Department of Planning and Environment

NSW Regional and Local Greenhouse Gas Emissions

Methods paper

environment.nsw.gov.au

Cover photo: Aerial view of Aberdeen, Hunter Valley. Jaime Plaza Van Roon/DPE

Published by:

Environment and Heritage
Department of Planning and Environment
Locked Bag 5022, Parramatta NSW 2124
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment and Heritage enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
See also www.environment.nsw.gov.au

ISBN 978-1-922899-54-5
EHG 2022/0459
September 2022

Find out more about your environment at:

www.environment.nsw.gov.au

Contents

List of tables

List of figures

Executive summary

The NSW Greenhouse Gas Inventory, updated annually and published by the Commonwealth Government as part of the National Greenhouse Accounts, includes annual emissions data on a state-aggregated basis.

The NSW Department of Planning and Environment (the department) has developed regional and local-scale greenhouse gas emissions data to inform state, regional and local climate mitigation actions.

This method paper outlines the assumptions, data and methods used to derive the first set of NSW regional and local-scale greenhouse gas emissions data. This Stage 1 dataset includes annual direct and indirect emissions for financial years ending June 2016 to June 2019 by local government area (LGA), with aggregations possible for NSW regions and for each of the Six Cities.

Direct (scope 1) emissions are inventoried based on a 'territorial approach' with emissions attributed to the LGA within which sources are located. Such profiling informs policies and strategies aimed at addressing emission sources.

Scope 1 emissions are presented by sector based on categories from the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories and in line with the National Greenhouse Accounts. Sectors and subsectors for which emissions and carbon sequestration are reported are as follows:

- electricity generation
- stationary energy (excluding electricity generation)
- fugitive emissions from coal and natural gas extraction, processing, storage or delivery
- industrial processes and product use
- agriculture – crops, beef, dairy, sheep, goats, pigs and other livestock
- land use, land-use change and forestry – cropland, grassland, forest land and settlements
- transport – road transport (freight and light vehicles), domestic aviation, domestic navigation, railways and other transport
- waste – solid waste and domestic/commercial and industrial wastewater.

Over 95–98% of scope 1 emissions are spatially allocated by LGA for each year. Emissions have not yet been spatially allocated for the following subsectors:

- agriculture – mineralisation from soil carbon loss, liming, urea, sewage sludge applied to land
- transport – buses and motorcycles
- land use, land-use change and forestry – harvested wood products, wetland conversions to other land use, private native forestry, mangroves and tidal marsh, fuelwood use, woody horticulture and sparse woody vegetation
- waste – biological treatment of waste, and incineration and open burning of waste.

Indirect (scope 2) emissions from the generation of purchased electricity are allocated to the LGA where the electricity is used. Scope 2 emissions are reported for residential consumption and for other non-residential uses, which are termed 'business' and include commercial, institutional and industrial consumption of purchased electricity.

NSW regional and local-scale emissions are accessible through the NSW Net Zero Emissions Dashboard on the Sharing and Enabling Environmental Data (SEED) portal.

Local-scale emissions will be updated annually to incorporate staged enhancements of the data.

Introduction

The NSW Government aims to achieve a 50% reduction in NSW emissions below 2005 levels by 2030 and to reach net zero emissions by 2050 (DPIE 2021; OEH 2016). The Net Zero Plan Stage 1: 2020–2030, released in March 2020, is the foundation for the NSW Government's action on climate change over the next decade (DPIE 2020a). It outlines how the NSW Government plans to grow the economy, create jobs and reduce the cost of living through strategic emissions reduction initiatives across the economy. The Net Zero Plan delivers on the objectives of the NSW Climate Change Policy Framework, which sets out the long-term policy directions for action to mitigate and adapt to climate change (OEH 2016).

Regional and city planners and local councils play an important role in supporting emissions reduction through their regional plans, local leadership, connection to communities and collective actions to support progress towards achieving the state's net zero emissions objectives.

The NSW Government's Net Zero Emissions Modelling Program includes the staged delivery of local-scale emissions data, which is consistent with published state aggregated emissions, to help inform state, regional and local net zero emissions actions.

This method paper sets out the staged approach for expanding the scope and coverage of the greenhouse gas (GHG) emissions data to be developed, and details the data and methods applied in deriving the Stage 1 data to be published in 2022.

Context

National and state greenhouse accounts

The Commonwealth Government maintains national, state and territory GHG emissions inventories for past years. The NSW Greenhouse Gas Inventory is updated annually and published as part of the National Greenhouse Accounts following the United Nations Framework Convention on Climate Change (UNFCCC) reporting rules.

The NSW Greenhouse Gas Inventory does not include sub-state emissions data and emissions are typically reported about 2 years behind the current year due to the time taken for the National Greenhouse Accounts to be prepared, undergo quality assurance and be published. For example, emissions data for the financial year ending June 2020 was published in June 2022.

Emissions are inventoried and published by sector, as classified within the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC 2019), and by Australian and New Zealand Standard Industrial Classification (ANZSIC) economic sector.

NSW greenhouse gas emissions modelling

In 2019 the NSW Government established GHG emissions modelling capabilities to deliver state- and economy-wide emissions to inform the NSW Government's actions and track progress towards achieving net zero emissions objectives. This includes the projection of future emissions within NSW by sector out to 2050, and the staged delivery of local-scale emissions across the state.

The NSW emissions projections for future years delivered in 2021 are published within the NSW State of the Environment 2021 report (EPA 2022). These projections and the first local-scale emissions data delivered in 2022 are accessible through the NSW Net Zero Emissions Dashboard on the Sharing and Enabling Environmental Data (SEED) portal (NSW Government 2022).

Regional and local emissions and reporting

A number of NSW councils undertake reporting of GHG emissions under the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) (World Resources Institute 2014), supported by the Resilient Sydney Platform. This approach was also applied by the Greater Sydney Commission (GSC) for emissions reporting for the Greater Sydney Region.

