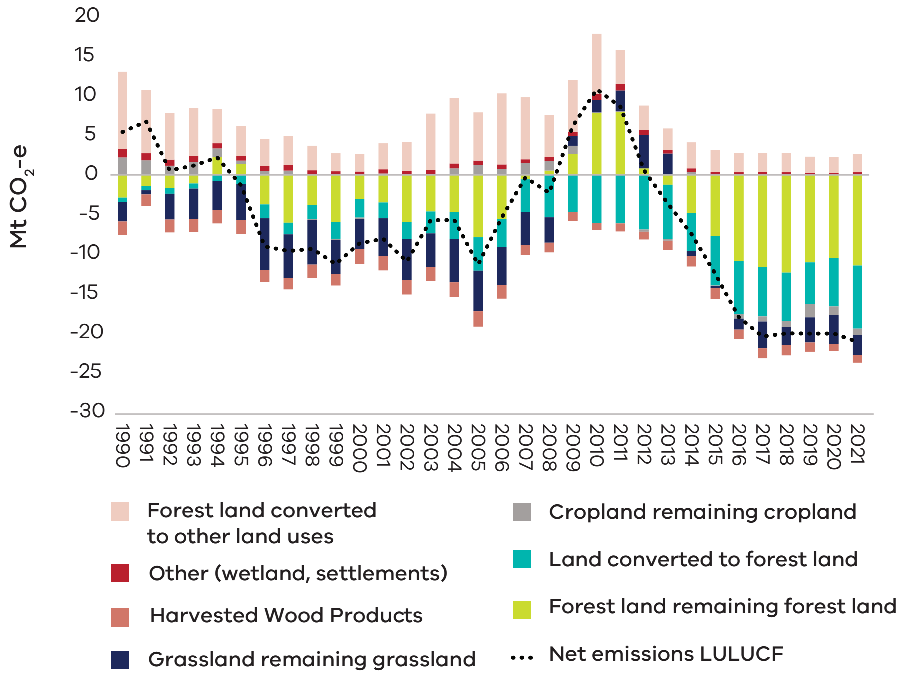
Forest land remaining forest land was the largest contributor to net emissions in 2021 at 11.5 Mt CO_2-e with substantial interannual variation (including being a net source in 1994 to 1995 and 2008 to 2012). Changes in this sub-category were driven by wildfire (also commonly referred to as "bushfire") emissions and removals, and changes to carbon pools from forest estates (see **a. Forest land remaining forest land** for further detail).

[22] Fires here refer primarily to controlled burning. Extreme natural disturbance fires are excluded.

[23] Forests include all vegetation with a vegetation height of at least 2 metres and crown canopy cover of 20% or more and lands with systems with a woody biomass vegetation structure that currently fall below the threshold but which, *in situ*, could potentially reach the threshold values of the definition of a forest.

[24] These four sub-categories account for more than 90% of total emissions from the LULUCF sector. While emissions from other sub-categories are not described in this section of the Report, the net emissions are accounted for in the total net LULUCF emissions presented in Figure 44 and Figure 45.

Figure 46: Emissions from LULUCF sub-categories – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Land converted to forest land was a net sink of 8.0 Mt CO_2-e in 2021. Removals by this sub-category increased in scale from 1990 to a peak in 2013 before declining slightly – and increased again to record levels of removals in 2021. A key historical driver of removals in this sub-category was the expansion of commercial forestry plantations. Since 2020, La Nina conditions producing wetter conditions have allowed vegetation to grow more rapidly and in turn increased removals.(see **b. Land converted to forest land** for further detail).

Grassland remaining grassland was a net sink of 2.6 Mt CO_2-e in 2021, predominantly due to grassland soils (which provided 96.3% of this removals). Throughout the 1990s and early 2000s, this sub-category provided a net sink, but became a net source of emissions between 2009 and 2013 before again providing a net sink from 2014 to 2021. Changes in this sub-category are largely driven by changes in land management practices (particularly changes in pasture, grazing and fire management) and climate, which determine the amount of live biomass and dead organic matter, as well as the amount of residues, root and manure inputs to soil carbon (see **c. Grassland remaining grassland** for further detail).

Forest land converted to other land uses was a relatively small contributor to net emissions in 2021 but fluctuated significantly between 1990 and 2021. The primary drivers of trends in this sub-category are primary forest clearing, farmers' terms of trade and weather conditions. Long-standing regulations on land clearing have assisted in constraining the emissions from this sub-category (see **d. Forest land converted to cropland, grassland, wetlands and settlements** for further detail).

Contributions from the other, harvested wood products and cropland remaining cropland sub-categories are relatively small with interannual variation based mainly on market demand for agricultural and harvested wood products.

a. Forest land remaining forest land

This sub-category includes emissions/removals derived from modelled changes in carbon pools in:

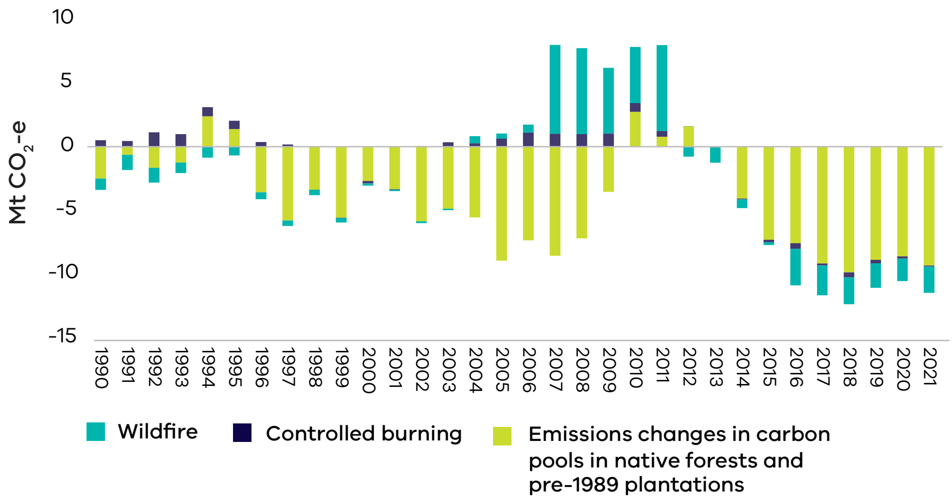
- harvested native forests;
- other native forests; and
- plantations established before 1990.

