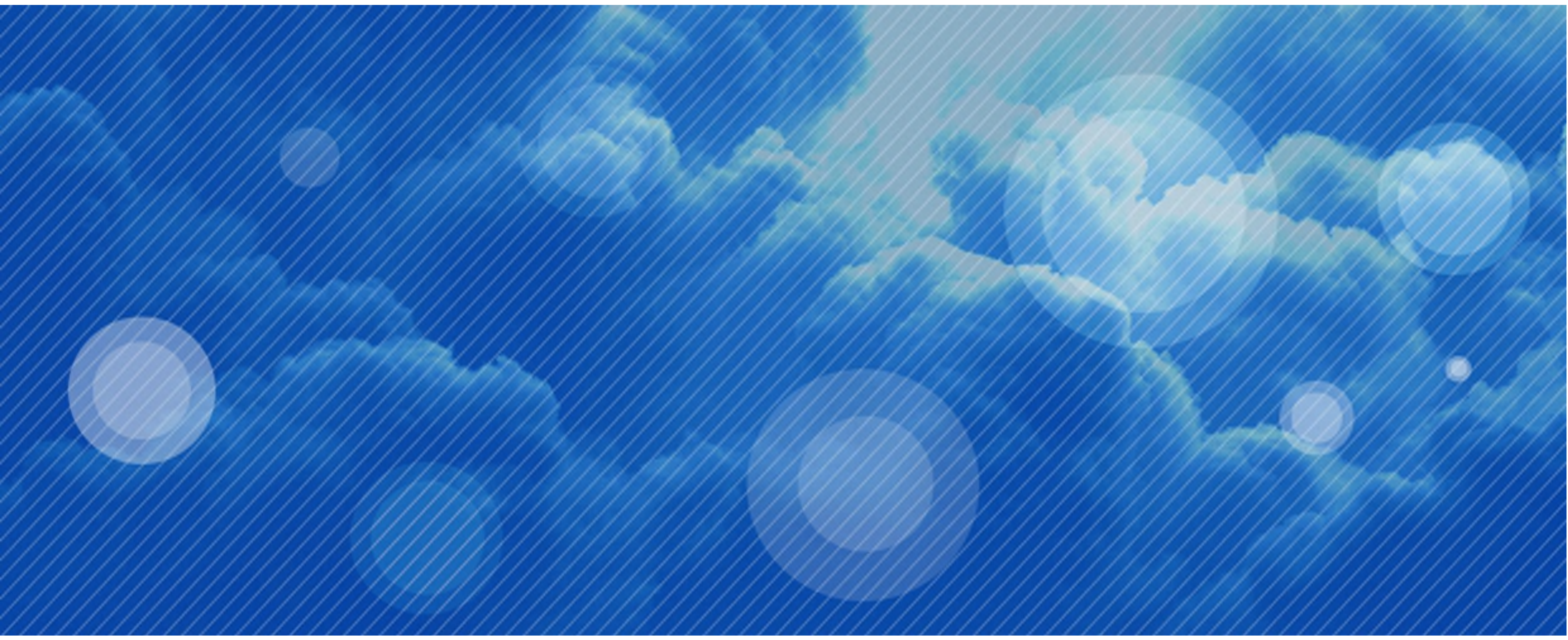
Australian Government
Department of Industry, Science, Energy and Resources

Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2020

Incorporating emissions from the NEM up to December 2020

Australia's National Greenhouse Accounts



Disclaimer

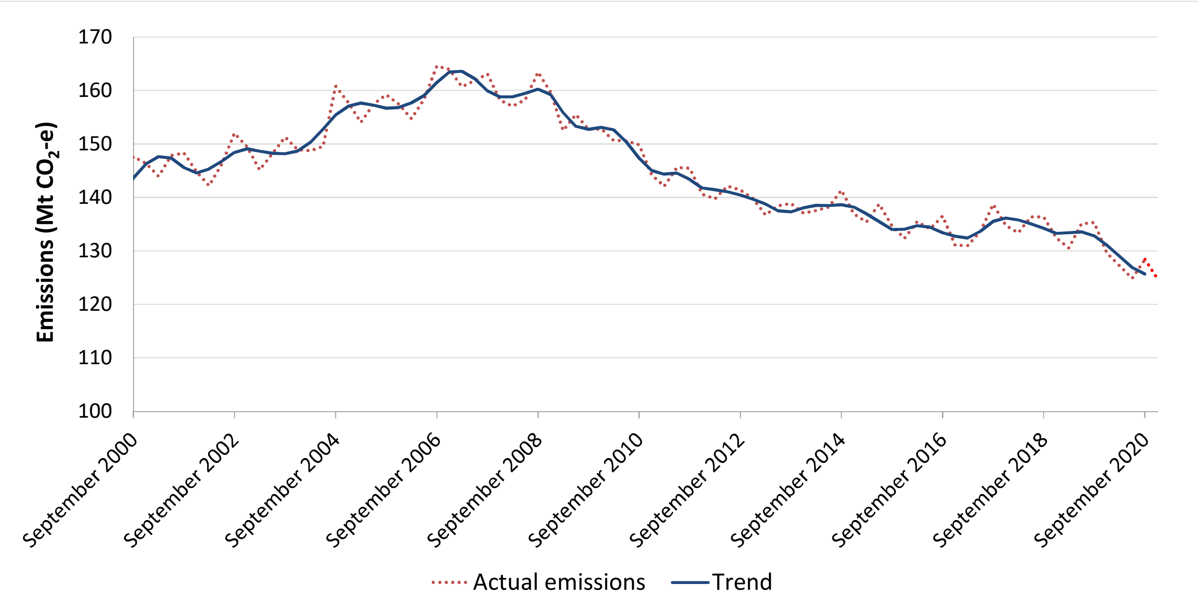
Preface

The *Quarterly Update* provides estimates of Australia's national inventory of greenhouse gas emissions up to the September quarter of 2020, and preliminary estimates of emissions for the December quarter 2020.

Emissions for the year to September 2020 are estimated to be 510.1 Mt CO_2-e, down 4.4 per cent or 23.3 Mt CO_2-e on the previous year. This decline in emissions reflects ongoing reductions in emissions from *electricity* (down 4.0 per cent) and *fugitive* emissions from fuel extraction (down 7.3 per cent) due, in part to a reduction in venting and flaring; and the short term effects of COVID restrictions on emissions from *transport* (which fell 10.2 per cent) and from last year's drought on *agriculture* (down 2.5 per cent).

Since their peak in the year to June 2007, Australia's greenhouse gas emissions have now declined 21.7 per cent. The emissions in the year to September were 8.1 per cent below emissions for the year to June 2000 and 19.0 per cent below emissions for the year to June 2005 (Figure P1).

Figure P1: Emissions[1], by quarter, September 2000 to September 2020 (including preliminary December 2020)



Source: Department of Industry, Science, Energy and ResourcesSource: Department of Industry, Science, Energy and Resources

On a quarterly basis, national emission levels[2] for the September quarter 2020 decreased 1.0 per cent or 1.2 Mt CO_2-e on the previous quarter, in trend terms[3]. On a seasonally adjusted and weather normalised basis, there were signs of recovery in activity and emissions (1.7 per cent) after the impacts of COVID on *transport* emissions (up 10.2 per cent) and from last year's drought on *agriculture* emissions (up 8.3 per cent), although preliminary data for the December quarter show total emissions falling again.

[1] 'Actual', 'seasonally adjusted, weather normalised' and 'trend' are defined in Section 5 - Technical notes

[2] National emissions levels are inclusive of all sectors of the economy, including Land Use, Land use Change and Forestry (LULUCF) and includes the application of the IPCC's natural disturbance provision.

[3] 'Actual', 'seasonally adjusted', 'weather normalised', and 'trend' are defined in Section 5: Technical Notes

In the year to September 2020, emissions per capita and the emissions intensity of the economy were at their lowest levels in 30 years. Emissions per capita were lower than 1990 by 46.2 per cent while the emissions intensity of the economy was 65.6 per cent lower than in 1990.

In the December quarter, emissions from the National Electricity Market (NEM) decreased 3.9 per cent on a seasonally adjusted and weather normalised basis compared with the previous quarter and were 5.6 per cent lower over the year to December 2020 compared with the same period in 2019.

Overall, national emissions are preliminarily estimated to be 505 Mt in the year to December 2020, a decrease of 5 per cent on the previous year.

Contents

1. Overview

Table 1: National Greenhouse Gas Inventory[4], September quarter 2020, rates of change

	September quarter 2020	Year to September 2020
Quarterly change – seasonally adjusted and weather normalised[5]	1.7%	
Quarterly change – seasonally adjusted and weather normalised – trend	-1.0%	
Annual Change		-4.4%

Table 2: National Electricity Market (NEM)[6] , December quarter 2020, rates of change

	December quarter 2020	Year to December 2020
Quarterly change – seasonally adjusted and weather normalised	-3.9%	
Quarterly change – seasonally adjusted and weather normalised – trend	-2.0%	
Annual Change		-5.6%

Summary of emissions in the September quarter 2020

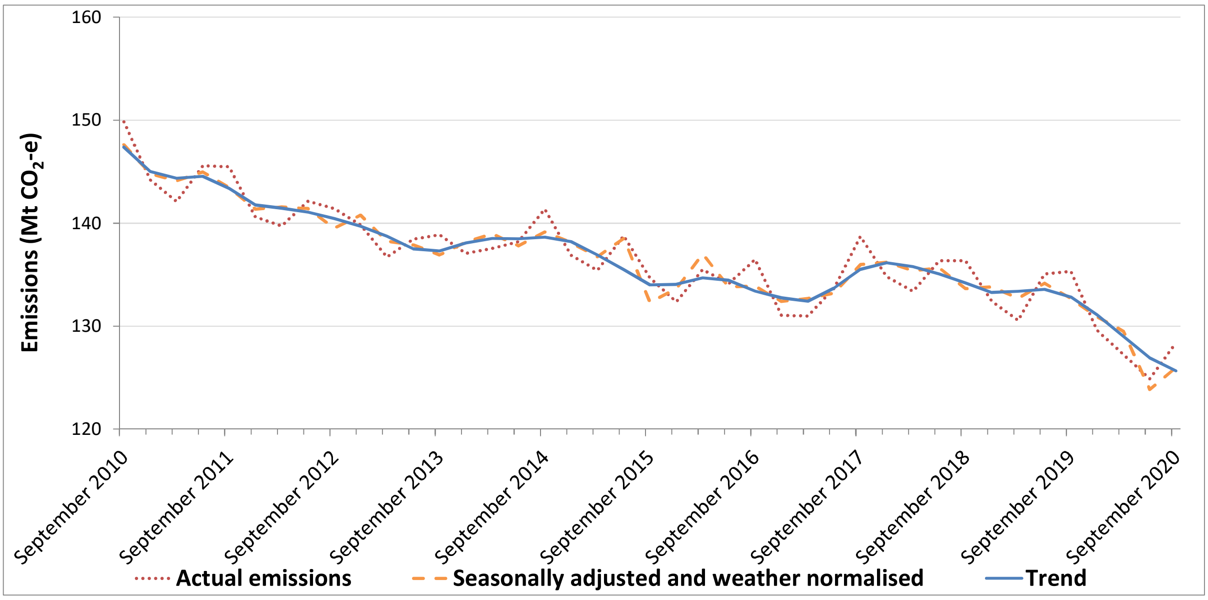
National emissions for the September quarter 2020 decreased 1.0 per cent or 1.2 Mt CO_2-e on the previous quarter in trend terms, mainly reflecting decreases in emissions from *transport*. On a seasonally adjusted and weather normalised basis, emissions were higher by 1.7 per cent or 2.1 Mt CO_2-e on the previous quarter, (Figure 1 and Figure 2) as there were strong rebounds in emissions from *transport* (10.2 per cent) as COVID related restrictions on movements have eased and from *agriculture* (8.3 per cent) as agricultural conditions have improved.

[4] National emissions levels are inclusive of all sectors of the economy, including *Land Use, Land Use Change and Forestry* (LULUCF).

[5] 'Actual', 'seasonally adjusted, weather normalised' and 'trend' are defined in Section 5: Technical notes

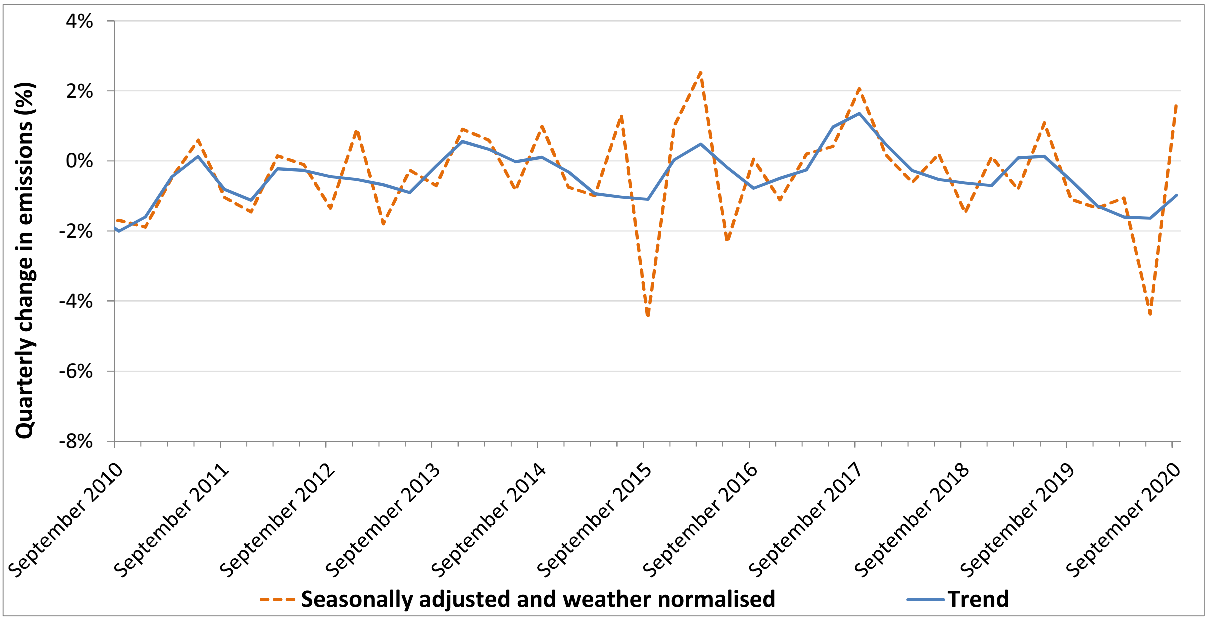
[6] The NEM includes grid electricity in the Eastern and South Eastern states and accounts for approximately 84 per cent of total *electricity* estimates in the year to December 2020.

Figure 1: Emissions[7], by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

Figure 2: Change in emissions, by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

[7] 'Seasonally adjusted', 'weather normalised', and 'trend' are defined in Section 5: Technical notes

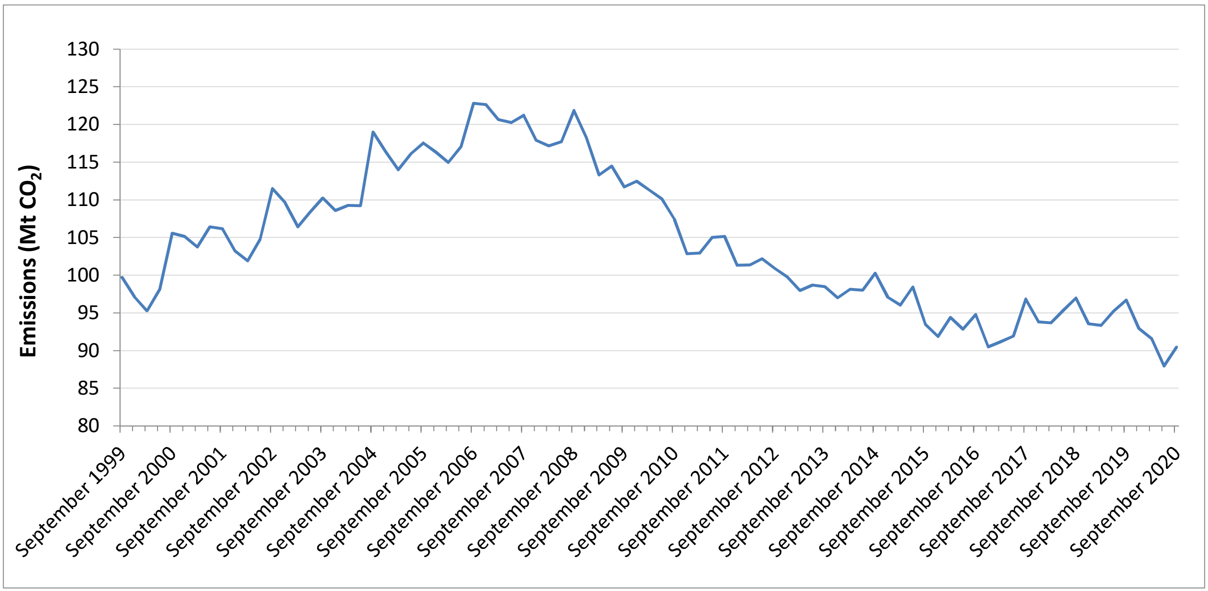
Summary of carbon dioxide emissions

Carbon dioxide contributes the largest share of aggregate emissions in Australia at around 70 per cent of total emissions.

Since September 2006, there has been a 26.4 per cent or 32.4 Mt decline in emissions of carbon dioxide to 90.4 Mt in September 2020 (Figure 3). The most important factors causing this long term decline in carbon dioxide emissions include the continuing shift in the generation of electricity towards renewable fuel sources, and away from coal, and decreasing emissions in the land sector.

Against these downward forces, the long term growth of emissions from transport activity and the expansion of LNG exports has placed upward pressure on this time series.

Figure 3: CO_2 Emissions, by quarter, September 1999 to September 2020



Source: Department of Industry, Science, Energy and Resources

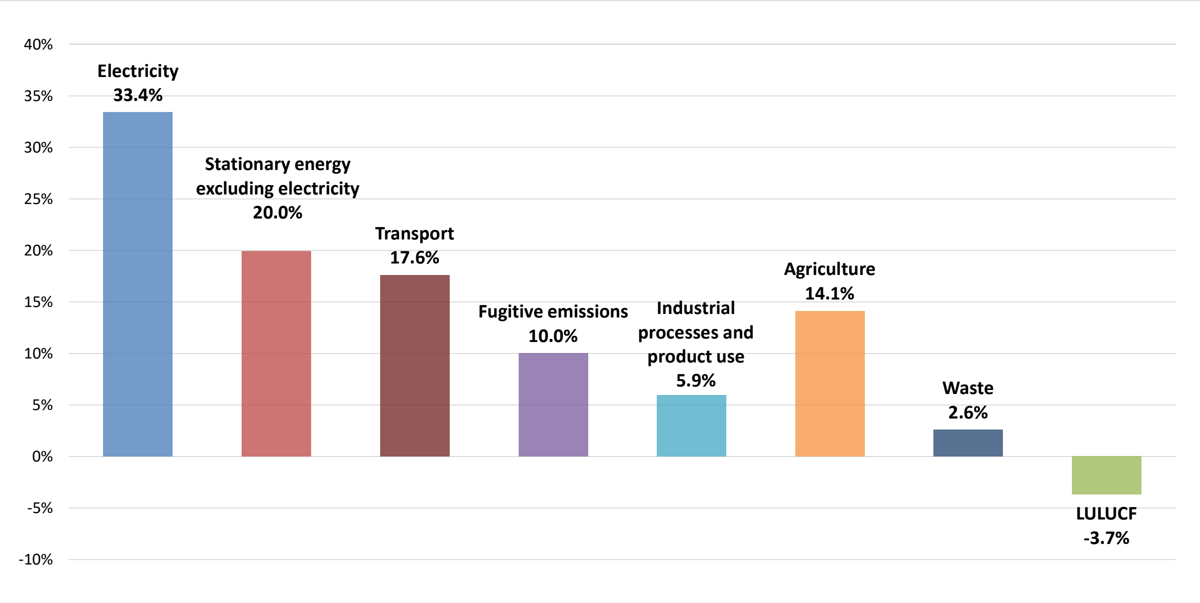
Summary of annual GHG emissions

Emissions for the year to September 2020 are estimated to be 510.1 Mt CO_2-e. The 4.4 per cent or 23.3 Mt CO_2-e decrease in emissions over the year to September reflects annual decreases in emissions from the *electricity, transport, fugitives, industrial processes, agriculture* and *waste* sectors. These decreases in emissions were partially offset by increases in emissions from the *stationary energy (excluding electricity)* and *land use, land use change and forestry* sectors (Table 3).