In 2022 the Greater Cities Commission (GCC) was established with the Greater Sydney Region being replaced with the Six Cities Region, which includes the Eastern Harbour, Central River, Central Coast, Lower Hunter and Greater Newcastle, the Western Parkland and Illawarra–Shoalhaven cities.

The GPC supports 2 approaches for developing and reporting inventories, a ‘territorial’ and a ‘city-induced’ approach. It makes provision for reporting on a subset of sources (BASIC reporting) or addressing sources more comprehensively including emissions arising from industrial processes, agriculture and the land sector (BASIC+ reporting). NSW councils reporting under the GPC primarily do BASIC reporting due to the unavailability of robust data for other sectors.

Staged delivery of spatial emissions

This method paper outlines the approach, assumptions, data and methods used to derive the first set of NSW regional and local-scale emissions data. This Stage 1 dataset comprises annual GHG emissions for the 4 financial years ending June 2016 to June 2019 by local government area (LGA), with aggregations for NSW regions and for each of the Six Cities.

The NSW Government’s Stage 1 local-scale emissions data addresses:

- direct (scope 1) emissions based on a territorial approach with emissions attributed to the LGA within which sources are located. Such profiling informs policies and strategies aimed at addressing emission sources
- indirect (scope 2) emissions from the generation of purchased electricity, with emissions allocated to the location where the electricity is used. This approach informs demand side policies and strategies.

Local-scale emissions will be annually updated to incorporate staged enhancements of the data. Future enhancements may include the addition of more granular data, scope 3 emissions and/or future projections of local-scale emissions consistent with the state emissions projections.

Method overview

Direct (scope 1) emissions are attributed to the LGA within which sources of these emissions are located, following a territorial inventory approach. This supports the profiling of emission sources by local area and the aggregation of emissions to approximate total NSW emissions. This approach is consistent with the NSW Greenhouse Gas Inventory and avoids double counting emissions since emissions can only be physically generated in one location.

To support emissions profiling by source, emissions are reported by sector and subsector using the sector definitions from the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2019).

Indirect (scope 2) emissions from the generation of purchased electricity are allocated to the location where the electricity is used. Such emissions are associated with electricity generators situated within or outside of NSW supplying the electricity being purchased within NSW.

Territorial scope 1 emissions inventoried by IPCC sector and subsector and indirect scope 2 emissions are mapped to GPC sectors to support BASIC and BASIC+ reporting under the *Global Protocol for Community-Scale Greenhouse Gas Inventories* (World Resources Institute 2014).

Spatial resolution

Emissions are inventoried at LGA resolution for the entire state consistent with the methods underpinning the National Greenhouse Accounts, with analysis to assess whether territorial emissions aggregate to approximate total NSW emissions for each IPCC sector and subsector. LGA emissions are then aggregated by city and region.

Greenhouse gases and global warming potentials

GHG emissions and removals by sinks resulting from human activities are addressed for the major GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). In accordance with IPCC guidelines, emissions of the GHG nitrogen trifluoride (NF_3) are considered negligible in Australia, and hence NSW, and are not estimated.

As GHGs vary in their radiative activity, and in their atmospheric resistance time, converting emissions into the carbon dioxide equivalent (CO_2-e) emissions allows the integrated effect of emissions of the various gases to be compared.

GHG emission estimates are expressed as the carbon dioxide equivalent (CO_2-e) using the 100-year global warming potentials in the IPCC's *Fifth Assessment Report* (AR5) (IPCC 2014). The Sixth Assessment Report (AR6) released in August 2021 has adjusted global warming potentials; however, AR5 warming potentials are applied for consistency with the National Greenhouse Accounts as they are currently prepared.[1]

Reporting boundaries

The NSW projections for aviation and waterborne navigation reflect the reporting boundaries adopted by the Commonwealth Government for the National Greenhouse Accounts to support reporting to the UNFCCC. The National Greenhouse Accounts include emissions from:

- *domestic aviation* from civil domestic passenger and freight traffic that departs and arrives in Australia, including take-offs and landings for these flight stages and travel between airports, excluding military aviation
- *domestic waterborne navigation*, including emissions from fuels used by vessels of all flags that depart and arrive in Australia.

Fuels used in international transport (international aviation and bunker fuels) are estimated by the Commonwealth Government but are reported separately as a Memo item under an international agreement that such items be reported separately from national total net emissions.

The Commonwealth Government uses activity data for domestic aviation and navigation based on fuel consumption as sourced from the Australian Energy Statistics (AES), with emissions calculated based on emission factors (EFs) for specific fuel types. Emissions are allocated to states and territories on the basis of fuel consumption, as reported within the AES and Australian Petroleum Statistics (APS).

[1] The Commonwealth Government prepares state and territory GHG inventories consistent with the rules adopted under the UNFCCC Paris Agreement (Decision 18/CMA.1 Annex 2.D Paragraph 37).

Inventory years

Inventory years for which local-scale emissions data are derived are: 2015–16, 2016–17, 2017–18, and 2018–19. They are reported as 2016, 2017, 2018 and 2019 respectively.

The NSW Greenhouse Gas Inventory for inventory year 2020 was published in June 2022 and is therefore included in the Stage 1 local-scale emissions dataset.

Verification and scaling

Energy consumption and electricity generation estimates were compared with the AES and APS. These sources are updated annually and are the authoritative and official source of energy statistics for Australia and the basis of Australia's international reporting obligations.

Where appropriate, emissions are proportionally scaled to ensure consistency with the NSW Greenhouse Gas Inventory as published by the Australia Government within the National Greenhouse Accounts (DISER 2021e). Where not appropriate to do so, approximated emissions are compared to inventory estimates and differences are addressed.

Further details of sector-specific verification and scaling approaches are provided in the relevant sections.

Protecting data confidentiality

In preparing the State and Territory Greenhouse Gas Inventory (STGGI), the Commonwealth Government uses emissions and data reported by facilities under the *National Greenhouse and Energy Reporting Act 2007* (NGER Act 2007).