Removals from this sub-category increased from 2020 to 2021, from 10.5 Mt CO_2-e to 11.5 Mt CO_2-e.

Figure 47 shows net emissions from forest land remaining forest land resulting from activities such as wildfire and prescribed burning; and other sources of emissions including changes in living biomass, dead organic matter and soil carbon in harvested native forest and other native and pre-1990 plantation forests. The years where wildfire and prescribed burning are net emissions sinks (e.g. 2012 to 2021) are years in which carbon removed through vegetation regrowth after wildfires and prescribed burns outweighed carbon released during fires.

Emissions changes in carbon pools [25] in native forests changed from a net sink in 2009 to a net source of emissions from 2010 to 2013. This was due to soils becoming a significant source of emissions from 2009 to 2014 as a change to wetter climate conditions during that period increased emissions from soils[26], overwhelming the contribution of living biomass and dead organic matter from 2010 to 2013. While soil emissions vary between a net sink or net source due to factors including temperature, moisture, clay and plant cover; removals from living biomass have been increasing since the mid-1990s due to reductions in native forest harvesting. This has contributed to the large net sink observed over the last five years between 2017 and 2021.

Figure 47: Net emissions from fire (wildfire and controlled burning) and other sources – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Note: Non-anthropogenic natural disturbances including some but not all wildfires are reported as a long-running trend in emissions, reflecting the balance of carbon lost and later reabsorbed by future regrowth. This approach is in accordance with the 'natural disturbance' provision of IPCC accounting rules and leaves anthropogenic emissions and removals as the main drivers.

b. Land converted to forest land

This sub-category includes net emissions/removals from:

- plantations established since 1990, which are mainly hardwood;
- environmental plantings established since 1990;
- regrowth of forest on land cleared for cropping or grazing; and
- regeneration of areas cleared of forest since 1972 from natural seed stocks. This may be a combination of regeneration for environmental purposes on protected land or on land that is maintained by the landowner. Regeneration on land cleared prior to 1990 is also captured in this sub-category.

Removals from this sub-category increased from 2020 to 2021, from 6.1 Mt CO_2-e to 8.0 Mt CO_2-e.

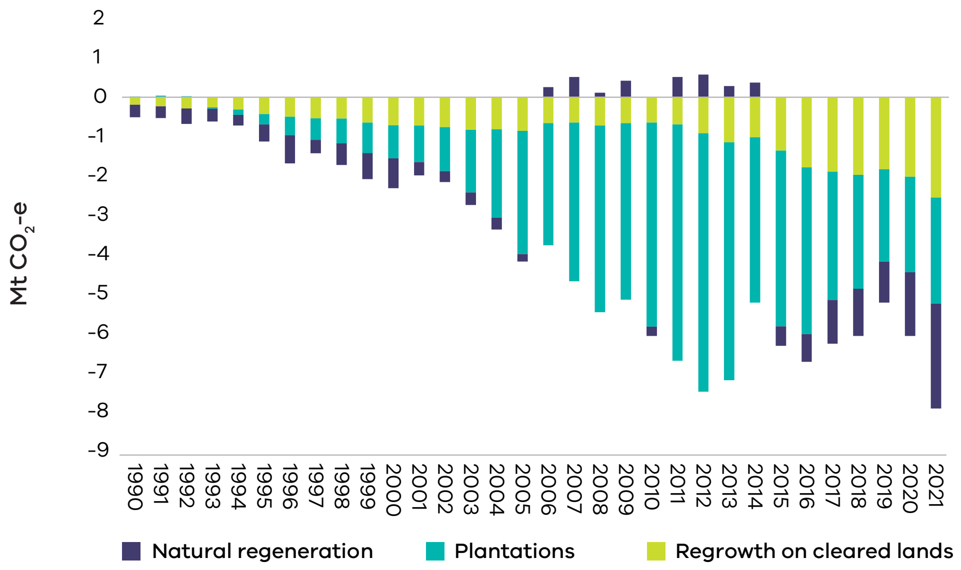
Over the past three decades, removals from plantations has increased significantly (Figure 48) in line with the rapid expansion of hardwood plantations in response to the Commonwealth Government's *Managed Investment Act 1998*, which increased the finance available for plantation establishment. *The Managed Investment Act* was repealed in 2016, after which the rate of plantation establishment in Victoria was close to zero from 2013 to 2018. Following the repeal of the *Managed Investment Act*, new plantations have been re-established from 2019 (ABARES, 2022).

Removals through regrowth on cleared land generally increased after 1990, and particularly so after 2012. Natural regeneration has been a source of both emissions and removals between 1990 and 2021. The years where natural regeneration was a net emissions source were due to the impacts of disturbances such as temporary forest dieback caused by factors like disease, insect attack and stressful climate conditions. Natural regeneration has record levels of removals in 2021 as La Nina conditions contributed to good growing conditions that increased forest cover.

25 Carbon pools are made up of living biomass (i.e. trees), soils and dead organic matter.

26 Wetter climate conditions (in combination with other factors) can stimulate microbial activity in soils, resulting in higher emissions from soil microbes.

Figure 48: Net emissions from land converted to forest land – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

c. Grassland remaining grassland

In Victoria, grassland remaining grassland includes:

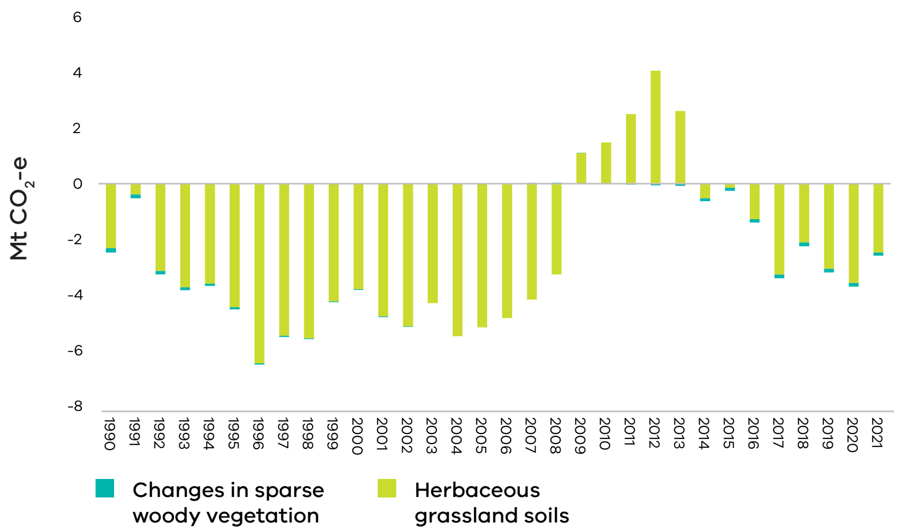
- herbaceous grassland (soil carbon);
- changes in sparse woody or shrubland extent (i.e. increases or losses of woody vegetation not categorised as forest); and
- biomass burning.