Table 3: 'Actual' annual emissions, by sector, for the year to September 2019 and 2020

Sector	Annual emissions (Mt CO_2-e)		Change (%)
	Year to September 2019	Year to September 2020	
Energy – Electricity	177.5	170.4	-4.0
Energy – Stationary energy excluding electricity	100.4	101.8	1.4
Energy – Transport	100.1	89.8	-10.2
Energy – Fugitive emissions	55.3	51.2	-7.3
Industrial processes and product use	32.2	30.3	-5.9
Agriculture	73.9	72.0	-2.5
Waste	13.6	13.3	-2.7
Land Use, Land Use Change and Forestry	-19.6	-18.8	4.1
National Inventory Total	**533.4**	**510.1**	**-4.4**

Figure 4: Share of total emissions, by sector, for the year to September 2020



Source: Department of Industry, Science, Energy and Resources

Over the year to September 2020 the 4.0 per cent decrease in emissions from the *electricity* sector was mainly due to a 4.7 per cent reduction in coal generation, and a corresponding 14.2 per cent increase in supply from renewable sources in the NEM.

Transport emissions decreased 10.2 per cent over the year to September reflecting a 10.7 per cent decrease in petrol consumption and a 37.2 per cent decrease in jet fuel consumption related to the COVID restrictions on movement.

The 2.5 per cent decline in emissions from the *agriculture* sector reflects the after-effects of the recent drought which led to a decline in livestock populations and fertiliser use.

Emissions from total export industries decreased 5.2 per cent (10.8 Mt CO_2-e) as a result of the plateauing of LNG exports, up just 1.0 per cent to 77.5 Mt of liquefied gas, and lower coal and agriculture exports. In addition, net fugitive emissions from LNG production declined over the same period due to reduced levels of venting and flaring.

In the year to December 2020, the preliminary estimate for total emissions is 505 Mt CO_2-e, which would be a decline of 5 per cent or 25 Mt CO_2-e on the year to December 2019.

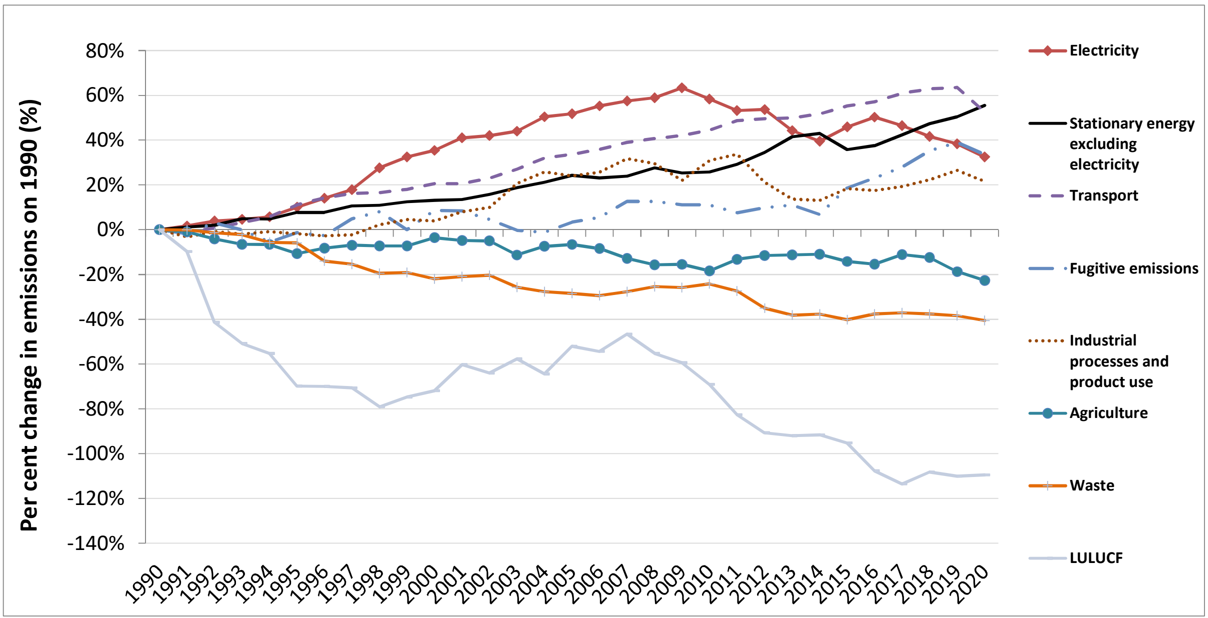
Long term sectoral trends

The most important sectoral drivers of Australia's long-term emissions trend have been:

- *Electricity* – where emissions have fallen by 19.5 per cent since June 2009, as renewables have displaced coal as a fuel source, reversing the long term increases experienced in earlier years;
- *Stationary energy (excluding electricity)* – where emissions experienced the largest increase in percentage terms since 1990. Emissions have increased 53.3 per cent or 35.4 Mt CO_2-e driven, in particular, by recent growth in the export of LNG;
- *Transport* - where emissions have increased 47.0 per cent or 28.7 Mt CO_2-e, despite recent volatility due to the impacts of the COVID pandemic in the June 2020 quarter;
- *Fugitives* – where emissions have increased 30.5 per cent or 12.0 Mt CO_2-e. Emissions were relatively stable until 2015 but have increased strongly as a result of the growth of the LNG industry;
- *Agriculture* – where emissions have declined by 21.5 per cent or 19.8 Mt CO_2-e in line with declining cattle and sheep populations; and,
- *Land Use, Land Use Change and Forestry (LULUCF)* – where emissions have decreased by the largest margin of any sector since 1990 (109.7 per cent or 212.4 Mt CO_2-e) due to reductions in land clearing and native forest harvesting and improvements in soil carbon.

The changes in emissions from each sector from the year to June 1990 to 2020 in percentage terms are presented in Figure 5.

Figure 5: Percentage change in emissions, by sector, since year to September 1990



Source: Department of Industry, Science, Energy and Resources

2. Sectoral Analysis

2.1. Energy – Electricity

Electricity generation is the largest source of emissions in the national inventory, accounting for 33.4 per cent of emissions in the year to September 2020 (Figure 4).

Electricity sector emissions are experiencing a long term decline, down 19.5 per cent (41.3 Mt CO_2-e) from the peak recorded in the year to June 2009 (Data Table 1A).

Electricity sector emissions increased 0.6 per cent in the September quarter of 2020 on a seasonally adjusted and weather normalised basis[8] (Figure 6). This reflected a 7.3 per cent decline in renewable generation and a consequent increase of 1.5 per cent in coal generation.

Over the course of the whole year to September 2020, emissions from *electricity* decreased 4.0 per cent compared with the year to September 2019, due to the ongoing substitution of renewable energy sources for coal-fired power.

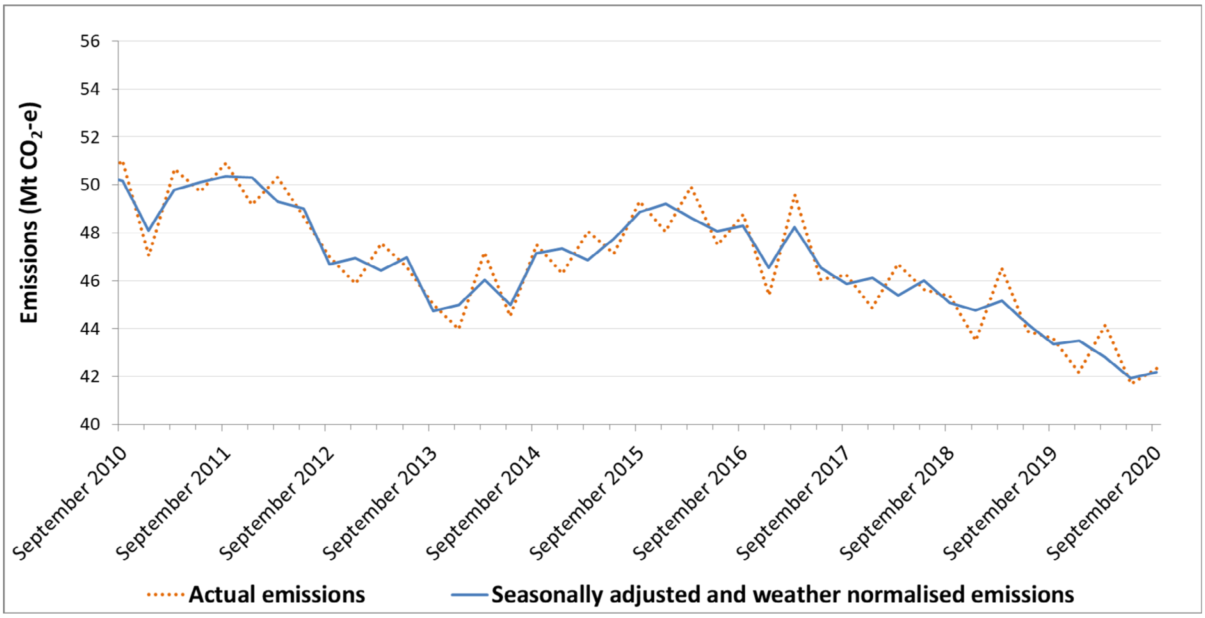
[8] Two adjustments are made:

a) Seasonal adjustment is a first-order adjustment using Eurostat software that systematically corrects emissions data for average fluctuations in seasonal conditions which, for example, controls for the effects of two seasonal peaks in electricity demand: one in winter (associated with demand for heating) and one in summer (associated with demand for cooling); and

b) Weather normalisation is a second-order adjustment that systematically corrects emissions data for atypical temperature effects on electricity demand within the year which, for example, controls for the effects of unusually cold winters or unusually hot summers.

The weather normalisation methodology is described in detail in 'Section 7: Special Topic' of the December 2011 *Quarterly Update*

Figure 6: *Electricity* sector emissions, by quarter, September 2010 to September 2020

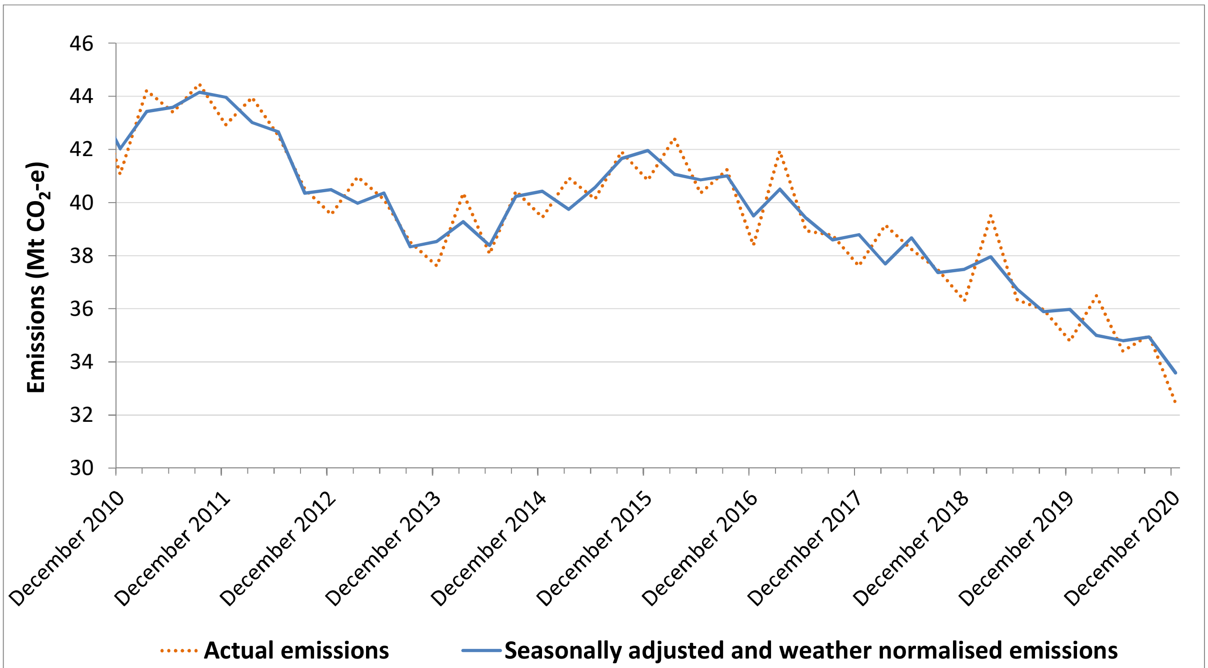


Source: Australian Energy Market Operator (AEMO, 2020), obtained using NEM-Review software

National Electricity Market (NEM) emissions

Emissions in the NEM for the December quarter 2020 decreased 3.9 per cent on a seasonally adjusted and weather normalised basis compared with the previous quarter (Figure 7).

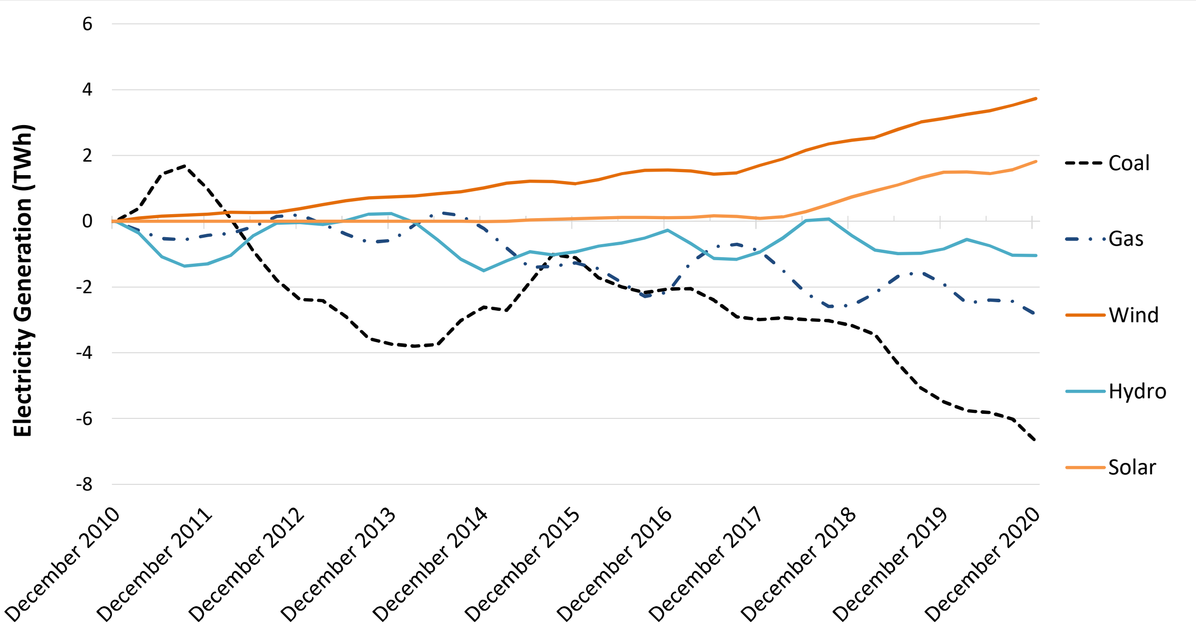
Figure 7: NEM *electricity* emissions, by quarter, December 2010 to December 2020



Source: Department of Industry, Science, Energy and Resources, Australian Energy Market Operator (AEMO, 2020), obtained using NEM-Review software

For the December 2020 quarter, generation from renewables increased 5.5 per cent in trend terms (Figure 8). This was due to increases in wind and solar generation.

Figure 8: Cumulative change in electricity generation in the NEM, trend, by fuel, by quarter, December 2010 to December 2020



Source: Australian Energy Market Operator (AEMO, 2020), obtained using NEM-Review software

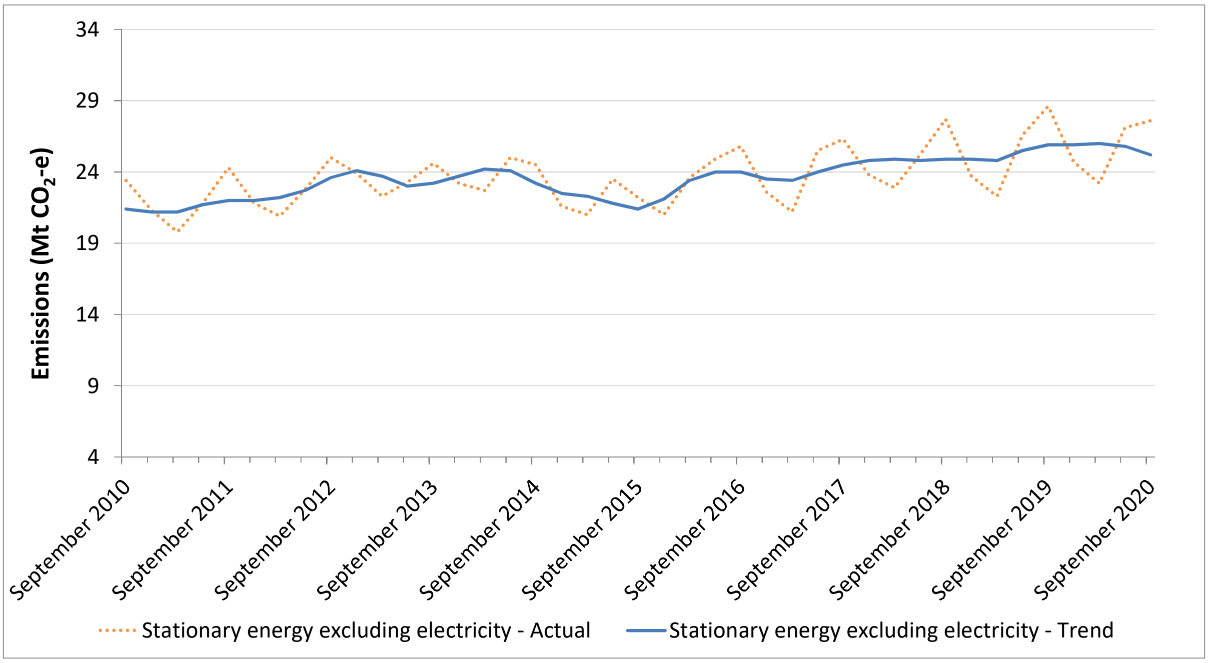
2.2. Energy – Stationary energy excluding electricity

Stationary energy excluding electricity includes emissions from direct combustion of fuels, predominantly from the manufacturing, mining, residential and commercial sectors.