To derive fine-scale accounts for the state, the NSW Government uses a combination of data reported under the National Greenhouse and Energy Reporting scheme (NGERs) and activity, emissions and other data from the STGGI and other sources. These accounts containing emissions at fine spatial scale and by subsector are classified as confidential and not for publication due to the confidentiality of the data used (Table 1).

The Clean Energy Regulator (CER) has strict rules regarding the disclosure of data reported under the NGERs, in accordance with the non-disclosure requirements under the NGER Act. Measures implemented to ensure the confidentiality of facility data reported under the NGERs are detailed in Appendix A. To ensure compliance with non-disclosure rules, public emissions data was identified for some facilities or proxies used to estimate emissions in some cases. Emissions were also aggregated to LGA resolution and by sector for certain IPCC sectors when preparing the local-emissions dataset for publication (Table 1).

Sectors and subsectors addressed by scope

Scope 1 territorial emissions

IPCC sectors and subsectors for which territorial scope 1 spatial emissions have been developed for publication are given in Table 1.

Table 1 Sectors and subsectors for spatial scope 1 emissions

IPCC sectors and subsectors	Sectors for NSW spatial accounts	Subsectors for fine-scale, internal (confidential) spatial accounts	Subsectors for public reporting
1. Energy (combustion + fugitive)			
Stationary energy			
Public electricity and heat production	Electricity generation	By specific fuel type	No subsectors to ensure NGER data confidentiality
Stationary energy (all other excluding public electricity and heat production)	Stationary energy	By subsector and fuel type Chemicals; coal mining; food processing, beverages, tobacco; gas distribution; iron & steel; non-metal minerals; non-ferrous; other construction; other manufacturing; other metal manufacturing; other mining; other textiles and leather; pulp, paper and print; agriculture, forestry and fishing; commercial/institutional; residential	No subsectors to ensure NGER data confidentiality
Transport	Transport	By subsector and fuel type Road transport – cars, light commercial vehicles (LCVs), motorcycles, buses, rigid and articulated trucks; domestic aviation; domestic navigation; railways; other	Road transport – light vehicles, heavy vehicles; domestic aviation; domestic navigation; railways; other
Fugitive emissions from fuel	Fugitives	Coal mining, oil and gas	No subsectors to ensure NGER data confidentiality
2. Industrial processes and product use	Industrial processes and product use	Minerals; chemicals; metals; non-energy products from fuels and solvent use; produce uses as ozone depleting substance (ODS) substitutes; other manufacture and use; other	No subsectors to ensure NGER data confidentiality
3. Agriculture	Agriculture	By commodity – beef, dairy, goat, pig, poultry, sheep, other livestock, crops	Beef, dairy, goat, pig, poultry, sheep, other livestock, crops

IPCC sectors and subsectors	Sectors for NSW spatial accounts	Subsectors for fine-scale, internal (confidential) spatial accounts	Subsectors for public reporting
4. Land use, land-use change and forestry	Land use, land-use change and forestry (LULUCF)	By subsectors – forest land remaining forest land, plantations and natural regeneration, regrowth on deforested land, cropland remaining cropland, land converted to cropland, grassland remaining grassland, land converted to grassland, land converted to settlement	By sector: cropland; forest land; grassland; settlements
5 Waste	Waste	Solid waste disposal; domestic/commercial wastewater treatment; Industrial wastewater treatment	Solid waste disposal; domestic/commercial wastewater treatment; Industrial wastewater treatment

Taking into account emissions reported within the NSW Greenhouse Gas Inventory, 95–98% of NSW's scope 1 emissions have been spatially allocated by LGA. Scope 1 emissions have not yet been spatially allocated for the following subsectors:

- Agriculture – mineralisation due to soil carbon loss, liming and urea, sewage sludge applied to land
- Waste – biological treatment of waste, and incineration and open burning of waste
- Transport – buses and motorcycles
- LULUCF – harvested wood products, wetland conversions to other land use, private native forestry, mangroves and tidal marsh, fuelwood use, woody horticulture and sparse woody vegetation.

Scope 2 emissions

Scope 2 emissions from the use of purchased electricity are developed for publication by LGA for 2 categories:

- Residential consumption
- Other non-residential uses, termed 'business' which includes commercial, institutional and industrial use, addressing low and high voltage and wholesale electricity use.

The non-residential uses category could not be consistently disaggregated for LGAs across the state without infringing the confidentiality of third party data sources.

Mapping IPCC sectors to GPC sectors

GPC sectors and subsectors are mapped to IPCC categories in Table 2, and emissions addressed in the NSW local-scale accounts indicated. Scope 2 emissions addressed in the spatial accounts for GPC sectors are shown in Table 3.

Table 2 Mapping of GPC sectors, subsectors and scopes to IPCC categories

GPC sector	GPC subsectors	IPCC categories for scope 1 emissions	Emissions addressed in NSW local-scale accounts
Stationary energy	Energy industries	1A1 Energy industries (excluding 1A1ai public electricity generation)	Direct combustion of all fuel types
Stationary energy	Energy generation supplied to the grid (not required for BASIC or BASIC+ reporting under the GPC; only for territorial)	1A1ai public electricity generation	Electricity generation (all fuel types)
Stationary energy	Manufacturing Industries and Construction	1A2 Manufacturing industries and construction	Direct combustion of all fuel types
Stationary energy	Commercial and institutional buildings and facilities	1A4a Commercial/ institutional	Direct combustion (gas and diesel combustion)
Stationary energy	Residential buildings	1A4b Residential	Direct combustion (gas, LPG, biomass combustion)
Stationary energy	Agricultural, forestry and fishing activities	1A4c Agricultural, forestry and fishing	Direct combustion (gas and diesel combustion)
Stationary energy	Fugitive emissions from mining and processing of coal	1B1 Fugitive emissions from fuels (solid fuels)	Fugitives from open cut and underground coal mining and handling; and from abandoned coal mines
Stationary energy	Fugitive emissions from mining, processing, storage and transportation of gas	1B2 Fugitive emissions from fuels (oil and natural gas)	Fugitives from natural gas venting, flaring, other (no oil related emissions in NSW after 2014)
Transportation	Aviation	1A3a Aviation	Domestic aviation emissions
Transportation	On-road	1A3b Road transportation	On-road transport (passenger and freight, all fuel types)
Transportation	Railways	1A3c Railways	Railway emissions
Transportation	Waterborne navigation	1A3d Waterborne navigation	Domestic navigation
Transportation	Off-road	1A3e Other transport	Other transport (off-road)
Waste	Solid waste disposal	5A Solid waste disposal	Territorial scope 1 (not included in BASIC reporting) Area-induced scope 1+3 (for BASIC/BASIC+ reporting)
Waste	Biological treatment of waste	5B Biological treatment of solid waste	Not addressed (minor source)
Waste	Incineration and open burning of waste	5C Incineration and open burning of waste	Not addressed (minor source)