Removals from this sub-category decreased by 1.1 Mt CO_2-e from 2020 to 2021, from 3.7 Mt CO_2-e to 2.6 Mt CO_2-e.

Herbaceous grassland soils are the dominant contributor to emissions and removals in this sub-category contributing 96.3% of removals in 2021. Herbaceous grassland soils changed from providing net removals from 1990 to 2008 to a net source of emissions from 2009 to 2013 – wetter climatic conditions may have contributed to this change (Figure 49).

Permanent changes in land management practices generate changes in the levels of soil carbon or woody biomass stocks. Over time the carbon stocks will reach a new equilibrium and the rate of net emissions or removals associated with the changed management practice will approach zero.

Figure 49: Net emissions from grassland remaining grassland – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

d. Forest land converted to cropland, grassland, wetlands and settlements

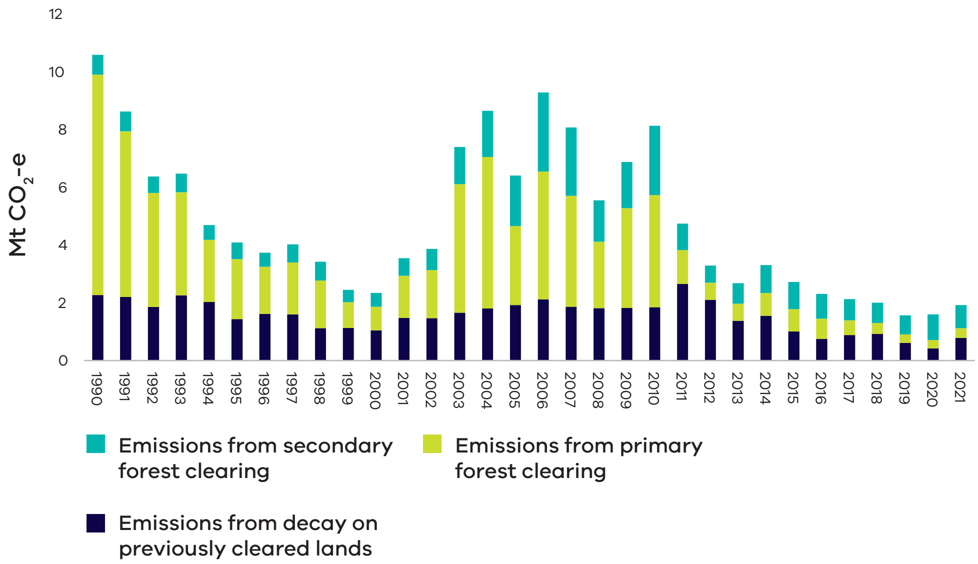
This sub-category includes the following:

- emissions from the primary conversion of land that was forested in 1972;
- emissions from secondary or re-clearance of forest which has regrown on cleared land – where forest regrows on converted lands, the removals are included in the sub-category land converted to forest; and
- indirect emissions from loss of soil carbon and other emissions and removals associated with the new land use, including emissions from decaying organic matter. Indirect emissions are highest in the two years after clearing and then decline. Non-CO_2 emissions associated with application of fertilisers and the management of crops are accounted for in the agriculture sector.

Emissions from this sub-category increased by 0.3 Mt CO_2-e from 2020 to 2021, from 1.6 Mt CO_2-e to 1.9 Mt CO_2-e (Figure 50).

The primary drivers of trends in this sub-category are primary forest clearing, farmers' terms of trade and weather conditions. Long-standing regulations on land clearing have assisted in constraining the emissions from this sub-category.

Figure 50: Sources of emissions and removals from forest land converted to cropland, grassland, wetlands and settlements – Victoria, 1990 to 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

Uncertainty in LULUCF emissions estimates

Uncertainty is a characteristic of any estimation process. According to *Australia's National Greenhouse Gas Inventory 2021* (NGGI), the estimated uncertainties for total net emissions in 2021 emissions are:

- +/- 3.5% excluding net emissions from LULUCF; and
- +/- 5.7% when LULUCF is included.

The higher uncertainty associated with LULUCF is due to the complexity of biological processes, the measurement and data collection techniques and the challenges of representing biological processes in mathematical models.

It is not practicable to directly measure emissions and removals in the LULUCF sector. Instead, the Full Carbon Accounting Model (FullCAM) is used to estimate emissions and removals arising from changes in above and below ground biomass, dead organic matter, soil carbon and changes in land use and management techniques.

FullCAM uses data on climate, soils and land management practices, as well as land use changes observed from satellite imagery, and is supplemented by additional data and models as appropriate.

The overarching approach to estimating net emissions in the LULUCF sector is continually reviewed by the DCCEEW, with changes being made to both the assumptions in FullCAM as knowledge advances; and to data as improved information becomes available.

When changes are made, these are applied to the historical data series back to 1990. Appendix A describes the main methodological changes between the *Victorian Greenhouse Gas Emissions Report 2020* and the current (2021) report and the impact they have had on LULUCF emissions data between 1990 and 2020.

Changes will continue to occur in future years as further improvements in estimation methods occur.

Updated historical LULUCF data

The LULUCF emissions presented in this report for the years 1990 to 2020 differ from those in the Victorian Greenhouse Gas Emissions Report 2020 due to improvements in data and emissions estimation methodologies. These include:

- Spatial data and time-series updates – Affecting the rate of tree growth in local growing conditions, resulting in increased tree growth in recent years;
- FullCAM updates – Function update and general improvements in system reliability; and
- Updated data sets – Addition of activity data and climate data for 2021–22 and annual updates to spatial datasets based on recent satellite observations.

Information on the recalculations involved is presented in Appendix A.