In the year to September 2020, *stationary energy excluding electricity* accounted for 20.0 per cent of Australia's national inventory (Figure 4).

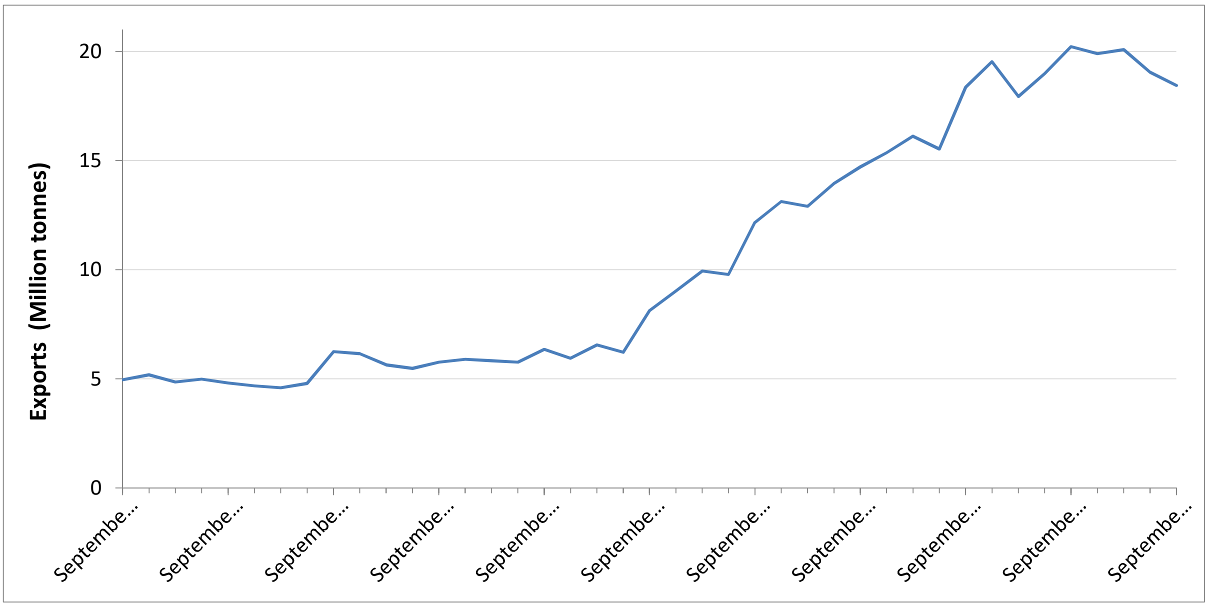
Emissions from *stationary energy excluding electricity* in the September quarter of 2020 decreased 2.1 per cent (0.5 Mt CO_2-e) in trend terms compared with the June quarter. Emissions over the year to September 2020, increased 1.7 per cent in trend terms when compared with the previous year (Figure 9) reflecting, in part, an increase in LNG exports in the year to September 2020 (Figure 10).

Figure 9: *Stationary energy excluding electricity* emissions, actual and trend, by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

Figure 10: LNG exports, by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

2.3. Energy – Transport

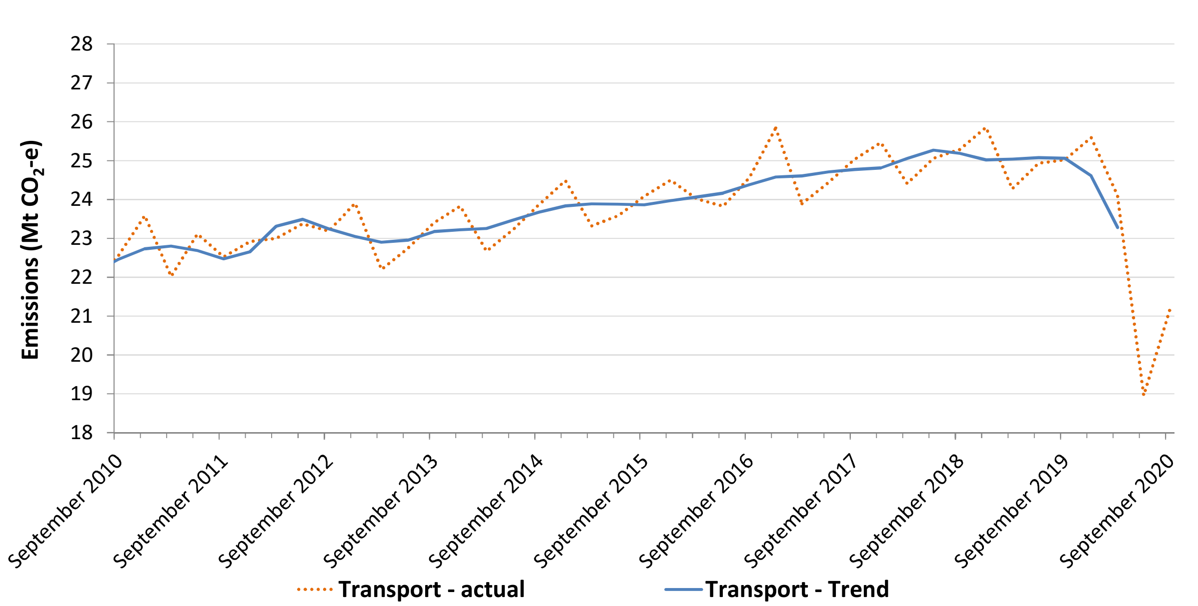
The transport sector includes emissions from the direct combustion of fuels in transportation by road, rail, domestic aviation and domestic shipping. The main fuels used for transport are automotive gasoline (petrol), diesel oil, liquefied petroleum gas (LPG) and aviation turbine fuel.

In the year to September 2020, transport accounted for 17.6 per cent of Australia's national inventory (Figure 4).

Emissions in the September 2020 quarter increased 11.7 per cent in actual terms on the June quarter 2020 recovering some of the declines experienced in the March and June quarters (Figure 11). This result reflects some degree of a return towards normal levels of transport activity following the most severe impacts from the restrictions on movement imposed in the June quarter.

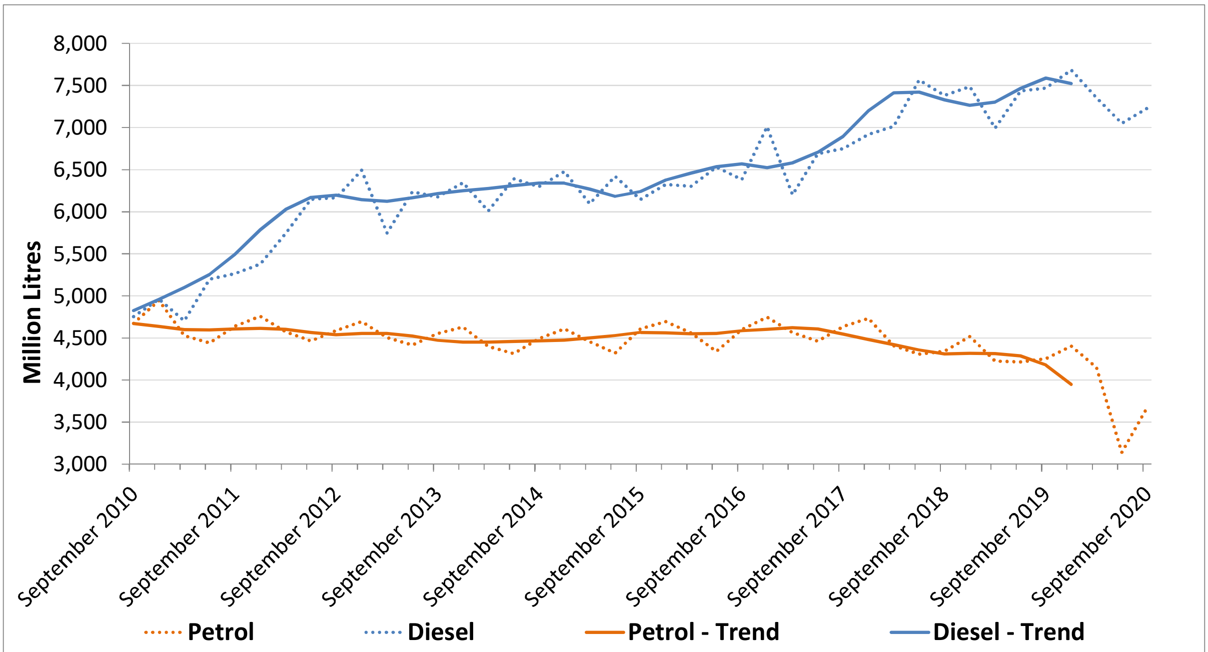
Emissions from transport over the year to September 2020 decreased 10.2 per cent when compared with the previous year. This decline in transport emissions was partly the result of a 10.7 per cent annual decline in petrol consumption associated with the impacts of the COVID pandemic and a decline of 0.2 per cent in diesel consumption (Figure 12).

Figure 11*: Transport* emissions, actual and trend, by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

Figure 12: Consumption of primary liquid fuels, actual and trend, by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

2.4. Energy – Fugitive emissions

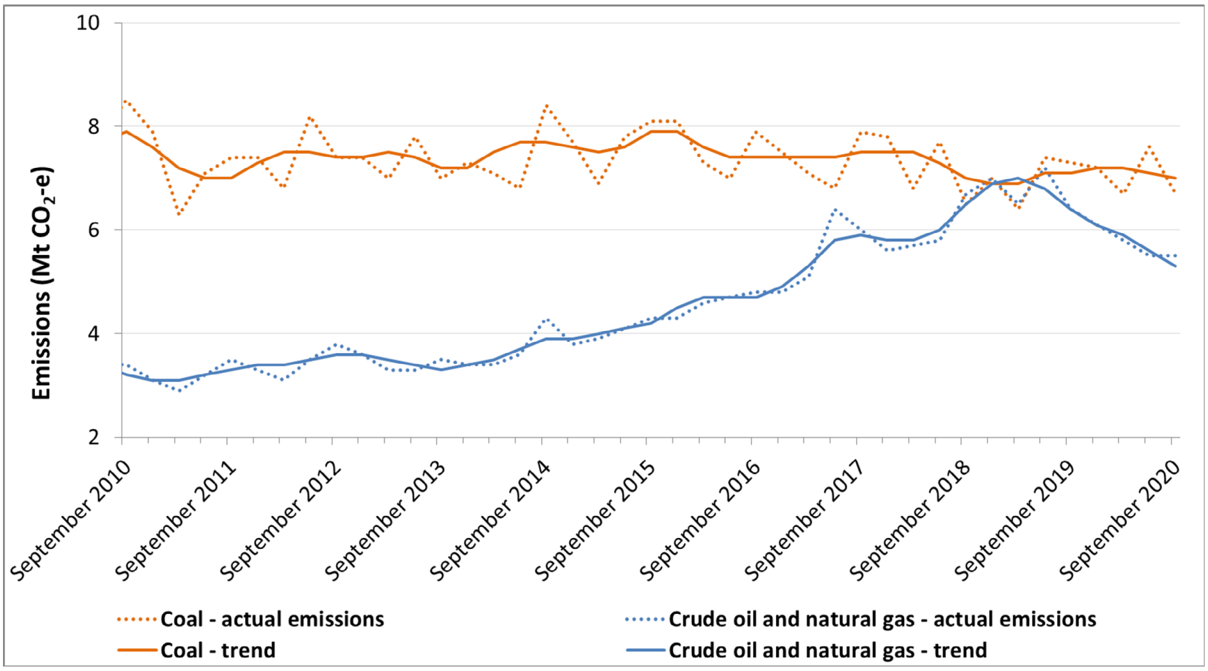
Fugitive emissions occur during the production, processing, transport, storage, transmission and distribution of fossil fuels. These include coal, crude oil and natural gas. Emissions from decommissioned underground coal mines are also included in this sector.

Fugitive emissions in the September quarter decreased by 4.3 per cent in trend terms.

Total gas production increased 0.4 per cent in the September 2020 quarter, while LNG exports decreased 3.2 per cent. Underground carbon dioxide injection from the Gorgon project and reduced levels of flaring acted to reduce fugitive emissions from the crude oil and natural gas sub-sector. Following a brief increase in coal production during the June 2020 quarter, coal production declined by 4.7 per cent in the September 2020 quarter contributing to the overall decrease in fugitive emissions.

Annual emissions in this sector decreased 7.3 per cent over the year to September 2020 (Figure 13).

Figure 13: *Fugitive* emissions, actual and trend, by sub-sector, by quarter September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

2.5. Industrial processes and product use

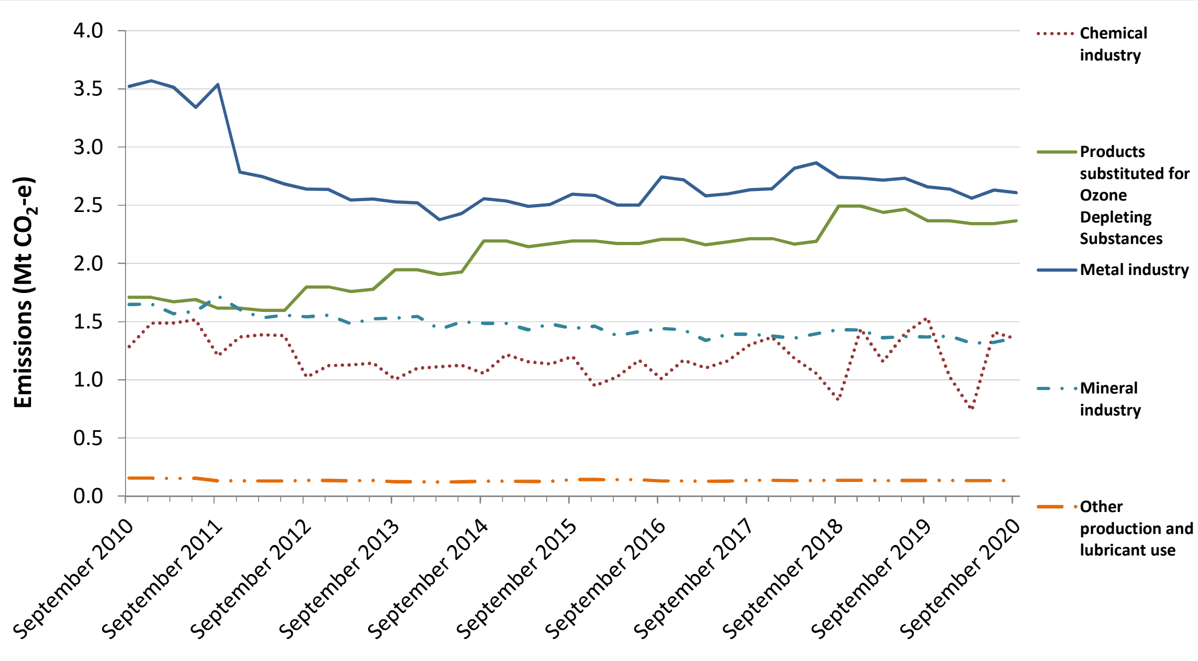
Emissions from *industrial processes and product use* occur as the result of by-products of materials and reactions used in production processes. This sector includes emissions from processes used to produce chemical, metal, and mineral products. It also includes emissions from the consumption of synthetic gases.

In the year to September 2020, *industrial processes and product use* accounted for 5.9 per cent of Australia's national inventory (Figure 4). Emissions declined 5.9 percent or 1.9 Mt CO_2-e over the

year to September 2020 (Figure 14) mainly reflecting declines in decreases in emissions from the chemicals sector.

Trend emissions for *industrial processes and product use* increased 2.8 per cent in the September quarter on the previous quarter.

Figure 14: *Industrial processes and product use* emissions, actual, by sub-sector, by quarter, September 2010 to September 2020



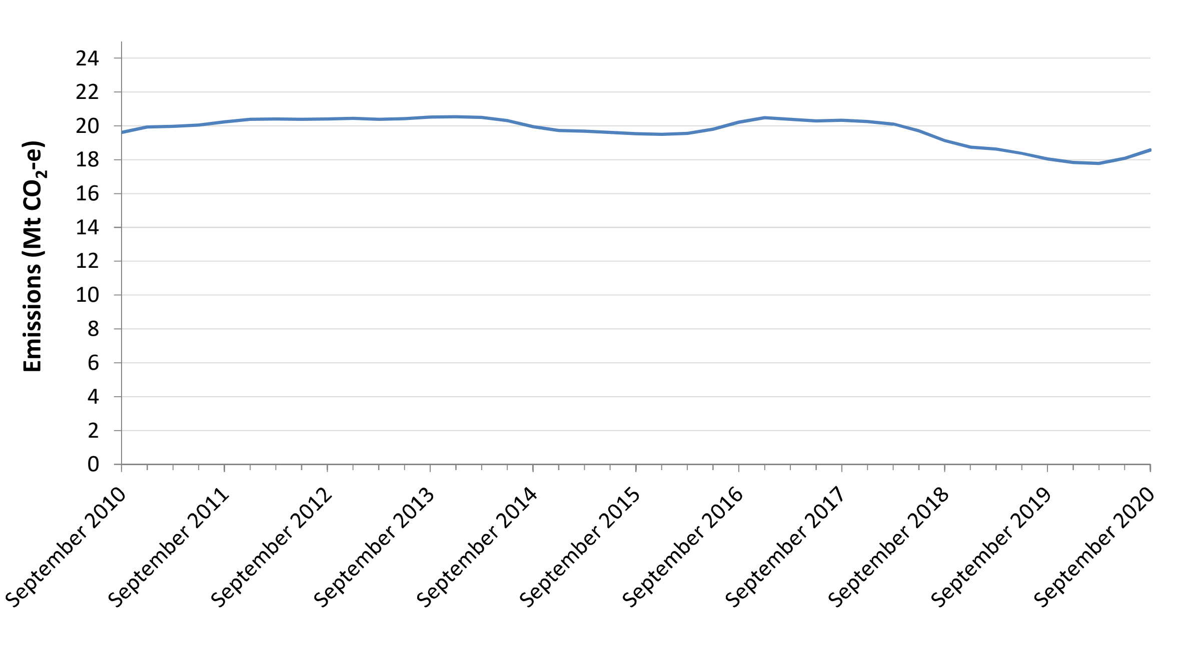
Source: Department of Industry, Science, Energy and Resources

2.6. Agriculture

Emissions from *agriculture* include methane, nitrous oxide and carbon dioxide. Methane and nitrous oxide emissions are estimated for enteric fermentation and manure management in livestock. They are also estimated for rice cultivation, agricultural soils and field burning of agricultural residues. Carbon dioxide emissions are reported from the application of urea and lime.

In the year to September 2020, *agriculture* accounted for 14.1 per cent of Australia's national inventory (Figure 4). Emissions from *agriculture* have decreased by 2.5 per cent over the year to September 2020 (Figure 15).