GPC sector	GPC subsectors	IPCC categories for scope 1 emissions	Emissions addressed in NSW local-scale accounts
Waste	Wastewater treatment	5D Wastewater treatment and discharge	Domestic/commercial and industrial wastewater treatment Territorial scope 1 (not included in BASIC reporting) Area-induced scope 1+3 (for BASIC/BASIC+ reporting)
Industrial processes and product use (IPPU)	Industrial processes Product use	2. Industrial processes and product use	Minerals, chemicals, metals, non-energy products from fuels and solvent use, produce uses as ODS substitutes, other manufacture and use, other industrial processes
Agriculture, forestry and other land use	Livestock	3. Agriculture – 3A Enteric fermentation, 3B Manure management	Agricultural emissions by commodity (beef, dairy, goats, pigs, poultry, sheep, other livestock)
Agriculture, forestry and other land use	Land	4. Land use, land-use change and forestry	LULUCF sectors addressed: cropland, forest land, grassland and settlements
Agriculture, forestry and other land use	Aggregate sources and non-CO_2 emission sources on land (includes rice cultivation, fertilizer use, liming, and urea application)	3. Agriculture – 3C Rice cultivation, 3D Agricultural soils, 3G Liming, 3H Urea application	Agricultural emissions – crops (emissions from agricultural soil, burning of agricultural residues and rice cultivation) Liming and urea application, N_2O emissions from organic fertilisers, and loss of soil carbon not addressed

Table 3 Scope 2 emissions addressed by GPC subsector

GPC sector	GPC subsector	Scope 2 emissions addressed in the NSW local-scale accounts
Stationary energy	Residential buildings	Scope 2 – electricity consumption (residential)
	Commercial and institutional buildings and facilities	Scope 2 – electricity consumption (non-residential, business)
	Manufacturing industries and construction	
	Energy industries	
	Agricultural, forestry and fishing activities	
	Non-specified sources	
Transport	On-road transports	Captured in the above data

GPC sector	GPC subsector	Scope 2 emissions addressed in the NSW local-scale accounts
	Railway	

Electricity generation and stationary energy

The stationary energy sector is reported within the NSW local-scale emissions as:

- electricity generation, which addresses stationary energy related emissions from fuel combustion in public thermal power stations including gross electricity generation and any heat produced by such power stations. Public thermal power stations generate electricity and/or heat for sale to third parties as their primary activity
- stationary energy, which refers to emissions arising from the burning of fuels for energy production, in the form of heat, steam or pressure (excluding public electricity generation and transport).

Data and methods applied for both sectors are addressed in this section.

Data sources

Data sources applied to develop fine-scale emissions for this sector are as follows:

- National Greenhouse Gas and Energy Reporting Scheme (NGERS) data for NSW facilities for financial years 2015–16, 2016–17, 2017–18 and 2018–19
- NSW Greenhouse Gas Inventory data for categories 1A1 Energy Industries, 1A2 Manufacturing Industries and Construction and 1A4 Commercial/Institutional up to FY 2018–19 (referred to as STGGI data)
- Jemena gas distribution data (GJs of natural gas distributed) for residential and business users by Australian Bureau of Statistics (ABS) Statistical Area 1 (SA1) complete for 2018–19
- AES data for Table K (fuel consumption by industry category) (DISER 2021a)
- NSW EPA Environment Protection Licences (NSW EPA EPLs) – the NSW EPA maintains a database of EPLs for licensing owners or operators of various industrial premises under the *Protection of the Environment Operations Act 1997* (POEO Act). Licence conditions relate to pollution prevention and monitoring, and cleaner production through recycling and reuse and the implementation of best practice. The licences regulate discharges of air and water pollutants. The list of facilities has additional facilities to those captured under NGER reporting thresholds
- the National Pollutant Inventory (NPI) 2019–20 (NPI 2020).

Emission estimation method

The calculation of GHG emissions from stationary combustion is divided into 3 categories as addressed in the National Inventory Report (NIR):

- 1A1 Energy Industries
- 1A2 Manufacturing Industries and Construction
- 1A4 Commercial/Institutional, Residential and Agriculture, Forestry and Fisheries.

1A1 is subdivided into:

- Public electricity and heat production

- Coke production
- Gas distribution
- Coal mining.

1A2 is subdivided into:

- Iron and steel
- Non-ferrous metals
- Chemicals
- Pulp, paper and print
- Food processing, beverages and tobacco
- Other – manufacturing (e.g. fabricated metals, etc.)
- Other – mining and quarrying
- Other – textiles and leather
- Other – non-metals
- Other – manufacturing of machinery
- Other – construction.

1A4 is subdivided into:

- Commercial, institutional
- Residential
- Agriculture, forestry and fisheries.

Use of NGERS data

Each subdivision in 1A1 and 1A2 is comprised of numerous industry groups identified by their ANZSIC code. GHG and energy consumption data is extracted from the NGERS reports according to groups of ANZSIC codes. The data is then aggregated according to the subdivisions above. These are then compared to the NSW GHG subdivision emissions for 1A1, 1A2 and 1A4. The location of each facility is part of the NGERS data and allows each facility to be mapped to an LGA (except for aggregated entities).

Refer to Appendix A for the approaches applied in the study to ensure NGERS data confidentiality requirements are met when publishing local-scale emissions.