3 Emissions by economic sector – 2021

Chapter 2 presented emissions data based on sectors defined in accordance with IPCC guidelines. This chapter presents information on Victoria's emissions by economic sector defined in accordance with the following Australian and New Zealand Standard Industry Classification (ANZSIC) divisions:

- electricity, gas, water and waste services
- manufacturing
- commercial services
- agriculture, forestry and fishing
- transport, postal and warehousing
- mining
- construction
- residential.

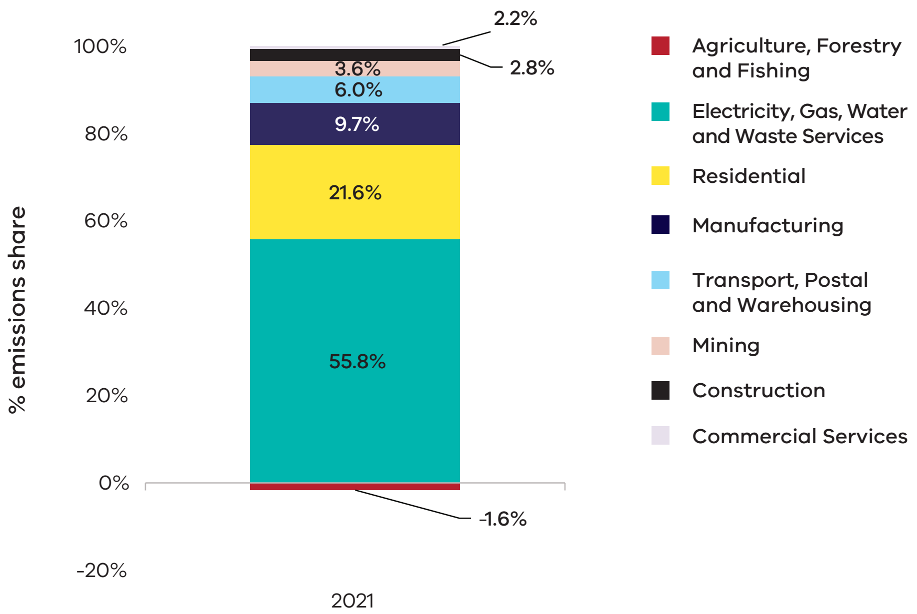
3.1 Direct (Scope 1) emissions by economic sector

Direct emissions (also known as Scope 1 emissions) result from an activity within an entity's own operational boundary – for example:

- Direct emissions from manufacturing include emissions resulting from combustion of fuels, transport, waste management and greenhouse gas leakage from industrial processes directly related to manufacturing processes such as the production of food, paper, textiles and chemicals.
- Direct emissions from agriculture, forestry and fishing include emissions from activities such as the application of fertilisers, livestock management and the combustion of fuels. It also includes emissions and removals of CO_2 from forest and grassland management.
- Direct emissions from the residential sector include emissions from transport activities, the consumption of gas for heating and cooking and emissions associated with the use of waste and wastewater services.

Figure 51 shows that in 2021, the electricity, gas and water supply sector (56%) was responsible for the largest share of Victoria's direct emissions, followed by the residential sector (22%), manufacturing (10%) and transport, postal and warehousing (6%).

Figure 51: Share of Scope 1 emissions by economic sector – Victoria, 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

3.2 Allocation of Scope 2 emissions from electricity generation to end-users

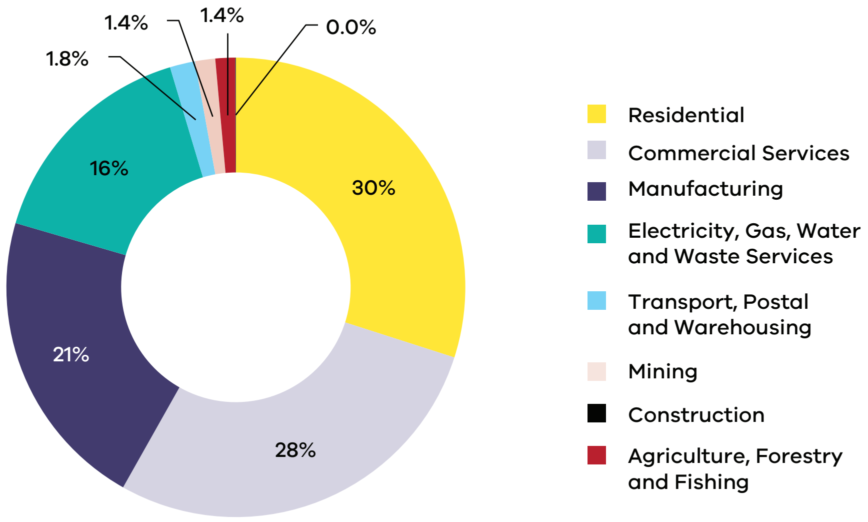
In this section, emissions resulting from electricity generation are allocated to economic sectors according to the volume of electricity consumed by each sector. The emissions attributable to electricity consumption are referred to as indirect or Scope 2 emissions.

Information on sectoral responsibility for Scope 2 emissions enables a deeper understanding of the demand drivers responsible for electricity sector emissions.

Figure 52 shows that in 2021, the residential sector (30%) was responsible for the largest share of Scope 2 emissions, followed by the commercial (28%) and manufacturing (21%) sectors. The electricity, gas, water and waste services sector (16%) includes emissions associated with electricity consumed by this sector for its own use.

Note: Unlike the emissions accounting reflected in Chapter 2 in which emissions from electricity generation are accounted for in the state or territory where generation takes place, the approach to allocating Scope 2 emissions to end-use economic sectors takes into account net imports and exports of electricity between jurisdictions through the National Electricity Market. Scope 2 emissions factors reflect data on electricity generation and emissions in each state or territory.