Figure 15: *Agriculture* emissions, trend, by quarter, September 2010 to September 2020[9]



Source: Department of Industry, Science, Energy and Resources

Although drought conditions have eased in the September quarter 2020, the cattle herd and sheep flocks are yet to fully recover. There has been some rebound in crop production in the September quarter 2020 due to more favourable climatic conditions. Emissions from crop production should continue to increase in future quarters, with wheat production forecast to rebound strongly[10].

2.7. Waste

The *waste* sector includes emissions from landfills, wastewater treatment, waste incineration and the biological treatment of solid waste. Emissions largely consist of methane, which is generated when organic matter decays under anaerobic conditions.

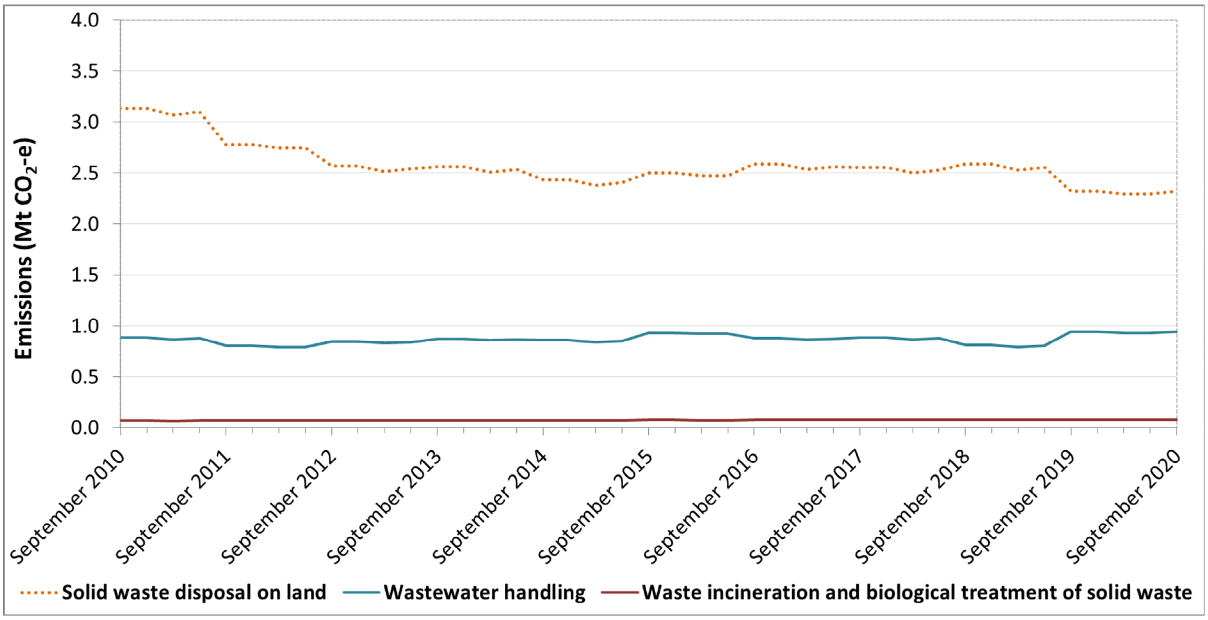
In the year to September 2020, *waste* accounted for 2.6 per cent of Australia's national inventory (Figure 4).

Emissions from *waste* decreased 2.7 per cent (0.4 Mt CO_2-e) over the year to September 2020 due to increased gas capture at solid waste disposal sites (Figure 16).

[9] The nature of the data underpinning the agriculture estimates creates an anomaly in the actual quarterly data which is managed through seasonal adjustment and weather normalisation (Data Tables 1B and 1C).

[10] Australian Bureau of Agricultural and Resource Economics and Sciences (2020). *Australian Crop Report,* December 2020.

Figure 16: *Waste* emissions, actual, by sub-sector, by quarter, September 2010 to September 2020



Source: Department of Industry, Science, Energy and Resources

2.8. Land Use, Land Use Change and Forestry

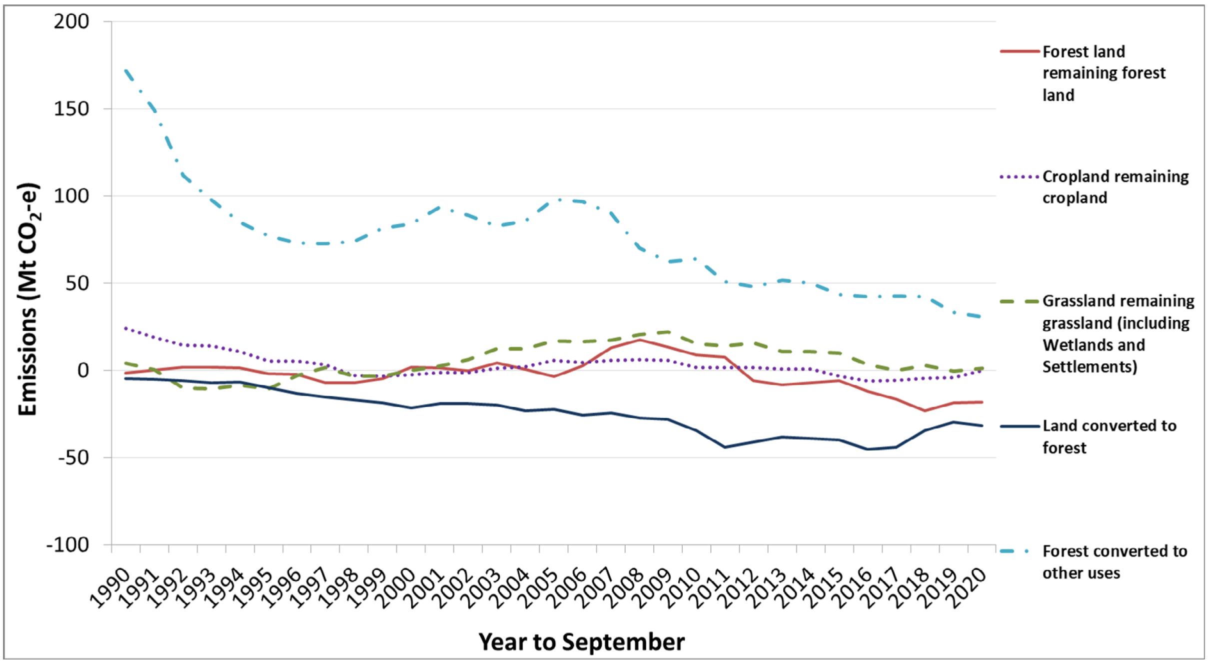
The Land Use, Land Use Change and Forestry (LULUCF) sector of the national inventory includes estimates of net anthropogenic emissions for forests and agricultural lands and changes in land use.

In the year to September 2020, the LULUCF sector[11] accounted for -3.7 per cent of Australia's national inventory – a net sink (Figure 4).

Net emissions for the LULUCF sector in the year to September 2020 are estimated to be -18.8 Mt CO_2-e (Figure 17). This net sink has declined by 4.1 per cent (0.8 Mt CO_2-e) on the previous twelve months due to continuing declines in land clearing and an increase in emissions from agricultural soil (Table 3).

[11] *LULUCF* includes Forest converted to other uses, Forest land remaining forest land, Land converted to forest land, Grassland remaining grassland (including Wetlands and Settlements) and Cropland remaining cropland.

Figure 17: *LULUCF* net anthropogenic emissions, by sub-sector, year to September, 1990 to 2020



Source: Department of Industry, Science, Energy and Resources

3. Emissions per capita and per dollar of GDP

In the year to September 2020 emissions per capita, and the emissions intensity of the economy are at their lowest levels in 30 years[12].

National inventory emissions per capita were 19.9 t CO_2-e per person in the year to September 2020. This represents a 46.2 per cent decline in national inventory emissions per capita from 37.0 t CO_2-e in the year to September 1990.

Over the period from 1989-90 to September 2020, Australia's population grew strongly from 17.0 million to around 25.7 million[13,14]. This reflects growth of 50.2 per cent.

Australia's real GDP (chain volume measures) also experienced significant growth over this period, expanding from $0.8 trillion in 1990 to around $1.9 trillion in the year to September 2020[15]. This represents a growth of 135.3 per cent.

National inventory emissions per dollar of real GDP fell from 0.8 kg CO_2-e per dollar in the year to September 1990 to 0.3 kg CO_2-e per dollar in the year to September 2020 (Figure 18). This represents a decline of 65.6 per cent from the year to September 1990.

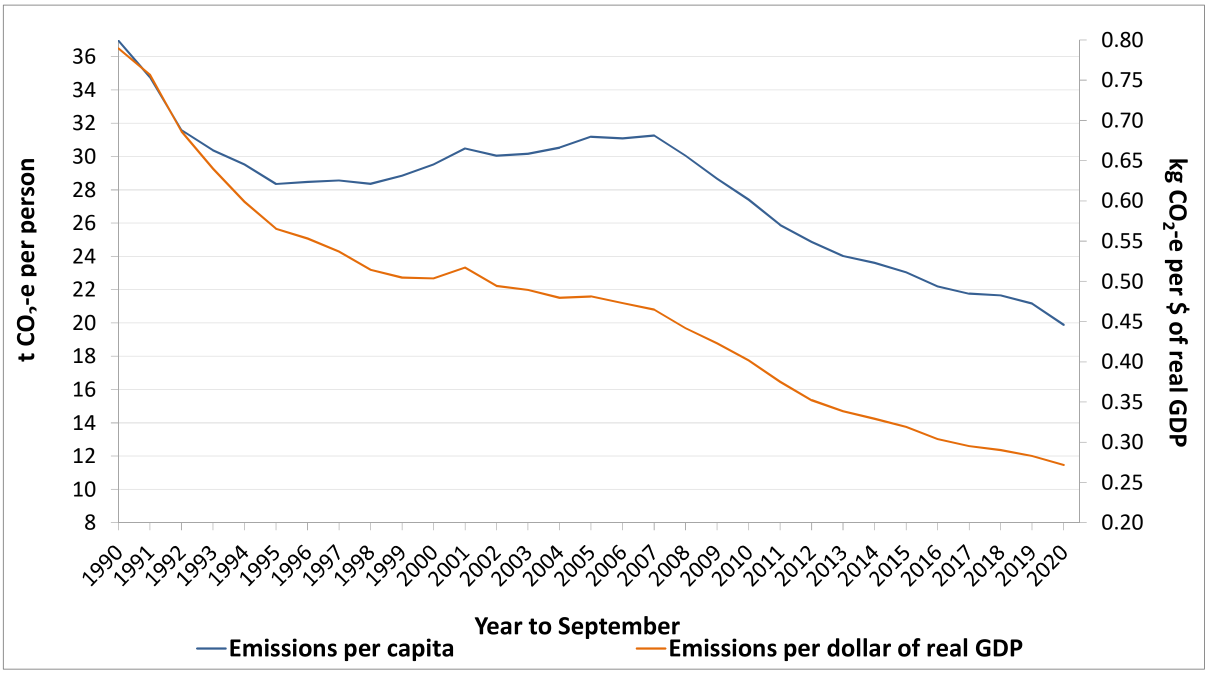
[12] Emissions per capita and per dollar of real GDP levels are inclusive of all sectors of the economy, including *Land Use, Land Use Change and Forestry* (LULUCF)

[13] Australian Bureau of Statistics (2020), *Australian Demographic Statistics*, pub. no. 3101 http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0

[14] Australian Bureau of Statistics (2020), *Population Clock*. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Web+Pages/Population+Clock

[15] Australian Bureau of Statistics (2020), *National Accounts: National Income, Expenditure and Product*, Cat. No. 5206.0 http://www.abs.gov.au/ausstats/abs@.nsf/mf/5206.0

Figure 18: Emissions per capita and per dollar of real GDP, actual year to September 1990 to 2020



Source: Department of Industry, Science, Energy and Resources

4. Consumption-based national greenhouse gas inventory

Table 4: Consumption-based national greenhouse gas inventory[16], September quarter and year to September 2020, emissions growth rates

	September quarter 2020	Year to September 2020
Quarterly change – seasonally adjusted[17]	3.5%	
Quarterly change – seasonally adjusted– trend	1.4%	
Annual Change		-3.3%

The consumption account estimates the impacts on emissions in Australia and in other countries due to Australian consumption or demand.

On an annual basis, the consumption-based inventory decreased 3.3 per cent or 14.4 Mt CO_2-e to 426.9 Mt CO_2 e in the year to September 2020, reflecting declining emissions from consumption of imports (down 1.9 per cent) and also the decline in the national greenhouse gas inventory, including emissions associated with the consumption of domestically produced goods. Emissions in the national greenhouse gas inventory associated with the production of goods for export are not included in the consumption-based inventory. After deducting emissions associated with production of exports, national greenhouse gas inventory emissions that are associated with domestic consumption declined by 3.8 per cent (12.4 Mt CO_2-e).

Household consumption was the most significant contributor at 341.7 Mt CO_2-e (or 80.0 per cent of total consumption emissions), followed by government final consumption emissions of 38.3 Mt CO_2-e (or 9.0 per cent of total consumption emissions). When combined with gross fixed capital formation from government and public corporations, the Government sector was responsible for emissions of 58.9 Mt CO_2-e (or 13.8 per cent of consumption-based emissions across the economy) (Table 5).

Emissions generated by Australian consumption are 138.2 Mt CO_2-e or 24.5 per cent lower compared to the year to June 2005. The analysis also shows that the emissions generated to support Australia's consumption are less than those reported as the (production-based) national greenhouse gas inventory by 83.2 Mt CO_2-e or 16.3 per cent in the year to September 2020 (Figure 20).

On a seasonally adjusted basis, Australia's consumption-based inventory was higher relative to the previous quarter (3.5 per cent or 3.7 Mt CO_2-e).

Consumption-based emissions are approximately 16.6 tonnes per person, which is around 3.2 tonnes per person less than the per capita emission calculation using the national greenhouse gas inventory.

[16] National emissions levels are inclusive of all sectors of the economy, including *Land Use, Land Use Change and Forestry* (LULUCF).

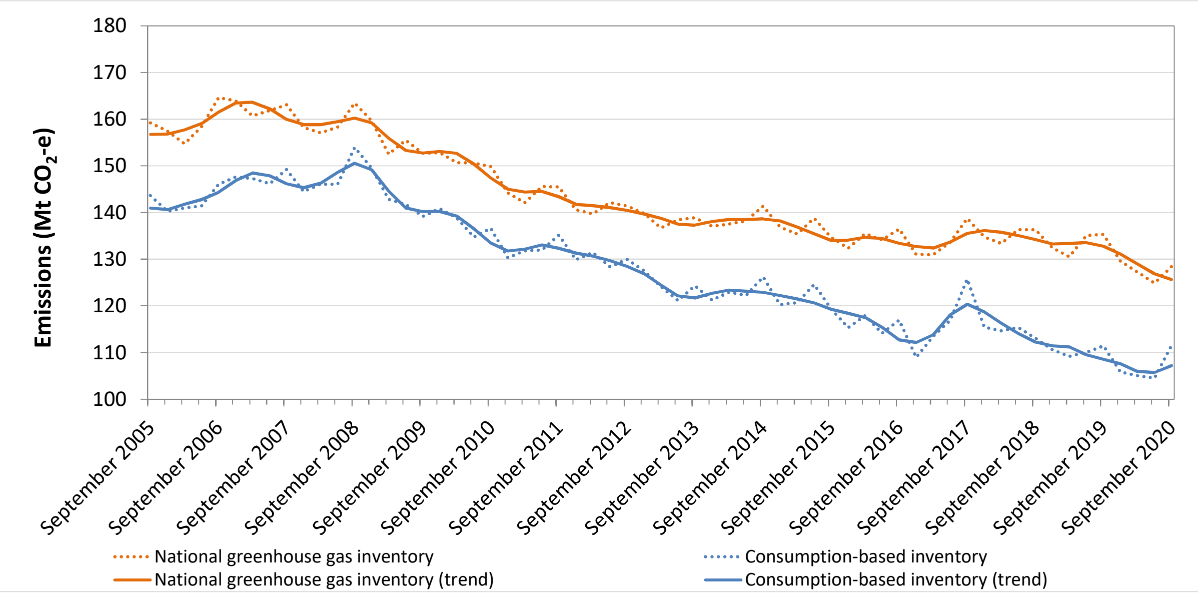
[17] 'Actual', 'seasonally adjusted and 'trend' are defined in Section 5: Technical notes

Table 5: Consumption-based national greenhouse gas inventory, year to September 2020, by sector

Consumption-based inventory sector	Year to September 2020
Household consumption	341.7
Government consumption	38.3
Fixed capital - Govt & Public corporations	20.6
Private fixed capital	77.4
Change in inventories[a]	-51.1
Total consumption-based inventory	426.9

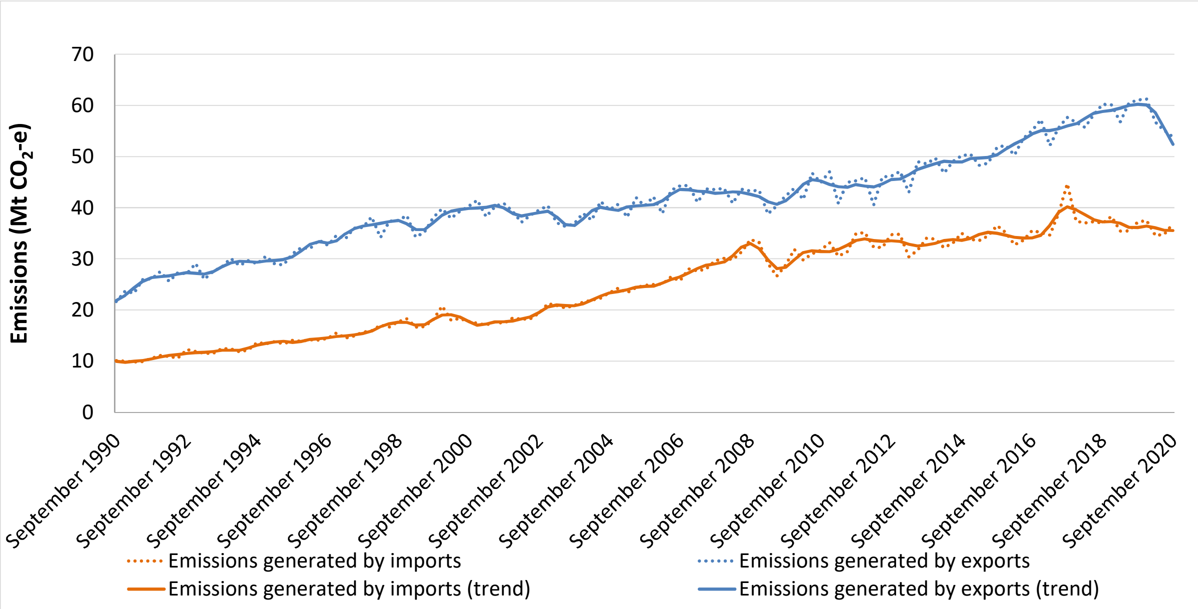
a. Includes carbon sequestered in forests and plantations available to be utilised in wood and paper production in the future.