Other data sources

Disaggregating 1A4 Commercial/Institutional, Residential, and Agriculture, Forestry and Fishing relied on several sources of proxy data as NGERS data usually accounted for only a fraction of emissions for these sectors reported under the STGGI.

For 1A4a Commercial/Institutional:

- Natural gas consumption – the Jemena SA1 dataset was used to spatially disaggregate emissions for commercial customers. Table K of the AES provides a cross-check of the gas consumption. Natural gas consumption accounts for 47% of 1A4a emissions.
- Diesel consumption – the method assumes the STGGI emissions are accurate with these emissions spatially disaggregated based on 2016 ABS employment data obtained from the ABS Census Table Builder (ABS 2016). A dataset of employment figures (based on geographical place of work) per LGA was generated. The Table Builder allows for further disaggregation by ANZSIC code (down to the 4-digit code). Using the 1-digit ANZSIC codes emissions were generated based on the percentage employed in the commercial/institutional subsector by LGA. The subsectors included closely

resemble the 1A4a commercial/ institutional subsectors as described in the NIR (DISER 2021c, p.109).[2] Diesel consumption accounts for 48–50% of 1A4a emissions.

The method can be improved following the release of the 2021 Census data (not yet available at the time of deriving the local-scale emissions) to generate annually interpolated employment data using the 2016 and 2021 Census data.

- LPG consumption – not yet estimated. It accounts for ≤3% of 1A4a emissions in the STGGI.
- Petrol consumption – accounted for less than 1% of 1A4a emissions in the STGGI and was not considered further at this stage of the spatial accounts.

For 1A4b Residential:

- Natural gas consumption – the Jemena SA1 dataset was used to spatially disaggregate emissions for residential customers. Table K of the AES provides a cross-check of the gas consumption.
- Residential LPG consumption – data from the NSW EPA Greater Metropolitan Region (GMR) Air Emissions Inventory was used (EPA 2012, 2019). This dataset provides assumptions and estimates for LPG used for indoor and outdoor uses by housing type.
- Petrol use, for example for lawnmowers, was not considered at this stage as emissions accounted for less than 4% of 1A4b emissions.
- Wood heating – the analysis is based on AECOM's cost–benefit analysis report prepared for the NSW EPA (AECOM 2014). This contains survey data on the number of houses using wood heating by region. This was further broken down into LGAs by the percentage of the population in the region. The STGGI emissions were then apportioned by the percentage of the LGA population in NSW. It was noted that wood heaters appeared to be over-represented in the South Coast and perhaps under-represented in the Hunter and New England regions. The calculations will be refined in future updates.

The key source of emissions for 1A4c Agriculture, Forestry and Fishing arises from diesel consumption (over 90% of sector emissions under the STGGI). To disaggregate diesel emissions the following observation was used: approximately 77% of fuel consumption under 1A4c is due to Agriculture, 17% Forestry and 6% Fishing (DISER 2021c, p.115).

On that basis, the STGGI emissions were split into 3 groups and disaggregated spatially as follows:

- Diesel for agriculture – this is based on data compiled for the NSW EPA non-road diesel emissions inventory. Diesel emissions are disaggregated based on the land area in each LGA under cultivation.
- Diesel for forestry – this is based on the area of each LGA in NSW dedicated to state forests. The data ignores the nature, extent and year of forestry activities in the LGA. The calculations will be refined when more detailed forestry activity data is received from Forestry Corp.
- Diesel for fishing – as for 1A4a diesel in the commercial/institutional subsector, the 2016 ABS Census data was used to generate a set of percentage employed per LGA in the fishing, hunting, trapping and aquaculture subsectors. These percentages were used to spatially disaggregate the STGGI emissions, noting the splits fuel consumption by 1A4c sector described above.
- LPG consumption – consumption reported under NGERs accounts for most of the STGGI emissions from this fuel and this data is used without change.

[2] The subsectors include emissions from water utilities, accommodation, communications, finance, insurance, property and business services, government and defence, education, health and wholesale and retail trade.

- Petrol use – not yet estimated. It accounts for only 5–6% of 1A4c emissions.
- CNG consumption – not yet estimated. It accounts for less than 1% of 1A4c emissions.

For several 1A2 subsectors, there are large gaps between NGERs and STGGI totals, possibly due to many facilities falling below the NGER facility reporting threshold. Therefore, as an additional check, the NSW EPA's EPL facilities list was checked against the list of NGERs facilities to identify additional facilities.

Verification

Stationary energy GHG emissions from the NGERS were compared with the NSW STGGI by subsector.

For 1A1, close agreement was observed in most cases:

- Fuel combustion for public electricity and heating – the agreement was between 98.1% and 99.6% over all financial years.
- Fuel combustion in coal mining – the agreement was 100% for all financial years.
- Fuel combustion related to gas exploration, processing, transmission and distribution – the agreement between STGGI and NGERs was poor in 2015–16, possibly due to over-estimated gas production reported in the STGGI. In 2017–18 and 2018–19, the NGERS and STGGI data were nearly 100% in agreement.
- Emissions associated with coke production are not reported in the NGERS. Based on the NSW EPA EPL facilities list, coke production occurs at BlueScope Steel Port Kembla operations. STGGI emissions for this subsector were therefore attributed to this facility.