Figure 52: Share of Scope 2 emissions by economic sector - Victoria, 20211



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

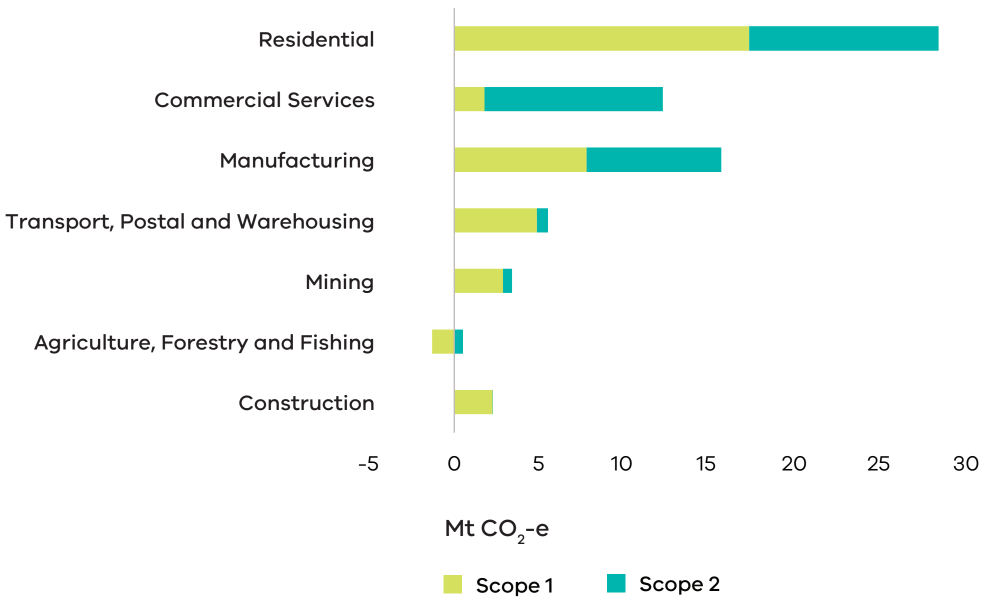
3.3 Scope 1 plus Scope 2 emissions by economic sector

This section combines the analysis in the previous two sections to allocate Scope 1 plus Scope 2 emissions to each economic sector.

Consistent with DCCEEW's approach to the National Greenhouse Gas Inventory, the electricity, gas, water and waste services sector is excluded from this allocation process to avoid double counting of Scope 1 emissions from electricity generation which are fully allocated to other sectors that consume the electricity [27].

Figure 53 shows that in 2021, the residential sector was responsible for the largest share of Scope 1 plus Scope 2 emissions (28.3 Mt CO_2-e, 43%), followed by commercial services (12.2 Mt CO_2-e, 18%) and manufacturing (15.6 Mt CO_2-e, 24%).

Figure 53: Scope 1 plus Scope 2 emissions by economic sector - Victoria, 2021



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e)

[27] The electricity, gas, water and waste services sector's Scope 2 emissions include own use by electricity generators that does not necessarily meet the National Greenhouse Accounts (NGA) Factors 2020 definition of scope 2 emissions.

Appendix A: Revision of historical greenhouse gas emissions data

DCCEEW reviews and, as necessary, revises national, state and territory greenhouse gas data annually to ensure that the data are produced in a manner consistent with the latest international methods, and to reflect improved estimation methods and new sources of information as these become available. To maintain consistency of data series across time, when revisions occur, past emission estimates are recalculated for all years in the historical record up to 1990.

This review process has resulted in revised emission data for Victoria from 1990 to 2020, particularly for Fuel Combustion and LULUCF. Consequently, data for 1990 to 2020 in this year's report differ from those presented in the Victorian Greenhouse Gas Emissions Report 2020.

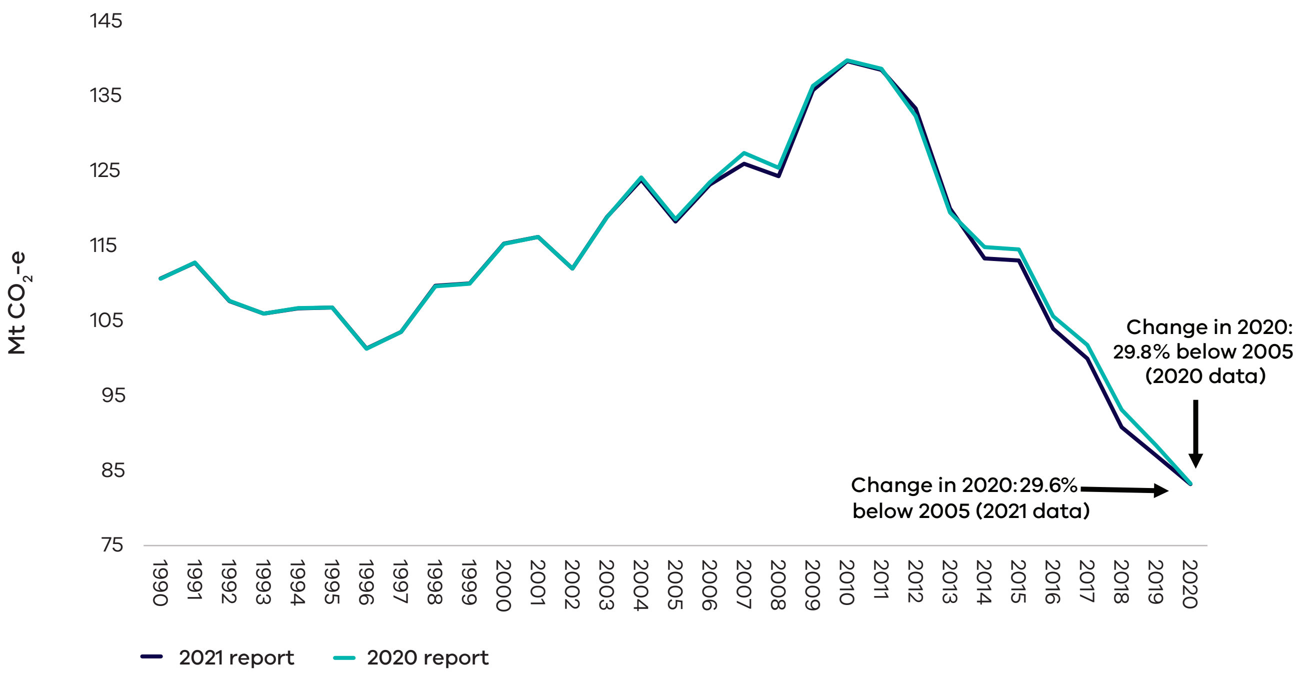
A summary of these recalculations by sector, together with an explanation of the changes, is pre-sented in Table 10.1 of the *National Inventory Report 2021* (DCCEEW, 2023d).