Figure 19: National Greenhouse Gas and Consumption-based inventories, Australia, by quarter, September 2005 to September 2020



Source: Department of Industry, Science, Energy and Resources

Figure 20: Global emissions generated during production of Australia's imports and exports, by quarter, September 1990 to September 2020



Source: Department of Industry, Science, Energy and Resources

Special Topic 1 – Methane emissions in the Surat Basin

New analysis shows that the methods used to estimate methane emissions in the national inventory are well-supported by an independent CSIRO 'top-down' study (Luhar et al 2020).

The CSIRO study, which used flux towers in the Surat Basin to monitor changes in methane concentrations in the atmosphere, generated estimates of methane emissions which were within 5% of estimates prepared by the Department using national inventory methods.

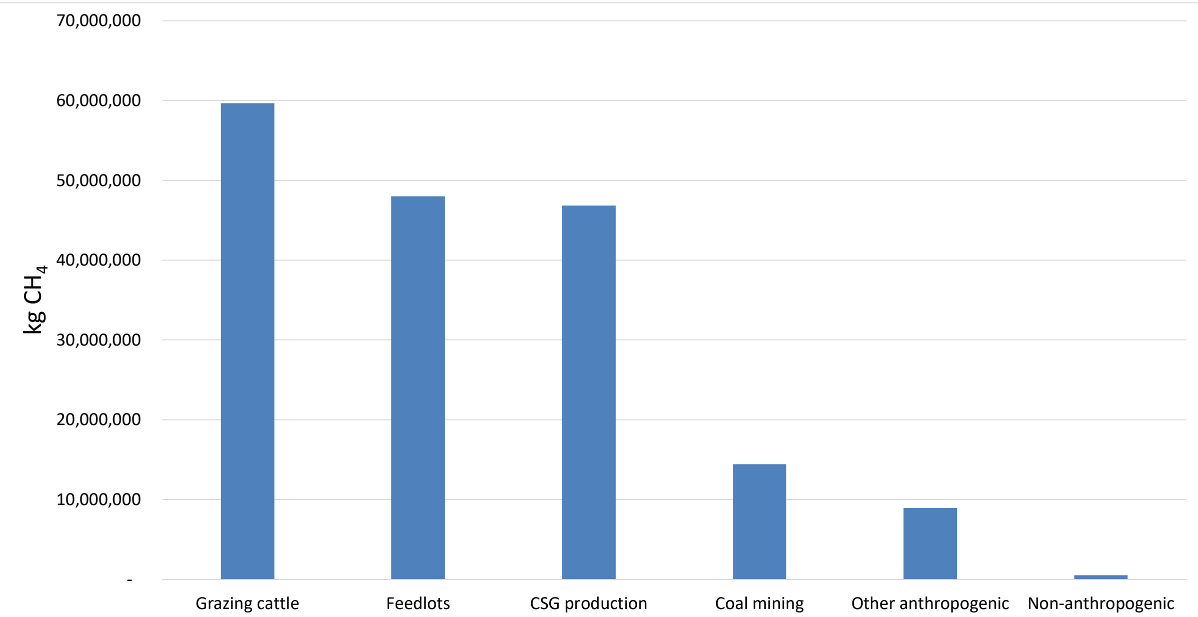
In that sub-part of the Surat Basin dominated by coal seam gas (CSG) production, the national inventory methods were assessed to produce emission estimates 10% above the CSIRO 'top-down' estimates.

The analysis presented here provides evidence that migratory or dispersed methane sources resulting from CSG operations are not likely to be material in the Surat Basin.

The Surat Basin

The Surat Basin, between Miles and Dalby in southern Queensland contributes around 3 per cent of the nation's total methane emissions, making it one of the most significant geographic areas for methane emissions in Australia.   This region is a major location for CSG activity but is also the centre of important grazing cattle, intensive feedlot and coal mining activity that all contribute significant amounts of methane emissions while minor contributions arise from landfills, water management, industry, households, vehicle traffic, river and ground seeps. Episodic biomass burning is also common from land clearing, prescribed burns and from bushfires.

Figure ST1: Estimated methane emissions, by source, Surat Basin, 2016 (kg)



The anthropogenic sources of methane emissions in the Miles-Dalby subregion of the Surat Basin defined in Luhar et al 2020 can be quantified using national inventory methods. In 2016, the most important methane sources included grazing cattle (32%) and feedlots (26%) while CSG operations accounted for 25% and coal mining 8% (Figure ST).

The quantification of non-anthropogenic sources such as river seeps in the Condamine River and from ground seeps is difficult and, in this study, the estimates presented are taken from Luhar et al 2020. Using the approach in the CSIRO study, non-anthropogenic sources are estimated to be 0.3% only of total methane emissions in the region, which is likely to be a conservative estimate.

Quality Assurance for the national inventory methods

The IPCC has identified that 'top-down' estimates of methane emissions such as those presented in Luhar et al 2020 can provide valuable quality assurance assessments of national greenhouse gas inventories.

Luhar et al 2020 undertook 'top-down' analysis to estimate methane emissions in the Surat Basin using direct measurements of methane in the atmosphere from flux towers stationed at Ironbark and Burncluith. The CSIRO authors applied inverse modelling techniques to these measurements, collected in 2015 and 2016, to attribute the changes in measured methane concentrations at Ironbark and Burncluith to emissions from broad locations across the region of study.

In Table ST1, these 'top-down'[18] estimates of methane emissions from the CSIRO study have been compared with estimates of methane emissions in the Surat Basin derived using 'bottom-up'[19] methods from the national inventory.

Overall, the two sets of estimates of methane emissions from the Surat Basin are very close – within 10% of each other.

Table ST1: Comparison between 'top-down' estimates and 'bottom-up' estimates

	Surat Basin: CSG Zone	**Surat Basin: Non-CSG Zone**	**Surat Basin: All**
National Inventory 'bottom up' estimates	74.9	103.5	178.4
CSIRO 'top down' estimates (Luhar et al 2020)	63.6	102.2	165.8
Difference – National Inventory –CSIRO (Luhar et al 2020)	+11.3 (17.7%)	+1.3 (1.3%)	+12.6 (7.7%)

Source: DISER estimates (see Appendix A), Luhar et al 2020.

The comparison for the entire study area shows that the 'bottom-up' estimate using national inventory methods is 7.7% higher than the CSIRO study 'top-down' estimates presented in Luhar et al 2020.

[18] 'Top-down' estimates are derived from measurements of methane concentrations in the atmosphere to deduce an estimate of emissions from all sources for a region. This method's advantage is that it is complete, capturing all sources of methane. However, it is not well-suited to pinpointing emissions to a particular source.

[19] 'Bottom up' estimates are derived from equations that relate emissions to observed activity data for specific point-sources - such as for the combustion of a quantity of fuel or from a particular number of cattle. This method's advantage is that it attributes emissions to well-known activity data – but is not well-suited to the estimation of dispersed emission sources.

In that part of the Surat Basin where CSG operations are concentrated, as identified by Luhar et al 2020, the national inventory method estimates for methane emissions are 17.7% higher than the top-down estimates presented in Luhar et al 2020.

In the non-CSG zone of the Basin, the national inventory method estimates are about 1.3% higher.

Overall, the data presented in Table ST1 support the conclusion that estimates of methane emissions using national inventory methods are consistent with estimates of methane emissions using the CSIRO 'top-down' technique.

Estimating dispersed emission sources

As the CSIRO monitoring systems capture all sources of methane, including both point sources and also dispersed sources not readily identified in the inventory, the CSIRO analysis constitutes a test of an additional hypothesis:

1. that migratory or dispersed methane sources resulting from CSG production are not material.

In the Department's view, this conclusion is also validated by the CSIRO analysis and the comparison presented in Table ST1. That is, the CSIRO data indicate that all significant methane emission sources from CSG production in the Surat Basin are well-captured by the national inventory methods.

Recent updates to national inventory methods for emissions from CSG production have increased estimates of methane emissions

The analysis presented in this study has been necessary since the results in Luhar et al 2020 did not provide a direct test of the national inventory estimation methodologies for methane emissions. This is because the 'bottom-up' analysis used by CSIRO in their paper - prepared by Katestone Environmental and reported in the Luhar et al 2020 supplement - did not reflect current national inventory methods for CSG production, grazing cattle or feedlots.

In this study, current national inventory methods have been utilised for these CSG, cattle and feedlot sources. For other sources - for piggeries, poultry, coal mining, landfill, wastewater, industry, motor vehicles and wood heating - the Katestone 'bottom-up' estimates have been retained. A few minor sources – abandoned gas wells, water bodies and wastewater from certain abattoirs - have also been added in this analysis.

The impact of using the national inventory methods - rather than the Katestone methods in Luhar et al 2020 - for the bottom-up inventory comparison is evident in Figure ST2 and Table ST2.

Estimated methane emissions for CSG production are much higher in the national inventory approach than estimated by Katestone (by +183.2%) and also for feedlots (+13.5%) whereas estimated emissions for grazing cattle are much lower using the national inventory methods (-35.8%).

Figure ST2: Methane emissions, Surat Basin, by sector, 2016 (kg): Estimates using national inventory and Katestone 'bottom-up' methods

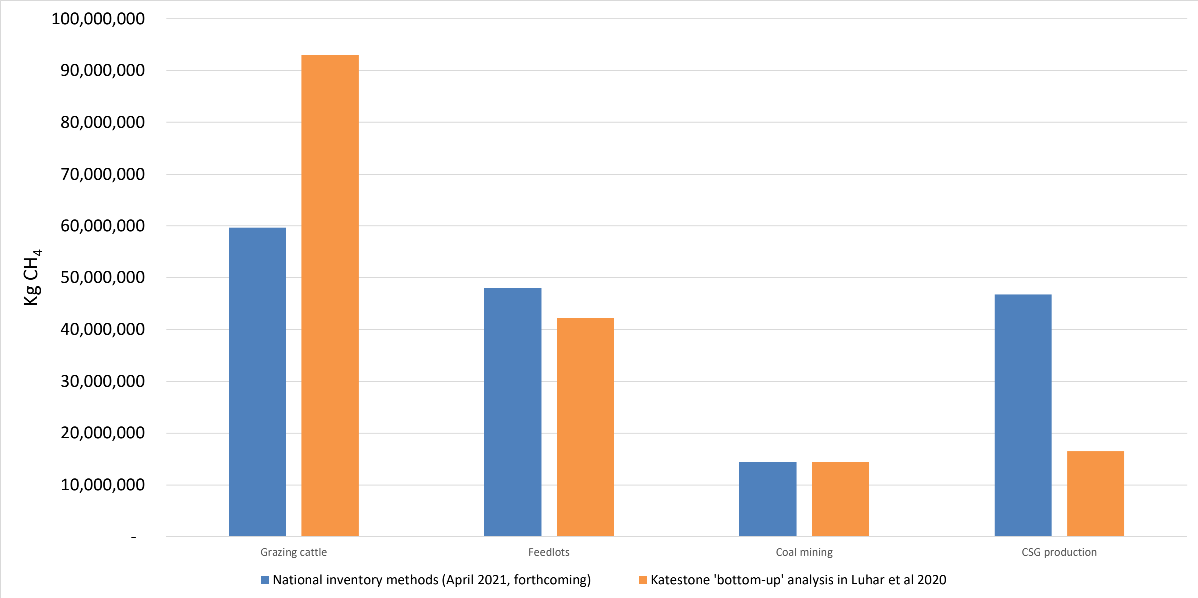


Table ST2: Methane emissions, Surat Basin, by sector, 2016 (kg): Estimates using national inventory and Katestone 'bottom-up' methods

	Cattle	Feedlots	CSG operations
National inventory 'bottom up' estimates (1)	59.7	48.0	46.8
Katestone 'bottom-up' analysis in Luhar et al 2020 (2)	93.0	42.3	16.5
Difference (1) – (2) %	-35.8%	+13.5%	+183.2%

The differences in estimates for grazing cattle and feedlots reflect differing sources and assumptions made in this study and in the Katestone 'bottom-up' analysis published in Luhar et al 2020.

In the case of CSG, however, the Katestone estimate for CSG production used in Luhar et al 2020 utilised estimation methods from the National Greenhouse and Energy Reporting system which were derived from the national inventory methods in place in 2015. Consequently, the difference in estimates of methane emissions for CSG production reported in Table ST2 reflect the impact of recent method updates used in the national inventory.

That is, in particular, updates to national inventory methods for methane emissions from CSG production since 2015 have caused a more than doubling of estimates of methane emissions from this source.

Ongoing empirical work

The CSIRO study has been especially valuable because the authors were able to routinely monitor methane emissions emanating from the Surat Basin over a two-year period during the course of 2015 and 2016.

New data from additional 'top-down' studies are emerging. A separate empirical study, as described in Lu et al 2020, is in the process of generating new data on methane emissions from the Surat Basin

using a ‘top-down’ approach. In this research, methane plumes flowing in the Surat Basin have been assessed using instruments located in plane flyovers.

This innovative work is also being supported by the Department and is opening up new possibilities for the study of methane emissions in the Surat Basin, and elsewhere.

The flyovers were undertaken over the course of a fortnight in September 2018 and the measurements provide a snapshot of methane emissions from the Surat Basin on those specific days in September 2018.

While the new data will provide valuable insights for future monitoring initiatives, the interpretation of the new data will be complicated since the measurements are limited to a single point in time and unlikely to be representative of annual conditions. For this reason, this study’s data, while providing new insights, and which may be valuable in identifying new emission sources, will be less robust and a less reliable indicator of annual emissions than the estimates presented in the Luhar et al 2020 study.

GISERA study

The CSIRO under the GISERA program is also undertaking a new ‘bottom-up’ empirical study examining leakage measurements of CSG equipment at sites in the Surat Basin. This new study will provide additional data on leakage rates of equipment in Australian conditions, and will add significantly to the existing empirical knowledge base. The Department expects this new study will provide valuable data to inform the development of leakage factors for future national inventory method updates.

Conclusion

The IPCC has identified that ‘top-down’ studies of methane emissions can provide a valuable quality assurance role for national greenhouse gas inventories.

Top-down data for the Surat Basin indicate that the set of methods used to estimate methane emissions in the Australian Government’s National Inventory Report 2021 (forthcoming) are well-supported by independent analysis undertaken by the CSIRO and reported in Luhar et al 2020.

Overall, the national inventory methods generated estimates of methane emissions for the Surat Basin for 2016 that were within 10% of the CSIRO’s independent, top-down analysis.

The good fit is partly the result of recent improvements in estimation methods for CSG production in the national inventory, which have led to a more than doubling of estimates of emissions from this source in the Surat Basin since 2016.

The data also support the view that migratory or dispersed sources of methane emissions from CSG operations are not likely to be material.

The Department expects that new empirical studies on methane emissions in Australia will continue to emerge over time and provide valuable information in relation to methane sources. The implications of these new studies will be taken into account in future national inventory method development as part of the inventory’s continuous improvement processes.

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Appendix A: National Inventory method estimation of methane emission, Surat Basin, 2016, kg

IPCC source	Total Surat Basin	CSG Zone	Non-CSG Zone	Implied Emission Factor (IEF)	Activity Data	Reference (IEF, AD)
Grazing cattle [a]	59,669,853	9,151,643	50,518,211	53.9kg/head	1,107,047 head	DISER 2021, Katestone* Table 8
Feedlots [a]	47,997,407	12,131,768	35,865,639	70.4kg/head	681,781 head	DISER 2021, Katestone* Table 8
CSG production leaks [b]	10,952,885	10,952,885	-	0.0006879 kg/m3 production	15,921,531,053 m^3	DISER 2021, Katestone* Table 15
CSG water production [c]	15,710,659	15,710,659	-	310 kg / Ml water produced	50,680 Ml	DISER 2021, Qld Govt 2020
CSG combustion slip [d]	4,321,324	4,321,324	-	0.0136085 kg / m3 combustion	317,546,667 m^3	DISER 2021, Qld Govt
CSG vents	14,499,257	14,499,257				Katestone Table 15
CSG flares	1,309,137	1,309,137				Katestone Table 15
Coal mining	14,424,564	3,672,900	10,751,664			Katestone Table 10
Landfills	1,905,644		1,905,644			Katestone Table 23
Waste water	1,137,905		1,137,905			Katestone Table 21
Industry	640,070		640,070			Katestone Table 30
Motor vehicles	24,000		24,000			Katestone Table 24
River seeps	375,905		375,905			Katestone Table 25
Ground seeps	127,714		127,714			Katestone Table 28
Wood heating	280,000		280,000			Katestone Table 23
Abandoned gas wells	57,500	57,500				DISER 2021
Water bodies	1,300,000	552,275	747,725			DISER 2021
Abattoirs	1,200,000		1,200,000			DISER 2021
Total	178,389,415	74,888,020	103,501,395			

a. Includes enteric fermentation and manure management. b. Leakage factor derived from DISER 2021. c. Leakage factor reported in DISER 2021. Water production from Qld Govt. 2020. d. Emission factor 0.36kgCH4/Gj in DISER 2021. Combustion quantities taken from Qld Govt 2020 (for conservativeness). *The Katestone study provided the bottom up analysis utilised by CSIRO and was reproduced in Luhar et al 2020 Supplement.

Special Topic 2 – Hydrofluorocarbon emissions in Australia

Monitoring of atmospheric hydrofluorocarbon (HFC) concentrations has been undertaken by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) at the Cape Grim Baseline Air Pollution Station in Tasmania since 2005.

Each year, the Department commissions CSIRO to make an independent, 'top-down ' estimate of annual emissions of HFCs from Australia and then compares this information with estimates of HFC emissions using the national inventory 'bottom-up' methods as part of its routine quality assurance program.

The CSIRO analysis (Dunse et al 2020) is especially valuable in this case for a number of reasons:

1. All emissions of HFCs are anthropogenic, and must be counted within the national inventory (unlike methane, for example, where some sources are considered to be non-anthropogenic), which simplifies the comparison estimates generated by 'top-down' and 'bottom-up' approaches; and
2. The national inventory 'bottom-up' methods are recognised to produce estimates with considerable uncertainties (given the absence of direct observations of leakages of HFCs from equipment, like air-conditioning, in many millions of pieces of equipment across the country).

In the inventory, the long run losses of HFCs are likely to be very well-known, since all HFC gases are supplied through imports into Australia, under license under the *Ozone Protection and Synthetic Gas Management Act 1989* and because all of these gases, used in equipment such as air-conditioning or refrigeration, will eventually leak out into the atmosphere unless they are captured and destroyed through a single facility managed by Refrigerant Reclaim Australia.

The time profile of these HFC losses are less well-known, however, largely because the time profile depends on factors including the fugitive leakages from a wide variety of equipment and the rate of recycling of gas at the point of equipment disposal in the economy.