For 1A2 the agreement between NGERS and STGGI data varies widely:

- For 1A2 iron and steel – the NGERS data includes emissions from all fuels except coke oven gas. In consultation with the then Commonwealth Department of Industry, Science, Energy and Resources (DISER) (Steven Oliver (DISER), pers. comm. by email, 9 October 2019), it was assumed that the difference between the STGGI total and the NGERS total was due to consumption of coke oven gas. Further, the emissions from consumption of coke oven gas were assumed to be attributed to the BlueScope Steel Port Kembla facility. This approach ensures 100% agreement between NGERS and STGGI datasets.
- For 1A2 non-ferrous metals – the NGERS emissions account for 50–60% of the STGGI emissions. Annual STGGI emissions vary between 180 and 200 kt CO_2-e. In consultation with the DISER (Nick Giles, DISER; pers. comm. by email, 28 October 2021), the difference was identified to be due to approximately 80 kt CO_2-e of emissions from 'other petroleum products'. This may either be due to residual emissions from a number of entities whose emissions fall below the NGERS reporting threshold or an over-estimation of the quantity of 'other petroleum products' reported under the AES. A review of entities reporting under the NPI (NPI 2020) resulted in the identification of only one further facility not included in the NGER data under ANZSIC codes 213 and 214. Therefore, it is concluded that the STGGI emissions for non-ferrous metals may be over-estimated. A review of the NSW EPA EPL list revealed no other facilities for this subsector.
- For 1A2 chemicals – the NGERS emissions account for only about 40% of STGGI total emissions. This may be due to residual emissions from a large number of facilities whose emissions fall below the NGERS facility reporting threshold. This was investigated by considering facilities that report under the NPI (NPI 2020) and NSW EPA EPL licence holders. Several smaller chemical manufacturing facilities were identified that are not included under the NGERS; however, these facilities are not of

sufficient capacity to account for the 1.2–1.3 Mt CO_2-e difference between NGERS and STGGI emissions totals.

The chemicals sector includes emissions from the consumption of a complex mix of energy commodities including coal, natural gas, diesel oil, ethane, ethylene, naphtha, LPG, and other petroleum and petrochemical products. It may be possible to validate the NGERS data for each fuel type against detailed energy consumption data in the AES, but such data is confidential and could not be obtained to inform this analysis.

A complicating factor when comparing NGERS and AES fuel consumption data is that about 25 PJ per year of energy consumption at one large facility is attributed to other petroleum products (including ethane, ethylene, naphtha, diesel oil and other petrochemicals). This lumped consumption figure in the NGERS makes verification against individual fuels in the AES difficult.

In discussions with DISER (Sean Lawson, DISER; pers. comm. by email between 15 October 2021 and 10 November 2021), the LPG and petroleum-based products consumption data was flagged for review in 2022. DISER also recommended the use of the NGERs data for LPG consumption over the AES data.

In conclusion, due to the difficulty in verifying the NGERS data against the AES, and given some of the AES data will be reviewed in 2022, the decision was taken to base the NSW 1A2 Chemicals inventory on the NGERS data until further detailed information is obtained.

- For 1A2 pulp, paper and printing – NGERS emissions account for about 100% of STGGI emissions.
- For 1A2 food processing, beverages and tobacco – total NGERS emissions account for about 90% of STGGI emissions.
- For 1A2 non-metal minerals – total NGERS emissions account for about 80% of STGGI emissions.
- For 1A2 other, mining – total NGERS emissions account for over 100% of STGGI emissions (5–20% over the STGGI total depending on the year).
- For 1A2 other, construction – total NGERS emissions account for only 40–60% of STGGI emissions. A comparison with the NSW EPA EPL list showed some additional entities beyond those reported under the NGERS, but none of a sufficient size to make up the gap in emissions.
- For 1A2 other, textiles and leather – NGERS emissions account for less than 1% of the STGGI emissions for this subsector. The STGGI indicates emissions for this subsector range from 90–97 kt CO_2-e. A number of tanneries were identified in the NSW EPA EPL list, although it is not clear if these facilities are able to produce the emissions shown in the STGGI.
- For 1A2 other, fabricated metal manufacturing – the NGERs emissions account for 60% of the STGGI emissions for this subsector. STGGI subsector emissions range from 47–57 kt CO_2-e per year.
- For 1A2 other, manufacturing – the NGERs emissions account for 10–15% of the STGGI emissions for this subsector. STGGI subsector emissions range from 5–7 kt CO_2-e per year.

Jemena natural gas data was compared to natural gas consumption data in Table K of the AES (2015–16 to 2018–19). The Jemena gas consumption data for commercial and institutional consumption was generally 6–12% higher than reported in AES Table K. For residential, the Jemena data was 5–7% lower than the STGGI. In terms of total gas consumption, the Jemena and AES totals for the sectors agree to within 3% or better.

Data limitations and quality

Uncertainties and data limitations

The largest source of uncertainty lies in the spatial estimates of emissions in 1A4 (stationary energy by commercial, institutional, residential, agriculture, forestry and fishery sectors).

Spatial disaggregation of emissions for 1A4b residential is based on surveys of air polluting activities dating back to 2014 produced for the NSW EPA. This includes residential wood heating, use of LPG, natural gas and lawnmowers. The surveys addressed only the GMR due to their being designed to inform the GMR Air Emissions Inventory, with no equivalent surveys available for the rest of the state.

The Jemena natural gas usage data used in 1A4a and 1A4b has been shown to be accurate in terms of the split between business and residential usage, and the spatial disaggregation should be of high quality.

Spatially resolved non-road diesel emissions in 1A4 for commercial/institutional and agriculture, fishing and forestry is problematic as described above. The emissions calculations will be refined when suitable proxies (e.g. 1A4a diesel consumption) and more accurate data (1A4b residential solid fuel consumption and 1A4c diesel consumption in agriculture and forestry) are identified.

The NSW STGGI data may also contain uncertainties as it is a top-down estimate of emissions by subdivision based on AES data. There is scope for misattribution of consumption of energy commodities between Australian states and between subdivisions. 1A2 manufacturing industries and construction is particularly complex in structure.

As discussed in a previous section, there are significant uncertainties in 1A2 for chemicals and non-ferrous metals. Discussions with the national emissions inventory team suggest the NGERs data may be more reliable at present and that some AES fuel consumption data (e.g. LPG) has being flagged for review.

Some facilities in the NGERs could not be mapped to an LGA and so were not spatially allocated (e.g. distribution networks). Emissions unable to be spatially allocated accounted for less than 0.3% of the total emissions for 1A1 and 1A2.

Areas requiring improved data or methods

The spatial accounts would benefit from improved data for 1A2 non-ferrous metals and chemicals as these subsectors had the largest differences compared with the NSW STGGI data. Better spatially resolved non-road diesel consumption in NSW is required for improve emission estimates for subsector 1A4. A proxy is needed to spatially disaggregate diesel consumption for 1A4a commercial/institutional.