The most significant changes to note in relation to Victoria are the following:

- Fuel combustion
  - Updates to Australia's official statistics on energy production and use, including for time series consistency, carried out to support improved understanding of Australia's energy systems. These updates mean emissions have been revised down—particularly in the commercial/institutional and residential subsectors.
- LULUCF
  - A change to the spatial data and time-series affecting the rate of tree growth based on seasonal and inter-annual variations in local growing conditions, which resulted in increased tree growth in recent years and a corresponding increase to CO_2 removals.
  - Updates to FullCAM function (particularly, in relation to temperate fire simulations) and general improvements in system reliability.
  - Data updates to include the addition of activity data and climate data for 2021-22 and annual updates to spatial datasets based on recent satellite observations. This resulted in a re-allocation of lands between land use categories; and thus recalculations across most subsectors.
  - Continuing improvement in the reservoir methane model to improve accuracy.

The trend in Victoria's total net emissions between 1990 and 2020 as presented in the *Victorian Greenhouse Gas Emissions Report 2020* and the current (2021) report is shown below (Figure 54).

Figure 54: Changes in trends in Victoria's total net emissions between 2005 and 2021 in the 2021 and 2020 Victorian Greenhouse Gas Emissions Reports



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and State and Territory Greenhouse Gas Inventories 2020 (DCCEEW, 2023c)

The impacts of these changes in 2005 and 2020 show the following (Table 2):

- Total net emissions in 2005 have been revised from 118.6 Mt CO_2-e to 118.2 Mt CO_2-e (a reduction of 0.3 Mt CO_2-e); and
- Total net emissions in 2020 have been revised from 83.3 Mt CO_2-e to 83.2 Mt CO_2-e (a reduction of 0.07 Mt CO_2-e).

Consequently, the *Victorian Greenhouse Gas Emissions Report 2021* shows that Victoria's total net emissions in 2020 were 29.6% below 2005 levels while the *Victorian Greenhouse Gas Emissions Report 2020* reported a reduction of 29.8% between 2005 and 2020.

Table 2: Changes in emissions by sector between 2005 and 2020 as reported in 2021 vs 2020 Victorian Greenhouse Gas Emissions Reports

Sector/subsector	Change in emissions (Mt CO_2-e)	
	2005	**2020**
Electricity generation	0.00	0.07
Fuel combustion	0.00	-1.15
Transport	0.00	-0.02
Fugitive emissions	0.00	0.00
IPPU	0.01	0.00
Agriculture	0.00	0.05
LULUCF	-0.31	0.97
Waste	**-0.05**	**0.02**
Total	**-0.34**	**-0.07**

Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and State and Territory Greenhouse Gas Inventories 2020 (DCCEEW, 2023c)

While there have been minor changes in historical data in most sectors and subsectors, the most significant changes were:

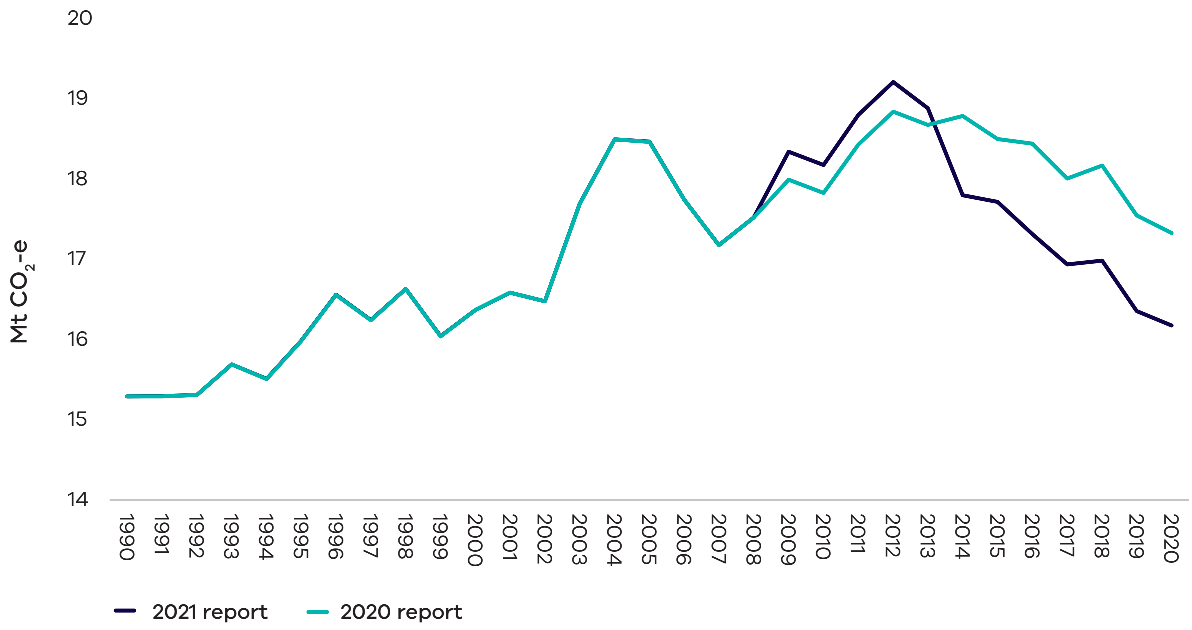
- in fuel combustion, with an estimated emissions decrease by 1.15 Mt CO_2-e in 2020 in the 2021 emissions report from the 2020 report.
- in LULUCF, with an estimated net removal increase of 0.31 Mt CO_2-e in 2005 and net emissions increase of 0.97 Mt CO_2-e in 2020 in the 2021 report from the 2020 report.

Further detail on the changes in the fuel combustion and LULUCF data is presented in Appendices A.1 and A.2 respectively.

A.1 Historical fuel combustion data revisions detail

The trend in fuel combustion emissions between 1990 and 2020 as presented in the 2020 and 2021 reports is shown below (Figure 55).