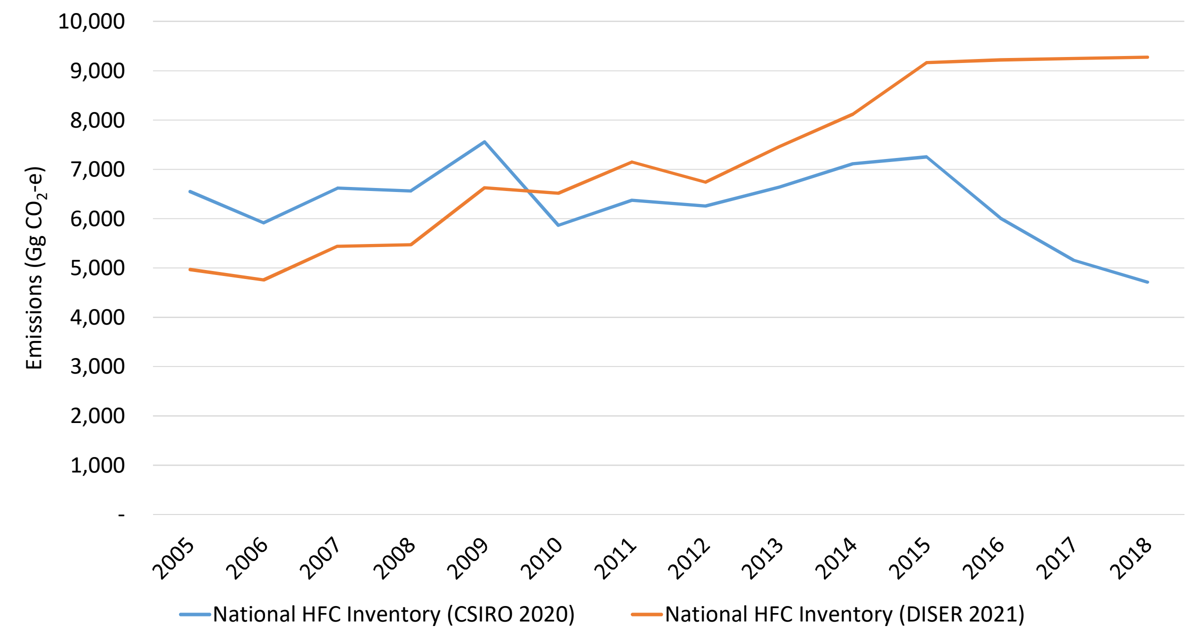
The comparison undertaken in DISER 2020 of national inventory 'bottom-up' estimates with the 'top-down' estimates based on the CSIRO Cape Grim measurements showed strong alignment between the two sets of estimates in the early years of the time series, but a growing gap between the two sets of estimates in recent years.

This gap has been recognised and addressed to some extent in DISER 2021 (forthcoming), in which assumed leakage rates for refrigeration and air conditioning equipment were comprehensively aligned with estimates in Expert Group 2018 rather than being aligned with IPCC default leakage rates, as was previously done for some equipment types.

With the changes in DISER 2021 (forthcoming), a new comparison between the revised national inventory 'bottom-up' methods and the CSIRO 'top-down' estimates is presented in Figure ST.

The new methods result in a closing of the gap between the 'bottom-up' and 'top-down' estimates, with an average difference of approximately 16% from 2005 to 2015; however, a gap persists in recent years in which the national inventory estimates remain higher.

Figure ST3: Comparison of National Inventory 'bottom-up' estimates (DISER forthcoming) with CSIRO 'top-down' estimates



Further work will be undertaken in upcoming inventory cycles to improve the bottom-up inventory estimates. The major avenues for further updates will include an assessment of the extent of refrigerant stockpiling and recycling within the Australian economy and a review of equipment retirement profiles for different classes of equipment.

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5. Technical notes

5.1. Quarterly Coverage

The *Quarterly Update* uses emissions estimates based on our United Nations Framework Convention on Climate Change (UNFCCC) inventory time series to better support implementation of Australia's 2030 target. This UNFCCC inventory will be used to track progress towards Australia's commitment to reduce emissions levels by 2030 under the Paris Agreement.

5.2. International guidelines

The Quarterly Update has been prepared in accordance with the international guidelines agreed for use for the Paris Agreement including the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for the Preparation of National Greenhouse Gas Inventories and, where applicable, the 2019 IPCC Refinement to the 2006 IPCC Guidelines.

The Quarterly Update reports on the national inventory with the application of the IPCC's natural disturbances provision since the Government indicated in its 2015 Nationally Determined Contribution (NDC) submission that it would meet its emission reduction commitments using this provision.

The national inventory prepared without the application of the natural disturbances provision will be reported in the Australian Government's National Inventory Report submitted to the UNFCCC Secretariat each year between 15 April and 27 May. This submission will provide full details of estimates of annual emissions from bushfires and sequestration from subsequent biomass recovery.

5.3. Greenhouse gases

Emissions are expressed in terms of tonnes of carbon dioxide equivalents using the Global Warming Potential (GWP) weighting factors indicated in Table 6.

GWPs have been used for each of the major greenhouse gases to convert them to carbon dioxide equivalents (CO_2-e). As greenhouse gases vary in their radiative activity and in their atmospheric residence time, converting emissions into CO_2-e allows the integrated effect of emissions of the various gases to be compared.

Commencing with the September Quarter 2020 the Department has applied the 100-year time GWP values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) to estimate emissions, consistent with rules adopted under the UN Framework Convention on Climate Change (UNFCCC) Paris Agreement (Decision 18/CMA.1 Annex 2.D Paragraph 37). This approach will also be used to track Australia's progress towards its Paris Agreement Nationally Determined Contribution of 26-28% below 2005 levels by 2030, on an emissions budget basis.

Paris Agreement update to Global Warming Potential for emission estimation

According to Paris Agreement Decision 18/CMA.1 Annex 2.D Paragraph 37 - "*Each Party shall use the 100-year time-horizon global warming potential (GWP) values from the IPCC Fifth Assessment Report, or 100-year time-horizon GWP values from a subsequent IPCC assessment report as agreed upon by the CMA, to report aggregate emissions and removals of GHGs, expressed in CO_2 eq*.".

Prior to this report, the GWPs used were the 100-year time-horizon GWPs contained in the 2007 IPCC Fourth Assessment Report of Climate Science (AR4), in accordance with previous UNFCCC decisions. Recalculations have been performed to the whole time-series of emissions estimates from 1990 to 2020 to adhere to the UNFCCC requirement of time-series consistency.

Table 6 compares the IPCC Fifth and Fourth Assessment Reports' 100-year GWPs.

Table 6: Comparison of the IPCC Fifth and Fourth Assessment Reports' 100-year GWPs

Major greenhouse gases	4th Assessment Report GWP (Table 2.14)	5th Assessment Report GWP (Table 8.7)
Carbon dioxide (CO_2)	1	1
Methane (CH_4)	25	28
Nitrous oxide (N_2O)	298	265
Perfluorocarbon - CF4	7,390	6,630
Perfluorocarbon – C2F6	12,200	11,100
HFC-23	14,800	12,400
HFC-32	675	677
HFC-41	92	116
HFC-43-10mee	1,640	1,650
HFC-125	3,500	3,170
HFC-134	1,100	1,120
HFC-134a	1,430	1,300
HFC-143	353	328
HFC-143a	4,470	4,800
HFC-152	53	16
HFC-152a	124	138
HFC-161	12	4
HFC-227ea	3,220	3,350
HFC-236cb	1,340	1,210
HFC-236ea	1,370	1,330
HFC-236fa	9,810	8,060
HFC-245ca	693	716
HFC-245fa	1,030	858
HFC-365mfc	794	804
Sulphur hexafluoride (SF_6)	22,800	23,500

Australia's emissions of the greenhouse gas nitrogen trifluoride (NF_3) are considered negligible and are not estimated.

5.4. Quarterly methodology and growth rates

Emission estimates have been compiled by the Department using the estimation methodologies incorporated in the Australian Greenhouse Emissions Information System (AGEIS) and documented in the National Inventory Report.

The estimates are calculated using the latest national inventory data and indicators from external data sources (listed in Section 7.6). These data are used to determine growth rates, which are applied to estimate quarterly emissions growth.

Quarterly growth rates are calculated as the percentage change between the estimates for the previous quarter and the current quarter. Annual growth rates are calculated as the percentage change between the estimates for the twelve months to the end of the equivalent quarter in the previous year, and the twelve months to the end of the current quarter.

5.5. Recalculations

Periodic recalculations of the quarterly emission estimates are undertaken as more complete and accurate information becomes available, and in response to changes in estimation methods and international reporting requirements. Future changes to estimation methods will likely reflect progressive implementation of the 2019 Refinement to the 2006 IPCC Guidelines; updates to estimation methods in the *land* and *fugitive emissions* sectors; and updates to indicators used to estimate emissions in the *stationary energy* sector.

Recalculations are designed to comply with international guidelines, are estimated on a time series consistent basis and are subject to annual international expert review.

Recalculations since the June Quarter 2020

The recalculations since the June 2020 edition of the *Quarterly Update* for the financial years 2005 and 2019 to 2020, by sector in Mt CO_2-e, are shown in Table 7 and are a result of:

- The adoption of IPCC Fifth Assessment Report global warming potentials for the calculation of aggregate CO_2-e emissions for all inventory sectors reported in the quarterly update (see Special Topic 1 for further details).
- The incorporation of revised activity data, emission factor and methodologies used to calculate annual inventory estimates.

Recalculations in this *Quarterly Update* also include updates to indicators used to derive emissions estimates in the quarters beyond the latest official 2018-19 inventory year to be reported in the Australian Government’s annual National Inventory Report submitted under the UN Framework Convention on Climate Change.

Table 7: Recalculations (Mt CO_2-e) since the June 2020 Quarterly Update, by sector, 2005 and 2019 to 2020

Sector	Financial Years and Quarters											
	2005				2019				2020			
	Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun
Agriculture	1.6	1.6	1.6	1.6	1.3	1.3	1.3	1.3	1.0	1.0	1.0	1.0
Electricity	0.0	0.0	0.0	0.0	0.2	0.1	-0.4	0.2	0.0	0.0	0.0	0.0
Stationary energy (excluding electricity)	0.0	0.0	0.0	0.0	2.5	-1.8	-1.9	1.2	3.3	-1.7	-2.2	0.9
Transport	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
Fugitive emissions	0.9	0.8	0.8	0.9	0.6	0.6	0.6	0.6	0.5	0.7	0.4	1.1
Industrial processes and product use	-0.2	-0.2	-0.2	-0.2	-0.7	-0.8	-0.8	-0.8	-0.9	-0.9	-0.9	-0.9
Waste	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
LULUCF	1.1	1.1	1.1	1.1	-0.1	-0.1	-0.1	-0.1	-0.3	-0.3	-0.3	-0.3
Total	**3.7**	**3.7**	**3.5**	**3.7**	**4.0**	**-0.5**	**-1.2**	**2.5**	**3.9**	**-0.8**	**-1.7**	**2.1**

5.6. Source Data

Preliminary activity data are obtained under the National Greenhouse and Energy Reporting System (NGERS) and from a range of publicly available sources, principally:

- Australian Bureau of Statistics (2020), Australian Demographic Statistics, pub. no. 3101 http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0
- Australian Bureau of Statistics (2020), Population Clock. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Web+Pages/Population+Clock
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- Department of Industry, Science, Energy and Resources (2020). Australian Energy Statistics: Table F. https://www.energy.gov.au/publications/australian-energy-update-2020
- Department of Industry, Science, Energy and Resources (2020), Australian Greenhouse Emissions Information System: http://ageis.climatechange.gov.au/

5.7. Actual time series

The ABS defines an original time series as showing 'the actual movements in the data over time'. The actual time series in this report are equivalent to an original time series.

5.8. Seasonal adjustment analysis

The ABS defines seasonal adjustment as follows: 'A seasonally adjusted time-series is a time-series with seasonal component removed. This component shows a pattern over one year or less and is systemic or calendar related.'

The actual quarterly data have been adjusted using Demetra to remove the effects of seasonal factors. Demetra is a standard seasonal adjustment tool, consistent with methods applied by the ABS.

5.9. Trend analysis

The trend series provides the best indication of underlying movements in the inventory by smoothing short term fluctuations in the seasonally adjusted series, caused for example, by extreme weather events such as floods or fires. The trend time series is estimated using the Demetra tool. More information on trend analysis is available on the ABS website http://www.abs.gov.au/websitedbs/D3310114.nsf/home/Time+Series+Analysis:+The+Basics.

5.10. Weather normalisation

The seasonally adjusted and trend estimates are further adjusted to correct for the effects of variations around average seasonal temperatures. This process is termed 'weather normalisation' and is designed to provide a clearer indication of the underlying trends in the emissions data.

Seasonal temperatures are an important predictor of emissions in Australia due to their influence on demand for electricity for heating and cooling (air conditioning). The seasonally adjusted series corrects for the regular effects of differences in average temperatures between seasons. The weather normalised series further corrects for fluctuations in average seasonal conditions.

The weather normalisation methodology is based on the Bureau of Meteorology concept of 'heating and cooling degree days,' and is applied to total emissions (excluding LULUCF) and the electricity sector. The methodology is described in detail in 'Section 7: Special Topic' of the December 2011 edition of the Quarterly Update.

5.11. Quarterly uncertainty

For all sectors the Department's assessment is that the 90 per cent confidence interval for the national inventory is ± 6.5 per cent (i.e. there is a 90 per cent probability that future revisions will be limited to ± 6.5 per cent of the current estimate).

5.12. Sectoral emissions sources and sinks

Energy

Electricity:

- Emissions from the combustion of fuel used to generate electricity for public use.

Stationary energy excluding electricity:

- Energy industries: petroleum refining, gas processing and solid fuel manufacturing (including coal mining and oil/gas extraction and processing).
- Manufacturing industries and construction: direct emissions from the combustion of fuel to provide energy used in manufacturing such as steel, non-ferrous metals, chemicals, food processing, non-energy mining and pulp and paper.
- Other sectors: energy used by the commercial, institutional, residential sectors as well as fuel used by the agricultural, fishery and forestry equipment. This also includes all remaining fuel combustion emissions associated with military fuel use.

Transport:

- Road transport: passenger vehicles, light commercial vehicles, trucks, buses and motorcycles.
- Domestic air transport: commercial passenger and light aircraft on domestic routes using either aviation gasoline or jet kerosene. International air transport is reported but not included in Australia's total emissions (in line with international guidelines).
- Coastal shipping: domestic shipping and small craft. International shipping is reported but not included in Australia's total emissions (in line with international guidelines).
- Rail transport: railways, but not electric rail, where fuel combustion is covered under the electricity sector.
- Transmission of natural gas.

Fugitive emissions:

Emissions, other than those attributable to energy use, from:

- Solid fuels: CO_2 and CH_4 from coal mining activities, post-mining and decommissioned mines and CO_2, CH_4 and N_2O from flaring associated with coal mining.

- Oil and natural gas: exploration, extraction, production, processing and transportation of natural gas and oil. Includes leakage, evaporation and storage losses, flaring and venting of CO_2, CH_4 and N_2O.

Industrial processes and product use:

- Mineral industry: CO_2 from cement clinker and lime production; the use of limestone and dolomite and other carbonates in industrial smelting and other processes; soda ash production and use; and magnesia production.
- Metal industry: CO_2 and PFCs from aluminium smelting; CO_2, CH_4 and N_2O from iron and steel production; and CO_2 from the production of ferroalloys and other metals.
- Chemical Industry: includes N_2O from the production of nitric acid; CO_2, from ammonia production, acetylene use and the production of synthetic rutile and titanium dioxide; and CH_4 from polymers and other chemicals.
- Other product manufacture and use: CO_2 from the consumption of CO_2 in the food and drink industry and the use of sodium bicarbonate, SF_6 from electrical equipment.
- Product uses as substitutes for Ozone Depleting Substances: HFC and refrigeration and air conditioning equipment, foam blowing, metered dose inhalers, fire extinguishers, solvent use.
- Non-energy products from fuel and solvent use: CO_2 produced by oxidation of lubricating oils and greases.

Agriculture:

CH_4 and N_2O emissions from the consumption, decay or combustion of living and dead biomass, including:

- Enteric fermentation in livestock: emissions associated with microbial fermentation during digestion of feed by ruminant (mostly cattle and sheep) and some non-ruminant domestic livestock.
- Manure management: emissions associated with the decomposition of animal wastes while held in manure management systems.
- Rice cultivation: CH_4 emissions from anaerobic decay of organic material when rice fields are flooded.
- Agricultural soils: emissions associated with the application of fertilisers, crop residues and animal wastes to agricultural lands and the use of biological nitrogen fixing crops and pastures.
- Field burning of agricultural residues: emissions from field burning of cereal and other crop stubble, and the emissions from burning sugar cane prior to harvest.
- Carbon dioxide emissions from the application of urea and lime.

Waste:

Emissions are predominantly CH_4. Small amounts of CO_2 and N_2O are generated through incineration and the decomposition of human wastes respectively. The main sources are:

- Solid waste: emissions resulting from anaerobic decomposition of organic matter in landfills.
- Wastewater: emissions resulting from anaerobic decomposition of organic matter in sewerage facilities (including on-site systems such as septic tanks) during treatment and disposal of wastewater.

- Incineration: emissions resulting from the incineration of solvents and clinical waste.
- Biological treatment of solid waste: emissions resulting from the anaerobic decomposition of organic material in composting and anaerobic digester facilities.

Land Use, Land Use Change and Forestry:

The LULUCF sector includes:

- Forest converted to other land uses: emissions and removals resulting from the direct human-induced removal of forest and replacement with pasture, crops or other uses since 1972. Emissions arise from the burning and decay of cleared vegetation, and changes in soil carbon from current and past events.
- Land converted to forest: emissions and removals (i.e. sinks) from forests established on agricultural land. Growth of the forests and regrowth on cleared lands provides a carbon sink, while emissions can arise from soil disturbance on the cleared lands (N_2O). Both new plantings and the regeneration of forest from natural seed sources contribute to this classification as well as sequestration projects under the Emission Reduction Fund.
- Forest land remaining forest land: emissions and removals in forests managed under a system of practices designed to support commercial timber production such as harvest or silvicultural practices or practices that are designed to implement specific sink enhancement activities. Forest harvesting causes emissions due to the decay of harvest slash and any subsequent prescribed burning. The regrowth of forests following harvesting provides a carbon sink and the harvested wood product pool can be a carbon sink or source depending on the rate of input and the rate of decay.
- Wildfire emissions on forest land are reported using IPCC guidance on natural disturbances. Further information on fire emissions occurring over the 2019-20 bushfire season will be reported in the Australian Government's National Inventory Report submitted in May 2020.
- Cropland: Anthropogenic emissions and removals on croplands occur as a result of changes in management practices on cropping lands, from changes in crop type (particularly woody crops) and from changes in land use.
- Grazing land: Anthropogenic emissions and removals on grasslands result from changes in management practices on grass lands, particularly from changes in pasture, grazing and fire management; changes in woody biomass elements and from changes in land use.
- Wetlands: Net emissions from the coastal lands including dredging of seagrass, aquaculture, and loss of tidal marsh areas. Changes in mangroves are reported under forest classifications.

5.13. Measurements

The units used in this quarterly update inventory are:

- grams (g)
- tonnes (t)
- metres (m)
- litres (L)

Standard metric prefixes used in this inventory are:

- kilo (k) = 10^3 (thousand)

- mega (M) = 10^6 (million)
- giga (G) = 10^9
- tera (T) = 10^{12}
- peta (P) = 10^{15}

In this report, emissions are expressed in Mt CO_2-e, which represents millions of tonnes of carbon dioxide equivalent gas.

5.14. Science and innovation in the national greenhouse gas inventory

There are many excellent greenhouse gas inventories in the world. Inventories submitted under the UN Framework Convention on Climate Change are prepared in accordance with IPCC guidelines and, for Annex I countries, audited each year by UNFCCC review teams.