Data quality

The quality of the data for the primary inventory year is considered moderate to high and can be further improved by addressing the areas discussed above.

Transport

Emissions in the transport sector result from the combustion of fuels for transportation and include emissions from road transport, domestic aviation, railways, domestic waterborne navigation and other transport sources (pipeline transport, off-road vehicles). Emissions from the generation of electricity used by electric vehicles and rail are accounted for in the Electricity consumption (scope 2) section.

The department engaged Ndevr Environmental to help develop methods to derive spatial emissions for non-road transport sectors (Ndevr Environmental 2022). The data inputs, method and results from this work are described in the relevant sections.

Road transport

Method overview and data

Bottom-up modelling of road transport emissions was undertaken to estimate emissions by LGA. Spatially resolved vehicle movement data were available to support the modelling of light duty vehicles (passenger cars and LCVs) and heavy duty vehicles (rigid and articulated trucks). Emissions associated with motorcycles and buses were not accounted for within the modelling for the Stage 1 spatial accounts.

An overview of the data and method applied to model road transport emissions is as follows:

- Light duty vehicle (LDV) and freight movement data was received from Transport for NSW (TfNSW) and included the number of vehicle trips by vehicle type by road link and information on vehicle speed by link. This data was available for all movements within the Sydney Greater Metropolitan Area (GMA) [3] and for interzonal movements for regional areas of NSW outside the GMA.
- Road links were allocated to LGAs through ArcGIS mapping and vehicle kilometres travelled (VKT) calculated for each road link within each LGA by vehicle type.
- State-aggregate VKT estimates by vehicle type were compared to ABS Survey of Motor Vehicle Use (SMVU) data (ABS 2020) and modelled fuel consumption compared to state-aggregate fuel use from the APS (DISER 2021b).
- Fleet and emissions modelling was conducted for the NSW and fleet-average EFs output (g CO_2-e/km) by vehicle type and speed class for specific years. The modelling of fleet-aggregate EFs accounted for the impact of seasonal effects, cold start correction factors and VKT splits by fuel/motive power for each vehicle type.
- Emissions by vehicle type were calculated for each LGA by applying the fleet-average EFs with VKT estimates. Emissions were calculated by vehicle type and speed class and then aggregated across speed bins and road links within each LGA.
- State-aggregate emissions by vehicle type were calculated by summing emissions across LGAs and compared to road transport emission estimates from the NSW Greenhouse Gas Inventory published by the Commonwealth Government.
- The gap between modelled emissions (this study) and inventory estimates was assumed to be due to intrazonal travel in areas outside of the GMA not being addressed in the available transport models with unaccounted emissions allocated to non-GMA LGAs so that total NSW emissions approximated inventory estimates for NSW within the STGGI.

---

[3] The Sydney GMA, as defined by the Australian Bureau of Statistics, includes: the Sydney Greater Capital City Statistical Area (GCCSA), several SA4 regions (Southern Highlands and Shoalhaven; Illawarra; Newcastle and Lake Macquarie) and 3 SA3 regions (Lower Hunter; Port Stephens; Maitland).

The data applied is summarised in Table 4. Information on the fleet and emission models applied to derive fleet-aggregated EFs for application in the study, and the methods used to model freight and light vehicle emissions by LGA are described in subsequent sections.

Table 4 Data used in the estimation of road transport emissions by LGA

Data reference	Description	Resolution	Source
Strategic Transport Model (STM, version 3.8)	Transport modelling based on STM (includes passenger vehicle data from the STM, business use LCV data from the LCV model and freight data from the Freight Movement Model (FMM)) with outputs given as movements by vehicle type for road links in the Sydney GMA	Trips by vehicle type (cars, LCVs, rigid and articulated trucks) for 4 periods (AM peak, intermediate period, PM and evening/overnight) by road link in the Sydney GMA	TfNSW 2021
FMM	Freight movements by truck type and average vehicle speeds for road links in the Sydney GMA	Trips by truck type (rigid and articulated truck types) for 4 periods (AM peak, intermediate period, PM, evening/overnight) by road link in the Sydney GMA. Data for 2016 and 2021	TfNSW 2021
Regional Travel Model (RTM)	A key strategic model for the whole of NSW owned by TfNSW. Transport modelling based on the RTM outputs light vehicle movements by road link in regional NSW	Passenger movements by road link in NSW with interzonal travel. Data for 2019	TfNSW 2021
Regional Freight Model (RFM)	NSW-wide freight movement data (but FMM outputs used for the Sydney GMA)	Average daily trips by truck type and commodity for road link in NSW with interzonal movements. Data for 2016 and 2021	TfNSW 2021
STGGI	Australian Government's emissions inventory estimates for NSW contained within the STGGI	State-aggregated road transport emissions data by vehicle type and year. Data for FYs 2016, 2017, 2018, 2019	DISER 2021e
ABS SMVU data	Survey of Motor Vehicle Use data from the ABS (ABS 2020)	Annual VKT data by vehicle type given for NSW and specified for capital cities, other cities and other regions. Data for 2017–18 and 2019–20	ABS 2020
Australian Bureau of Infrastructure, Transport and Regional Economics (BITRE) VKT projections	BITRE VKT projections	Annual VKT projections for NSW by vehicle type	BITRE 2021a
APS fuel consumption	APS fuel use data	Annual fuel consumption data by fuel type and by sector	DISER 2021b

Fleet and emissions modelling

The department fleet and emissions models are based on those developed for the NSW EPA Air Emissions Inventory (EPA 2012, 2019). These models were extended for NSW-application and updated to incorporate the latest EFs and vehicle sales trends:

- The Australian National In-Service Emissions study (DEWHA 2009) was used for petrol vehicle emissions up to ADR79/01 (Euro 3 & Euro 4 vehicles). The test drive cycles used were developed from extensive on-road tests in 5 Australian capital cities.
- ADR79/02 (Euro 4) to ADR 79/04 (Euro 5) emissions and fuel consumption are estimated by reference to the European Monitoring and Evaluation Programme (EMEP) Guidebook (EEA 2019), which is the basis of the COPERT model, and consideration of the historical Australian data.
- Diesel vehicle EFs and fuel consumption are based on limited Australian test data and the guidebook/COPERT data.