Figure 55: Changes in trends in fuel combustion emissions between 1990 and 2020 in the 2021 v 2020 Victorian Greenhouse Gas Emissions Reports



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and State and Territory Greenhouse Gas Inventories 2020 (DCCEEW, 2022c)

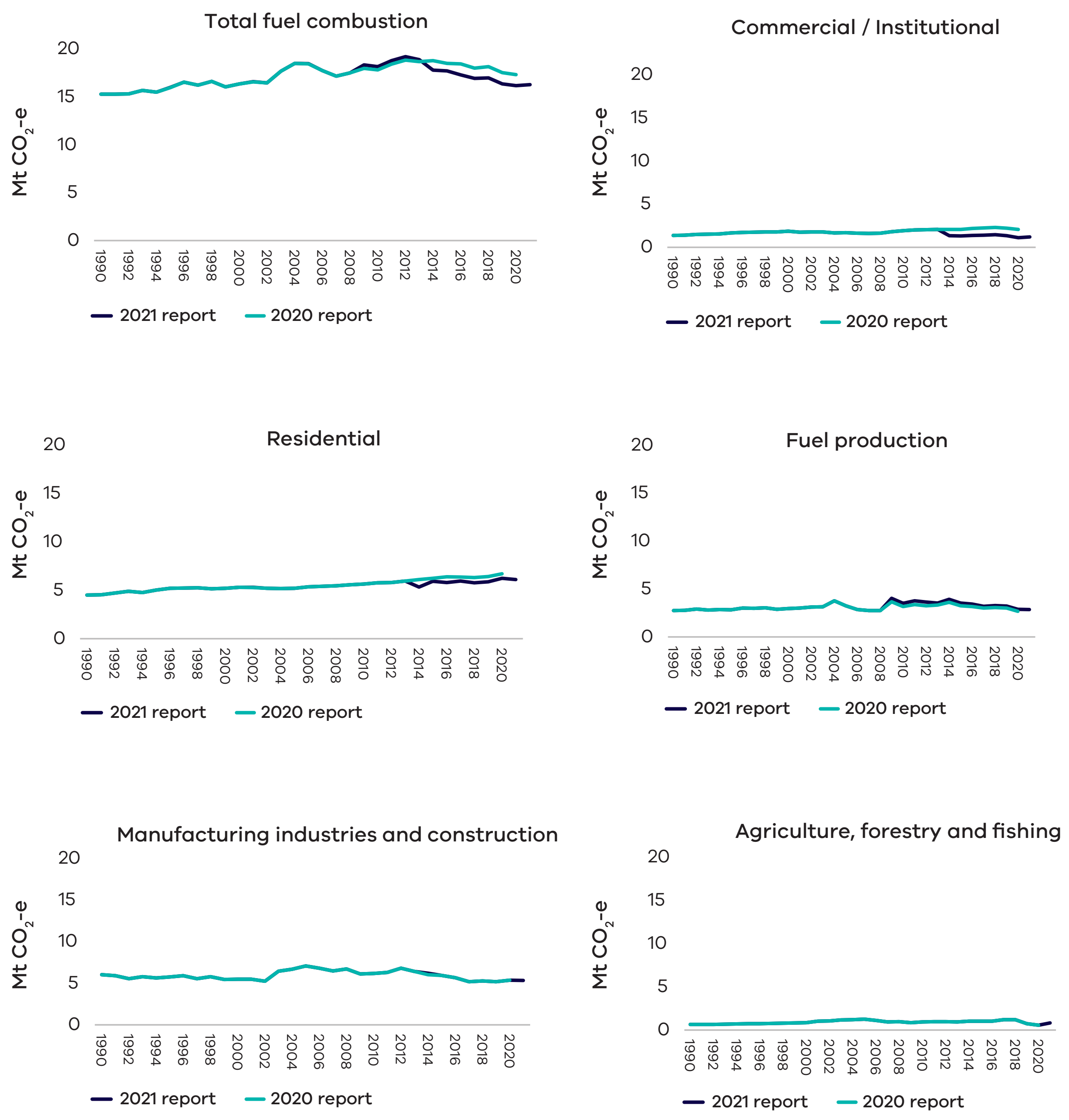
Australia's official statistics on energy production and use (AES) received a periodic update to support improved understanding of Australia's energy systems (Figure 56). These updates are reflected in the inventory.

Changes by Fuel Combustion sub-category

Data are disaggregated according to major fuel combustion sub-categories (Figure 56) as follows:

- Commercial/institutional, residential and fuel production subsectors—emissions in this category are estimated based on fuel combustion reported in the AES, which has been recently updated. Adjustments were made to the historical data in the 2021 report, compared to the 2020 report, resulting in a particularly noticeable decrease around 2014 onwards. There has also been a time series reallocation of emissions from the combustion of lubricants from the category non-energy use of fuels to residential sector, which includes residential equip-ment such as mowers and off-road vehicles.

Figure 56: Emissions from Victoria's main fuel combustion sub-categories: comparison between 2020 and 2021 Victorian Greenhouse Gas Emissions Reports

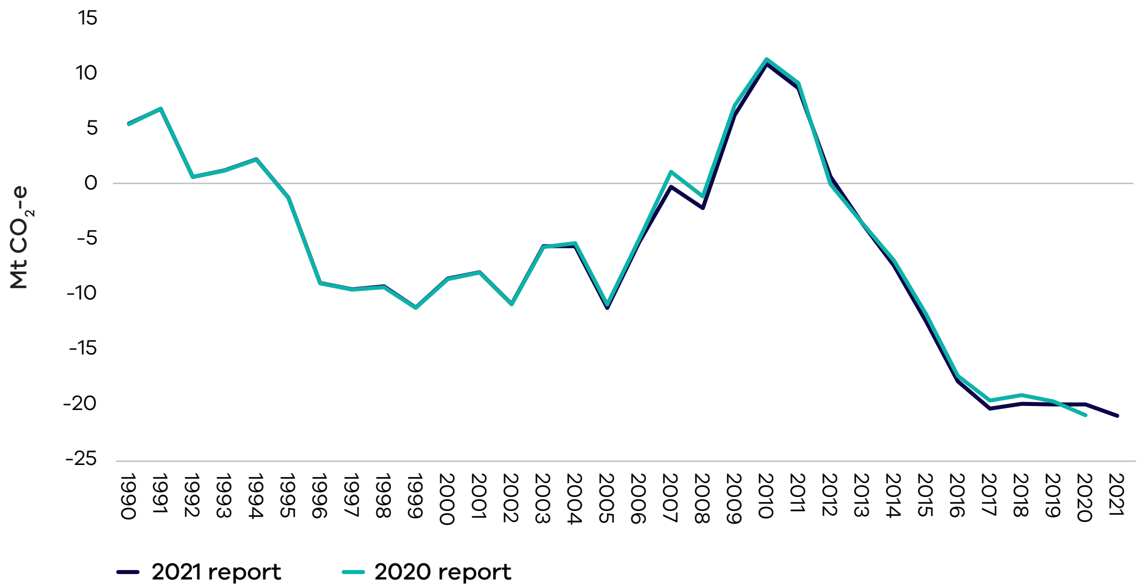


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and State and Territory Greenhouse Gas Inventories 2020 (DCCEEW, 2022c).