The Australian national greenhouse gas inventory meets international standards and has been reviewed by the UNFCCC on fifteen occasions and by the Australian National Audit Office twice. The most recent ANAO audit, conducted in 2017 at cost of $0.5million, found the inventory emissions calculations to be accurate to within 99.9 per cent.

The inventory is prepared by a team of officials in the Department of Industry, Science, Energy and Resources with extensive international experience. Eight members of the team have participated in UN reviews of other countries' data and five contributed to the most recent update of the IPCC Guidelines for the preparation of national greenhouse gas inventories. Inventory methods and data are reviewed before publication by the National Greenhouse Gas Inventory Committee, comprising representatives of the States and Territories under an agreement reached by the Council of Australian Governments in 1991.

The inventory estimates are based on the best available science. The inventory methods are supported by research and analysis through long term partnerships with the CSIRO Data61, CSIRO Land and Water, CSIRO Oceans and Atmospheric and the ANU and shorter term contributions from many academic institutions around Australia including UNSW, University of Sydney, Monash University, University of Queensland.

Timely emissions data has been released through the Quarterly Update of the National Inventory since 2010. Very few other governments provide such timely information (known updates are published by a number of smaller countries including the Netherlands, Sweden and New Zealand) with these updates usually being partial in coverage and focussed on the electricity or energy system only.

The Australian inventory systems have been built upon important innovations and early adoptions of emerging international techniques to measure, estimate and verify greenhouse gas emissions.

1. With the ***National Greenhouse and Energy Reporting Act 2007***, the Australian parliament was among the first to legislate an integrated greenhouse gas emissions company reporting system, after the European Union in 2004, and the NGER system remains one of the most comprehensive integrated company reporting systems for greenhouse gas emissions anywhere.

2. Australian governments have invested in **customised emissions data modelling software** (AGEIS), which supports efficient production of high-quality data. Promotion of enhanced data monitoring and transparency internationally has been a long-standing objective of Australian Governments and the Australian approach to emissions data modelling and management has been used to assist the Thai Government to develop its own software (TGEIS) while information on software development has been shared with both the US Environment Protection Agency and the China Ministry of Ecology under a bilateral program managed by DFAT.

3. The Australian Government was the first to introduce the use of **remote sensing techniques** to detect forest loss and land clearing in national greenhouse gas inventories. Estimates of forest loss and land clearing for Australia, for each State and Territory and for some regions are updated and published every single year through this system. Australian Governments have championed the use of remote sensing techniques around the world and, in particular, have strongly supported the introduction of similar systems in Indonesia through bilateral partnerships managed by DFAT.

4. Net emissions from the land use, land use change and forestry sector are modelled through an **integrated carbon stock model** (FullCAM) which was originally supported through the commissioning of around 40 scientific reports and remains a leading example of integrated vegetation and soil carbon stock models around the world.

5. The use of **'top-down' inverse modelling** techniques to test and raise the quality and robustness of emissions data, with a focus on methane and HFCs, has been introduced in the Australian inventory (see Special Topics 2 and 3) and this remains a rare example (Switzerland and the United Kingdom are examples of others) of the use of these techniques in national greenhouse gas inventory systems.

6. The national inventory is produced as part of a set of **National Greenhouse Accounts,** which includes emissions data published at national, state and territory and industry levels as well as on consumption-basis (see section 4.)

5.15. Future publications

The December 2020 Quarterly Update of Australia's National Greenhouse Gas Inventory will be published by 31 May 2021.

6. Data tables

Data table 1A: Actual emissions (Mt), by sector, by quarter, since 2001-02[20]

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2001-2002	September	47.5	19.4	18.9	10.9	7.0	22.0	4.5	130.3	18.0	148.3
	December	44.2	19.4	19.5	10.2	6.9	22.0	4.5	126.8	18.0	144.8
	March	45.4	18.6	18.4	9.5	6.7	21.6	4.4	124.6	17.6	142.2
	June	46.8	19.2	18.6	10.5	7.0	21.8	4.4	128.4	17.8	146.2
2002-2003	September	48.6	19.9	19.5	10.5	7.6	20.6	4.2	130.9	21.2	152.0
	December	46.2	19.9	20.2	9.6	7.6	20.6	4.2	128.3	21.2	149.5
	March	45.4	19.2	19.0	9.1	7.6	20.1	4.1	124.5	20.7	145.2
	June	46.4	19.6	19.2	10.1	7.5	20.4	4.1	127.3	20.9	148.2
2003-2004	September	49.0	20.4	20.3	10.4	8.0	21.4	4.1	133.5	17.7	151.3
	December	46.8	20.3	21.0	9.5	8.1	21.4	4.1	131.2	17.7	149.0
	March	50.0	19.4	19.8	9.0	7.9	21.2	4.0	131.2	17.5	148.8
	June	49.1	20.0	20.0	10.1	7.7	21.2	4.0	132.0	17.5	149.6

[20] This table presents estimates of quarterly emissions by sector since 2001-02, in actual terms. As numbers are rounded, the sum of the sectors may not exactly equal the totals.

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2004-2005	September	50.9	20.9	20.8	10.7	7.8	21.7	4.0	136.8	24.0	160.8
	December	48.1	20.9	21.1	10.1	7.8	21.7	4.0	133.7	24.0	157.8
	March	48.8	19.9	19.7	9.4	7.7	21.2	3.9	130.6	23.5	154.0
	June	48.8	20.5	20.5	10.6	7.9	21.4	4.0	133.7	23.8	157.5
2005-2006	September	50.9	20.7	20.5	10.9	8.1	21.2	4.0	136.4	22.8	159.2
	December	48.9	20.6	21.8	10.2	7.9	21.2	4.0	134.6	22.8	157.4
	March	50.6	19.4	20.5	9.6	7.7	20.8	3.9	132.4	22.3	154.8
	June	50.8	20.7	20.5	11.0	7.9	21.0	3.9	135.8	22.6	158.4
2006-2007	September	52.1	20.5	21.1	11.6	8.2	20.2	4.1	137.9	26.7	164.6
	December	50.8	21.0	21.9	10.9	8.3	20.2	4.1	137.2	26.7	163.9
	March	51.6	19.8	21.0	10.3	8.2	19.8	4.0	134.6	26.1	160.7
	June	49.5	20.6	21.3	11.7	8.3	20.0	4.0	135.4	26.4	161.9
2007-2008	September	53.5	21.4	21.6	12.4	8.2	19.5	4.2	140.8	22.3	163.1
	December	50.3	21.3	22.1	10.4	8.1	19.5	4.2	135.9	22.3	158.2
	March	51.6	20.3	21.1	10.4	8.0	19.3	4.1	135.0	22.1	157.1
	June	50.5	21.4	21.6	11.2	8.2	19.3	4.1	136.2	22.1	158.3

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2008-2009	September	55.4	21.9	22.1	11.1	8.8	19.6	4.2	143.1	20.3	163.4
	December	52.3	21.4	22.5	11.2	8.1	19.6	4.2	139.3	20.3	159.6
	March	52.4	19.2	21.1	9.9	6.7	19.2	4.1	132.6	19.9	152.5
	June	51.5	20.3	21.5	11.7	7.0	19.4	4.1	135.4	20.1	155.5
2009-2010	September	51.4	20.7	22.4	11.7	7.9	18.9	4.3	137.3	15.4	152.7
	December	51.3	21.1	22.9	10.7	8.3	18.9	4.3	137.4	15.4	152.8
	March	52.5	20.4	21.4	10.2	8.4	18.5	4.2	135.6	15.1	150.7
	June	49.9	21.1	21.8	11.2	8.3	18.7	4.2	135.3	15.3	150.6
2010-2011	September	51.0	23.2	22.6	11.9	8.3	20.1	4.1	141.2	8.7	149.8
	December	47.0	21.1	23.6	11.0	8.6	20.1	4.1	135.5	8.7	144.2
	March	50.6	19.6	22.0	9.2	8.4	19.7	4.0	133.6	8.5	142.1
	June	49.7	21.6	23.1	10.3	8.3	19.9	4.0	137.0	8.6	145.6
2011-2012	September	50.9	24.1	22.5	11.0	8.2	20.5	3.7	140.9	4.6	145.5
	December	49.1	21.6	22.9	10.7	7.5	20.5	3.7	136.0	4.6	140.6
	March	50.3	20.7	23.0	9.9	7.4	20.2	3.6	135.2	4.6	139.7
	June	48.7	22.6	23.4	11.7	7.3	20.2	3.6	137.6	4.6	142.1

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2012-2013	September	47.0	24.8	23.2	11.2	7.1	20.6	3.5	137.4	4.0	141.4
	December	45.9	23.7	23.9	11.0	7.2	20.6	3.5	135.8	4.0	139.8
	March	47.5	22.1	22.2	10.4	7.0	20.1	3.4	132.8	3.9	136.7
	June	46.5	23.1	22.7	11.2	7.1	20.4	3.5	134.5	4.0	138.4
2013-2014	September	45.0	24.4	23.4	10.5	7.1	20.7	3.5	134.7	4.2	138.9
	December	44.0	23.0	23.8	10.7	7.2	20.7	3.5	132.9	4.2	137.1
	March	47.2	22.5	22.7	10.5	6.9	20.2	3.4	133.4	4.1	137.5
	June	44.5	24.8	23.2	10.4	7.1	20.4	3.5	134.0	4.2	138.2
2014-2015	September	47.5	24.3	23.9	12.6	7.4	19.9	3.4	139.0	2.4	141.4
	December	46.3	21.4	24.5	11.5	7.6	19.9	3.4	134.5	2.4	136.9
	March	48.1	20.8	23.3	10.7	7.3	19.5	3.3	133.0	2.4	135.4
	June	47.1	23.3	23.6	11.9	7.4	19.7	3.3	136.4	2.4	138.8
2015-2016	September	49.3	22.0	24.1	12.5	7.6	19.6	3.5	138.5	-3.9	134.7
	December	48.0	20.8	24.5	12.5	7.3	19.6	3.5	136.2	-3.9	132.4
	March	49.9	23.4	24.0	12.0	7.2	19.4	3.5	139.3	-3.8	135.5
	June	47.5	24.7	23.8	11.7	7.4	19.4	3.5	137.9	-3.8	134.1

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2016-2017	September	48.8	25.6	24.6	12.7	7.5	20.6	3.5	143.3	-6.8	136.5
	December	45.4	22.4	25.8	12.3	7.7	20.6	3.5	137.8	-6.8	131.0
	March	49.6	21.0	23.9	12.2	7.3	20.2	3.5	137.6	-6.6	131.0
	June	46.0	25.3	24.4	13.2	7.5	20.4	3.5	140.4	-6.7	133.7
2017-2018	September	46.2	26.1	25.0	13.9	7.7	20.3	3.5	142.8	-4.1	138.7
	December	44.9	23.6	25.5	13.4	7.7	20.3	3.5	138.9	-4.1	134.8
	March	46.7	22.7	24.4	12.6	7.7	19.9	3.4	137.4	-4.0	133.4
	June	45.6	25.0	25.1	13.5	7.6	20.1	3.5	140.4	-4.0	136.4
2018-2019	September	45.3	27.5	25.3	13.2	7.6	18.9	3.5	141.3	-5.0	136.3
	December	43.5	23.5	25.9	14.0	8.2	18.9	3.5	137.4	-5.0	132.4
	March	46.5	22.1	24.3	12.9	7.8	18.4	3.4	135.4	-4.9	130.6
	June	43.9	26.4	24.9	14.6	8.1	18.7	3.4	140.0	-4.9	135.1
2019-2020	September	43.6	28.4	25.0	13.7	8.1	17.9	3.3	140.0	-4.7	135.3
	December	42.2	24.5	25.6	13.3	7.5	17.9	3.3	134.3	-4.7	129.6
	March	44.2	23.0	24.1	12.5	7.1	17.7	3.3	131.9	-4.7	127.2
	June	41.7	26.9	19.0	13.1	7.8	17.7	3.3	129.5	-4.7	124.9
2020-2021	September	42.3	27.4	21.2	12.3	7.8	18.8	3.3	133.1	-4.7	128.4
	December										
	March										

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
	June										

Data table 1B: Seasonally adjusted emissions (Mt), by sector, by quarter, since 2001-02[21]

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2001-2002	September	46.2	19.0	18.7	10.3	6.8	21.9	4.5	127.6	17.3	144.9
	December	45.2	19.1	18.8	10.4	6.8	21.9	4.5	126.9	17.8	144.6
	March	45.8	19.2	18.9	10.3	6.8	21.8	4.4	127.3	18.1	145.5
	June	46.7	19.4	19.1	10.2	7.1	21.9	4.4	128.5	18.1	146.4
2002-2003	September	47.2	19.5	19.3	9.9	7.4	20.5	4.2	128.1	20.7	148.7
	December	47.1	19.6	19.4	9.8	7.6	20.5	4.2	128.3	20.9	149.2
	March	45.7	19.8	19.5	9.8	7.8	20.3	4.1	127.1	21.2	148.5
	June	46.4	19.8	19.7	9.8	7.6	20.4	4.1	127.4	21.1	148.4
2003-2004	September	47.6	19.9	20.0	9.8	7.8	21.3	4.0	130.7	17.3	148.2
	December	47.8	20.0	20.2	9.7	8.0	21.3	4.0	131.2	17.5	148.6
	March	50.2	20.1	20.3	9.7	8.0	21.4	4.1	133.9	18.0	152.1
	June	49.4	20.1	20.4	9.8	7.8	21.2	4.0	132.3	17.5	149.7
2004-2005	September	49.4	20.4	20.5	10.1	7.7	21.6	4.0	133.8	23.8	157.7
	December	49.1	20.6	20.3	10.3	7.7	21.5	4.0	133.6	23.8	157.3
	March	48.9	20.6	20.2	10.2	7.8	21.4	4.0	133.2	23.9	157.2
	June	49.4	20.6	20.9	10.3	8.0	21.4	4.0	134.3	23.7	157.8

[21] This table presents estimates of quarterly emissions by sector since 2001-02, in seasonally adjusted terms. Estimates for the national inventory total and the electricity sector include weather normalisation, as described in Section 5: Technical Notes. Seasonally adjusted estimates for all other sectors are presented without weather normalisation. As numbers are rounded, the national inventory total may differ from the sum of the rows.

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2005-2006	September	49.4	20.3	20.3	10.3	8.0	21.2	4.0	133.3	22.7	156.2
	December	49.8	20.2	21.1	10.3	7.8	21.1	3.9	134.4	22.8	157.0
	March	50.6	20.2	21.0	10.4	7.8	21.0	3.9	135.1	22.7	157.8
	June	51.6	20.8	20.8	10.6	8.0	21.0	4.0	136.5	22.2	158.7
2006-2007	September	50.6	20.0	20.9	10.9	8.1	20.2	4.0	134.8	26.9	161.6
	December	51.7	20.6	21.2	10.9	8.3	20.1	4.0	137.1	26.7	163.6
	March	51.4	20.7	21.6	11.2	8.3	20.0	4.0	137.2	26.3	163.6
	June	50.3	20.6	21.7	11.4	8.4	20.0	4.0	136.2	25.8	162.3
2007-2008	September	51.9	20.8	21.4	11.7	8.0	19.5	4.2	137.5	22.8	160.2
	December	51.2	20.9	21.4	10.4	8.0	19.4	4.2	135.8	22.5	158.1
	March	51.3	21.3	21.7	11.4	8.2	19.5	4.2	137.5	22.1	159.7
	June	51.4	21.4	21.9	10.9	8.3	19.2	4.2	136.8	21.2	158.5
2008-2009	September	53.9	21.3	21.9	10.5	8.6	19.6	4.2	140.0	21.1	160.6
	December	53.4	21.0	21.8	11.2	8.0	19.5	4.2	139.4	20.5	159.8
	March	51.9	20.3	21.7	10.8	6.9	19.4	4.1	135.0	19.7	154.9
	June	52.3	20.3	21.7	11.3	7.1	19.4	4.1	135.9	19.0	155.5

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2009-2010	September	50.1	19.9	22.3	11.1	7.8	18.8	4.3	134.4	16.4	150.2
	December	52.4	20.8	22.2	10.7	8.1	18.8	4.2	137.5	15.7	153.2
	March	51.8	21.6	22.1	11.2	8.5	18.7	4.2	137.9	14.9	153.0
	June	50.4	21.1	22.1	10.9	8.4	18.8	4.2	135.8	14.2	150.2
2010-2011	September	50.2	22.1	22.4	11.3	8.2	20.0	4.1	138.2	9.7	147.6
	December	48.1	21.0	22.9	11.0	8.4	20.0	4.1	135.8	9.0	144.8
	March	49.8	20.8	22.6	10.1	8.5	19.9	4.0	135.8	8.2	144.1
	June	50.1	21.6	23.3	10.0	8.4	20.0	4.0	137.4	7.7	145.0
2011-2012	September	50.4	22.8	22.4	10.5	8.1	20.3	3.7	137.9	5.5	143.5
	December	50.3	21.6	22.2	10.7	7.4	20.3	3.6	136.4	4.9	141.4
	March	49.3	22.0	23.7	10.7	7.5	20.5	3.6	137.3	4.3	141.6
	June	49.0	22.5	23.6	11.3	7.4	20.3	3.6	137.8	3.8	141.4
2012-2013	September	46.7	23.3	23.1	10.8	7.1	20.5	3.5	134.5	4.8	139.5
	December	46.9	24.0	23.2	11.0	7.1	20.4	3.5	136.4	4.3	140.8
	March	46.4	23.5	22.8	11.1	7.2	20.4	3.4	134.9	3.6	138.3
	June	47.0	22.6	22.9	10.9	7.2	20.4	3.4	134.5	3.3	137.9

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2013-2014	September	44.7	23.0	23.3	10.2	7.1	20.6	3.5	131.9	4.9	136.9
	December	45.0	23.5	23.1	10.6	7.1	20.5	3.5	133.7	4.5	138.2
	March	46.0	23.9	23.3	11.1	7.1	20.5	3.5	135.5	3.9	139.0
	June	45.0	24.1	23.5	10.2	7.1	20.4	3.5	133.8	3.6	137.8
2014-2015	September	47.1	23.0	23.7	12.3	7.4	19.8	3.4	136.2	3.0	139.2
	December	47.3	22.1	23.8	11.4	7.4	19.8	3.3	135.5	2.7	138.1
	March	46.8	22.2	23.9	11.3	7.5	19.7	3.3	135.2	2.1	136.7
	June	47.7	22.4	23.8	11.8	7.5	19.6	3.3	135.9	1.9	138.5
2015-2016	September	48.9	20.8	23.9	12.1	7.5	19.6	3.5	135.8	-3.3	132.3
	December	49.2	21.7	23.8	12.4	7.2	19.5	3.5	137.3	-3.6	133.6
	March	48.6	25.1	24.7	12.5	7.4	19.6	3.5	141.6	-4.1	137.0
	June	48.1	23.7	24.1	11.6	7.4	19.2	3.5	137.3	-4.2	133.8
2016-2017	September	48.3	23.8	24.4	12.3	7.5	20.7	3.5	140.4	-6.3	133.9
	December	46.5	23.4	25.1	12.3	7.5	20.5	3.5	139.1	-6.6	132.4
	March	48.2	22.8	24.5	12.8	7.5	20.4	3.5	140.0	-6.8	132.7
	June	46.5	24.2	24.7	13.1	7.5	20.2	3.5	139.6	-7.0	133.2