A.2 Historical LULUCF data revisions detail

The trend in LULUCF emissions between 1990 and 2020 as presented in the 2020 and 2021 reports is shown below (Figure 57).

Figure 57: Changes in trends in LULUCF emissions between 1990 and 2020 in the 2021 v 2020 Victorian Greenhouse Gas Emissions Reports

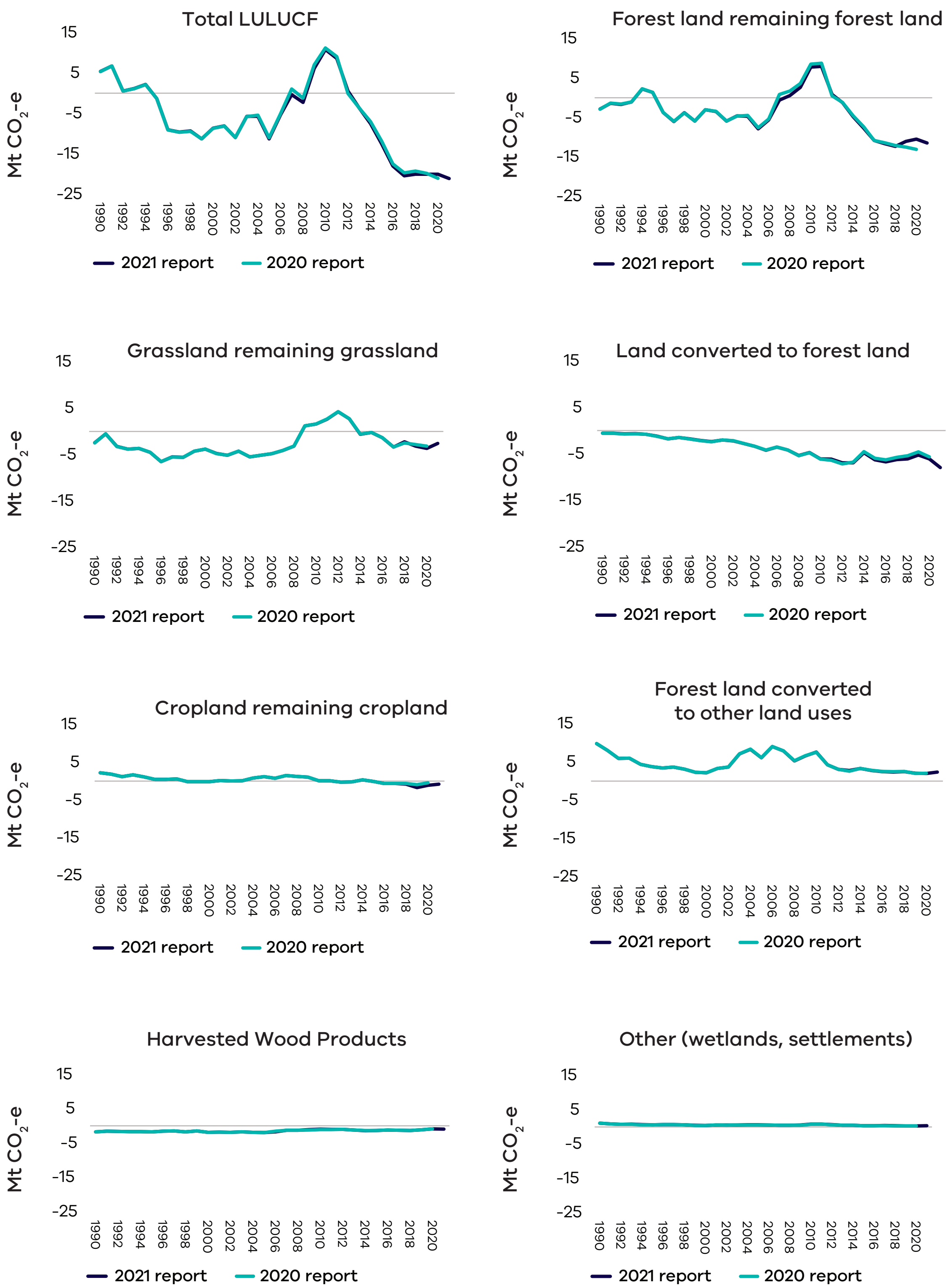


Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and State and Territory Greenhouse Gas Inventories 2020 (DCCEEW, 2022c)

Changes by LULUCF sub-category

There are a range of technical updates applied to the LULUCF sector including refinement of tree growth modelling as new spatial data allowed for calibration of formulas, improved accuracy modelling fire events in temperate forests and allocation of lands between land use sub-categories based on satellite observations. Data are disaggregated according to LULUCF sub-categories shown in Figure 58.

Figure 58: Emissions from Victoria's main LULUCF sub-categories: comparison between 2020 and 2021 reports



Source: State and Territory Greenhouse Gas Inventories 2021 (DCCEEW, 2023e) and State and Territory Greenhouse Gas Inventories 2020 (DCCEEW, 2022c)

Abbreviations and acronyms

ABS	Australian Bureau of Statistics
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AES	Australian Energy Statistics
ANZSIC	Australian and New Zealand Standard Industrial Classification
BITRE	Bureau of Infrastructure and Transport Research Economics
CER	Clean Energy Regulator
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEECA	Victorian State Department of Energy, Environment and Climate Action
FullCAM	Full Carbon Accounting Model
GPG	Gas-powered generation
GSP	Gross State Product
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
LULUCF	Land use, land use change and forestry
Mt	Million tonnes
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
ODS	Ozone-Depleting Substances
PFCs	Perfluorocarbons
PJ	Petajoules
SF_6	Sulphur hexafluorides
The Act	Climate Change Act 2017
UNFCCC	United Nations Framework Convention on Climate Change

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