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2017-2018	September	45.9	24.1	24.9	13.6	7.6	20.4	3.5	139.8	-3.7	136.0
	December	46.1	24.6	24.7	13.4	7.6	20.2	3.5	140.3	-4.0	136.2
	March	45.4	25.0	25.1	13.2	7.8	20.1	3.5	139.9	-4.2	135.4
	June	46.0	24.1	25.3	13.2	7.6	19.9	3.5	139.5	-4.2	135.6
2018-2019	September	45.1	25.1	25.2	13.0	7.6	19.0	3.5	138.3	-4.8	133.6
	December	44.8	24.6	25.0	13.9	8.1	18.8	3.5	138.9	-4.9	133.8
	March	45.1	24.5	25.0	13.5	8.0	18.6	3.4	138.0	-5.0	132.7
	June	44.2	25.4	25.2	14.2	8.1	18.4	3.4	139.0	-5.0	134.2
2019-2020	September	43.4	25.8	24.9	13.5	8.0	18.0	3.3	137.0	-4.6	132.7
	December	43.5	25.6	24.8	13.2	7.4	17.8	3.3	135.8	-4.7	130.9
	March	42.8	25.7	24.8	13.2	7.3	17.8	3.3	134.5	-4.7	129.5
	June	41.9	25.8	19.1	12.7	7.8	17.5	3.3	128.5	-4.7	123.9
2020-21	September	42.2	24.8	21.1	12.1	7.8	18.9	3.3	130.2	-4.6	126.0
	December										
	March										
	June										

Data table 1C: Trend emissions (Mt), by sector, by quarter, since 2001-02[22]

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2001-2002	September	46.0	19.0	18.7	10.5	6.9	21.9	4.5	127.5	18.0	145.6
	December	45.5	19.1	18.8	10.4	6.8	21.9	4.5	127.3	17.5	144.6
	March	45.8	19.2	18.9	10.3	6.9	21.8	4.4	127.5	17.9	145.3
	June	46.7	19.4	19.1	10.2	7.1	21.4	4.4	128.0	18.7	146.8
2002-2003	September	47.2	19.5	19.3	10.0	7.4	20.8	4.3	128.3	20.1	148.4
	December	46.9	19.6	19.4	9.8	7.6	20.4	4.2	127.8	21.1	149.1
	March	46.3	19.7	19.5	9.8	7.7	20.3	4.1	127.5	21.4	148.7
	June	46.4	19.8	19.7	9.8	7.7	20.5	4.1	128.1	20.3	148.3
2003-2004	September	47.5	19.9	20.0	9.8	7.8	21.0	4.1	129.8	18.2	148.2
	December	48.7	20.0	20.2	9.7	8.0	21.3	4.0	131.7	17.2	148.7
	March	49.4	20.1	20.3	9.7	8.0	21.3	4.0	132.8	17.9	150.3
	June	49.6	20.2	20.5	9.8	7.8	21.3	4.0	133.3	19.7	152.8
2004-2005	September	49.3	20.4	20.5	10.1	7.7	21.5	4.0	133.5	22.4	155.5
	December	49.1	20.6	20.4	10.2	7.7	21.5	4.0	133.6	23.9	157.1
	March	49.0	20.7	20.4	10.2	7.8	21.5	4.0	133.6	24.0	157.6
	June	49.2	20.5	20.5	10.2	8.0	21.4	4.0	133.6	23.5	157.3

[22] This table presents estimates of quarterly emissions by sector since 2001-02, in trend terms. Estimates for the national inventory total and the electricity sector include weather normalisation, as described in Section 5: Technical Notes.' Trend estimates for all other sectors are presented without weather normalisation. As numbers are rounded, the national inventory total may differ from the sum of the rows.

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2005-2006	September	49.4	20.3	20.8	10.3	7.9	21.2	4.0	133.8	22.9	156.7
	December	49.8	20.2	21.0	10.3	7.8	21.1	3.9	134.5	22.6	156.8
	March	50.7	20.2	21.0	10.4	7.8	21.0	3.9	135.1	22.5	157.7
	June	51.1	20.4	20.9	10.6	8.0	20.8	4.0	135.6	23.9	159.1
2006-2007	September	51.2	20.5	20.9	10.9	8.1	20.4	4.0	136.1	26.1	161.5
	December	51.4	20.6	21.2	11.0	8.2	20.1	4.0	136.5	27.0	163.5
	March	51.2	20.7	21.5	11.2	8.4	20.0	4.0	136.9	26.5	163.6
	June	51.0	20.7	21.6	11.4	8.3	19.9	4.1	136.9	25.2	162.2
2007-2008	September	51.3	20.8	21.4	11.4	8.1	19.5	4.1	136.7	23.4	160.0
	December	51.5	21.0	21.4	11.3	8.0	19.4	4.2	136.6	22.3	158.8
	March	51.1	21.3	21.7	11.2	8.2	19.4	4.2	136.9	22.0	158.8
	June	52.0	21.4	21.9	10.8	8.4	19.4	4.2	138.0	21.4	159.5
2008-2009	September	53.3	21.3	21.9	10.7	8.4	19.5	4.2	139.0	21.0	160.3
	December	53.3	20.9	21.8	10.9	8.0	19.5	4.1	138.6	20.5	159.2
	March	52.4	20.5	21.7	11.1	7.3	19.4	4.1	136.9	19.9	155.9
	June	51.7	20.1	21.8	11.2	7.2	19.3	4.2	135.5	18.6	153.3
2009-2010	September	51.6	20.1	22.2	11.0	7.7	19.0	4.2	135.8	16.8	152.8
	December	51.9	20.8	22.2	10.9	8.2	18.7	4.2	136.6	15.6	153.1
	March	51.8	21.3	22.1	10.9	8.5	18.8	4.2	137.2	14.7	152.7
	June	50.8	21.3	22.1	11.1	8.4	19.1	4.2	137.3	13.0	150.4

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2010-2011	September	49.6	21.2	22.5	11.2	8.3	19.6	4.1	136.7	10.8	147.4
	December	49.1	21.0	22.7	10.9	8.4	19.9	4.1	136.3	9.1	145.0
	March	49.4	21.0	22.8	10.2	8.5	20.0	4.0	136.5	8.3	144.4
	June	50.2	21.5	22.7	10.0	8.4	20.1	3.9	136.9	7.3	144.6
2011-2012	September	50.4	21.8	22.5	10.4	8.1	20.2	3.8	137.3	5.9	143.4
	December	50.1	21.8	22.7	10.7	7.7	20.4	3.7	137.4	4.8	141.8
	March	49.6	22.0	23.3	10.9	7.5	20.4	3.6	137.1	4.2	141.5
	June	48.5	22.5	23.5	11.1	7.3	20.4	3.6	136.9	4.1	141.1
2012-2013	September	47.3	23.4	23.2	11.0	7.2	20.4	3.5	136.3	4.5	140.4
	December	46.6	23.9	23.0	10.9	7.1	20.4	3.5	135.7	4.4	139.7
	March	46.7	23.5	22.9	11.1	7.2	20.4	3.4	135.0	3.5	138.8
	June	46.0	22.8	23.0	10.8	7.1	20.4	3.5	133.9	3.7	137.5
2013-2014	September	45.1	23.0	23.2	10.4	7.1	20.5	3.5	133.2	4.5	137.3
	December	45.1	23.5	23.2	10.6	7.1	20.5	3.5	133.6	4.6	138.1
	March	45.5	24.0	23.3	11.0	7.1	20.5	3.5	134.4	3.9	138.5
	June	45.9	23.9	23.5	11.2	7.2	20.3	3.4	135.1	3.5	138.5
2014-2015	September	46.7	23.0	23.7	11.4	7.3	20.0	3.4	135.3	3.1	138.6
	December	47.3	22.3	23.8	11.4	7.5	19.7	3.3	135.5	2.7	138.2
	March	47.1	22.1	23.9	11.4	7.5	19.7	3.3	135.5	2.1	136.9
	June	47.7	21.6	23.9	11.7	7.5	19.6	3.4	135.5	0.5	135.5

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2015-2016	September	48.8	21.2	23.9	12.1	7.4	19.5	3.4	136.3	-2.0	134.0
	December	49.1	21.9	24.0	12.4	7.3	19.5	3.5	137.5	-3.6	134.1
	March	48.6	23.2	24.1	12.3	7.4	19.6	3.5	138.9	-4.0	134.7
	June	48.3	23.8	24.2	12.0	7.4	19.8	3.5	139.8	-4.7	134.5
2016-2017	September	47.9	23.8	24.4	12.1	7.5	20.2	3.5	139.9	-5.9	133.4
	December	47.4	23.3	24.6	12.4	7.5	20.5	3.5	139.7	-6.7	132.7
	March	47.0	23.2	24.6	12.7	7.5	20.4	3.5	139.6	-7.0	132.4
	June	46.5	23.8	24.7	13.2	7.5	20.3	3.5	139.7	-6.3	133.7
2017-2018	September	46.1	24.3	24.8	13.4	7.6	20.3	3.5	140.0	-4.7	135.5
	December	45.8	24.6	24.8	13.4	7.7	20.3	3.5	140.1	-3.8	136.2
	March	45.8	24.7	25.1	13.2	7.8	20.1	3.5	139.8	-4.1	135.8
	June	45.6	24.6	25.3	13.1	7.7	19.7	3.5	139.3	-4.3	135.1
2018-2019	September	45.2	24.7	25.2	13.2	7.7	19.1	3.5	138.8	-4.7	134.2
	December	44.9	24.7	25.0	13.5	7.9	18.7	3.4	138.6	-5.0	133.3
	March	44.9	24.6	25.0	13.9	8.1	18.6	3.4	138.6	-5.0	133.4
	June	44.2	25.3	25.1	14.0	8.1	18.4	3.4	138.2	-4.9	133.6
2019-2020	September	43.5	25.7	25.1	13.7	7.9	18.1	3.3	137.1	-4.7	132.8
	December	43.3	25.7	24.6	13.3	7.5	17.8	3.3	135.7	-4.6	131.1
	March	42.8	25.8	23.3	13.1	7.4	17.8	3.3	135.0	-4.7	129.0
	June	42.2	25.6	21.3	12.7	7.6	18.1	3.3	128.7	-4.7	126.9

Year	Quarter	Energy				Industrial processes and product use	Agriculture	Waste	Total excluding LULUCF	LULUCF	National Inventory Total
		Electricity	Stationary energy excl. electricity	Transport	Fugitive emissions						
2020-2021	September	41.8	25.0	19.5	12.2	7.8	18.6	3.3	129.0	-4.7	125.7
	December										
	March										
	June										

Tracking Australia's emissions

The data presented in Table 8 and Figure 21 include Australia's annual emissions for 2000 to 2020.

Australia's annual emissions for the year to September 2020 are estimated to be 510.1 Mt CO_2-e. This figure is 8.1 per cent below emissions in the year to June 2000 (555.2 Mt CO_2-e) and 19.0 per cent below emissions in the year to June 2005 (630.1 Mt CO_2-e).

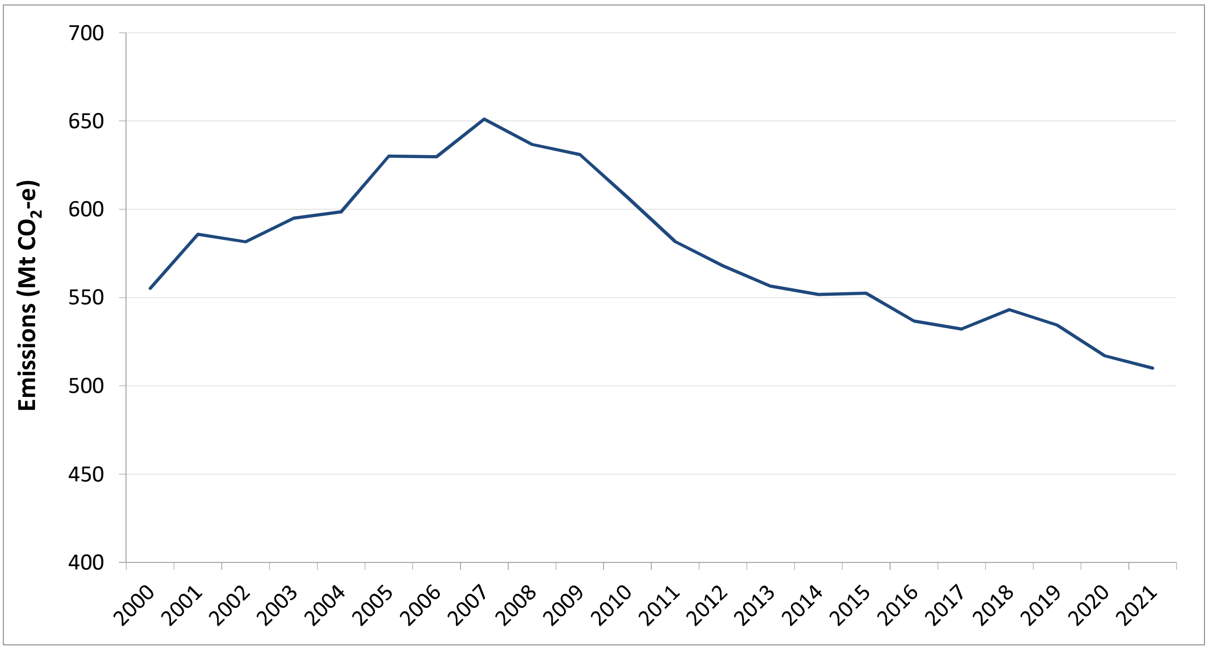
Table 8: National inventory total from 2000 to 2020, by financial year[23]

Financial Year	Emissions (Mt CO_2-e)
2000	555.2
2001	585.8
2002	581.6
2003	594.9
2004	598.5
2005	630.1
2006	629.8
2007	651.1
2008	636.7
2009	631.1
2010	606.8
2011	581.7
2012	567.9
2013	556.4
2014	551.7
2015	552.4
2016	536.7
2017	532.2
2018	543.2
2019	534.4
2020	517.0
2021[a]	510.1

a – year to September 2020

[23] 2000-2020 are year to June data. 2021 is year to September 2020 data.

Figure 21: National inventory total, from 2000 to 2020, [24]by financial year to 2020 and year to September 2020



Source: Department of Industry, Science, Energy and Resources

[24] 2000-2019 are year to June data. 2020 is year to September data.

7. Related publications and resources

Australia’s national Greenhouse Accounts

The following Department of Industry Science Energy and Resources (DISER) publications are all available at: https://www.industry.gov.au/policies-and-initiatives/australias-climate-change-strategies/tracking-and-reporting-greenhouse-gas-emissions

National Greenhouse Gas Inventory: Quarterly Updates

Quarterly Updates of Australia’s National Greenhouse Gas Inventory are the most up to date source of information on Australia’s national emissions. They provide a summary of Australia’s national emissions, updated on a quarterly basis. They give timely information to policy makers, markets and the public to demonstrate how Australia is tracking against its targets.

Access past and future quarterly updates: https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-quarterly-updates

National Inventory Report 2018

The three volumes comprising Australia’s forthcoming National Inventory Report 2018 were submitted under the UNFCCC and the Kyoto Protocol in May 2020. These reports contain national greenhouse gas emission estimates for the period 1990-2018 and preliminary estimates for 2019 compiled under the rules for reporting applicable to the UNFCCC.

- Volume 1: Includes Australia’s data for energy (*stationary energy, transport and fugitive emissions*), *industrial processes and product use*, and *agriculture*.
- Volume 2: Australia’s data for the *Land Use, Land Use Change and Forestry* (LULUCF) and *waste* sectors, recalculations and improvements.
- Volume 3: Australia’s data for Kyoto Protocol LULUCF, Kyoto Protocol accounting requirements, annexes, glossary and references.

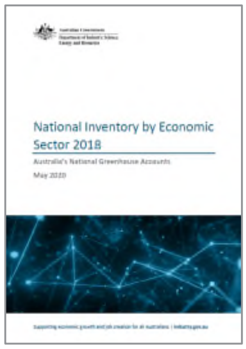
Read the report: https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-report-2018

State and Territory Greenhouse Gas Inventories 2018

This document provides an overview of the latest available estimates of annual greenhouse gas emissions for Australia’s States and Territories. It complements Australia’s *National Inventory Report 2018* and the *National Inventory by Economic Sector 2018*.

Read the inventories: https://www.industry.gov.au/data-and-publications/state-and-territory-greenhouse-gas-inventories-2018

National Inventory by Economic Sector 2018

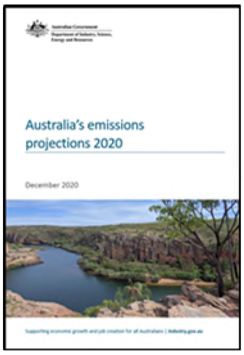


This document provides an overview of the latest available estimates of annual greenhouse gas emissions, disaggregated by Australia-New Zealand Standard Industrial Classifications (ANZSIC). It complements Australia's *National Inventory Report 2018* and the *State and Territory Greenhouse Gas Inventories 2018*.

Read the inventory: https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-by-economic-sector-2018

Australian Greenhouse Emissions Information System (AGEIS)

The AGEIS centralises the Department's emissions estimation, emissions data management and reporting systems. AGEIS is being used to compile national and State and Territory inventories. The interactive web interface provides enhanced accessibility and transparency to Australia's greenhouse emissions data: https://ageis.climatechange.gov.au/



Australia's Emissions Projections 2020

The report provides detail on emissions trends, including sector specific analysis of factors driving emissions. The report estimates the emissions reduction effort required to meet Australia's emissions reduction targets. The projections include sensitivity analyses to illustrate how emissions may differ under changes in economic growth. https://www.industry.gov.au/data-and-publications/australias-emissions-projections-2020

1qqFull Carbon Accounting Model

The Full Carbon Accounting Model (FullCAM) is the calculation engine which supports the estimation of carbon stock change on forest and agricultural systems. FullCAM can be downloaded from the Department's webpage: https://www.industry.gov.au/data-and-publications/full-carbon-accounting-model-fullcam

Australia's Seventh National Communication/Fourth Biennial Report

Australia's Seventh National Communication (2017) summarises information on Australia's implementation of its UNFCCC and Kyoto Protocol obligations including: emissions and removals of greenhouse gases; national circumstances; policies and measures; vulnerability assessment; financial, technology and capacity building cooperation; education, training, and public awareness. Countries such as Australia are required to submit these reports to the UNFCCC every four years. In accordance with international reporting requirements, the 2017 National Communication also incorporates Australia's Third Biennial Report. Australia has recently submitted its Fourth Biennial Report (2019).

These must be submitted every two years and outline Australia's progress in achieving emission reductions and the provision of financial, technology, and capacity-building support. More

information is available at:
http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/10138.php

and https://unfccc.int/sites/default/files/resource/Australia%20Fourth%20Biennial%20Report.pdf

What the rest of the world is doing

Other developed countries are also required to produce annual greenhouse gas inventories. More information regarding the reporting requirements and various international reports (including reports by Australia) are located online. https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

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