The department vehicle emissions model is used to generate fleet-aggregate fuel consumption and EFs based on stock projections from the fleet model. Emissions of GHGs (CO_2, N_2O, CH_4) are aggregated and expressed as carbon dioxide equivalents (CO_2-e). Fleet-aggregate EFs account for technology uptake rates and the impact of seasonal effects, cold start correction factors and VKT splits by fuel/motive power for each of the base vehicle types. Fleet-aggregated EFs derived by vehicle type and speed class are illustrated in Figure 1. These EFs are applied with annual VKT estimates by vehicle category and speed bin for each year to estimate total emissions for modelled years.

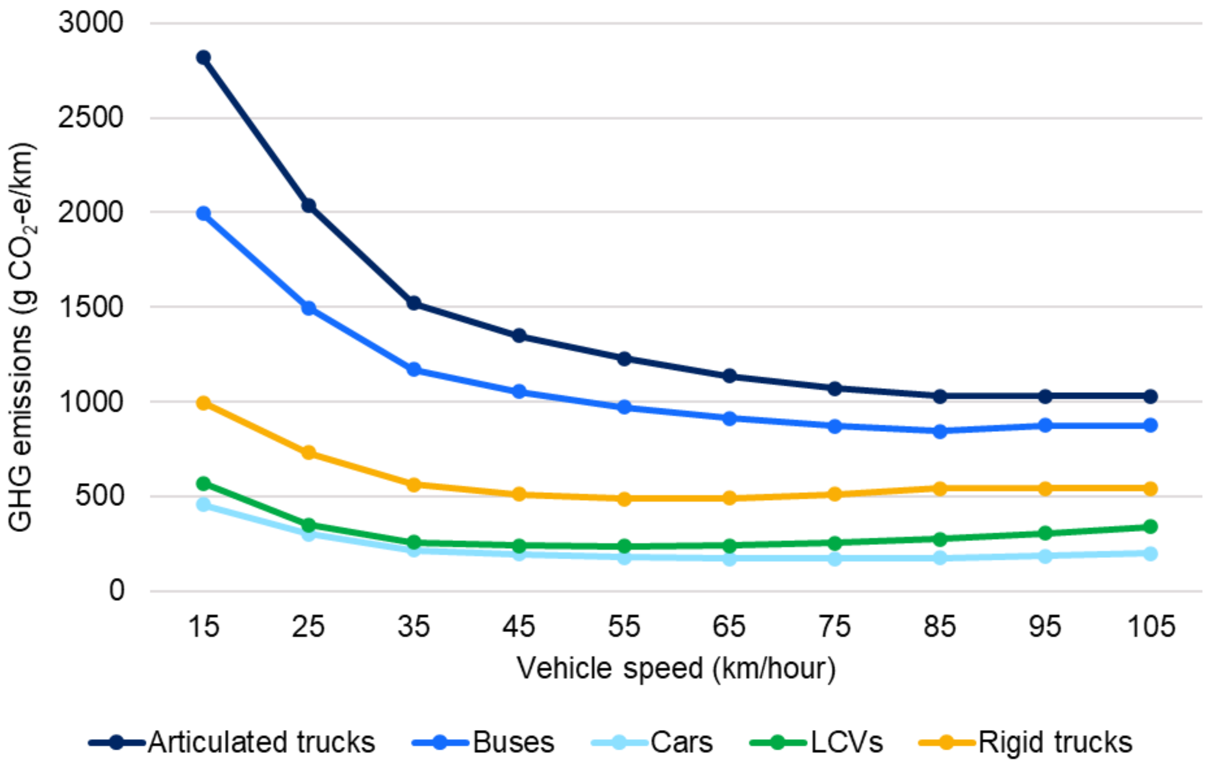

Figure 1 NSW fleet-aggregated emission factors by vehicle type and speed class for 2021

Freight method

Modelling of VKT and emissions by vehicle type and road link

RFM and FMM data is available at 5-yearly intervals with data for 2016 and 2021 used to inform the derivation of local-scale emissions in this study. The FMM is based on movement of freight across the GMA using land-use and econometrics data. The RFM uses centroid-based demand matrices to assign the movement of commodities along road and rail networks and covers all of NSW. The models provide freight movement by number of trucks of each type (rigid and articulated) by commodity type for each road link. Both models provide outputs for the Sydney GMA with the more detailed modelling for the FMM used to address truck movements in this region.

FMM and RFM model data were treated separately. Truck trips in the FMM were summed across each of the 4 daily time intervals (AM peak, intermediate, PM and evening/overnight) to provide daily trip values. Truck trips in the RFM are provided as daily values. Daily truck trips were then scaled to yearly values using a factor of 300 (accounting for weekday to weekend trip ratios, on advice from TfNSW).

Road links were allocated to LGAs using ArcGIS. Where road links cross LGA boundaries, all attributes for the road link were duplicated and link lengths recalculated, retaining the assigned truck flow. VKT was calculated based on the number of trips for each truck type multiplied by the length of the road link, with VKT by truck type calculated for each LGA. Modelled VKT for 2016 and 2021 were used to interpolate annual VKT for intermediate years.

Emissions were calculated using fleet-average EFs by truck type determined through the department's fleet and emissions modelling of the NSW heavy duty vehicle fleet. This modelling accounts for year-specific NSW rigid and articulated truck fleets (in terms of truck size, age, emission standards, etc.). EFs were calculated for 5 road types, for which the weighted average is calculated to give an EF at a base speed. The department vehicle emission model also calculates coefficients for a 6th order polynomial used to calculate a speed correction factor, allowing calculation of the EF (and resulting emissions) at the speed of each road link.

Road links in the FMM data have 'congested speed' as an attribute, and this was used to calculate the speed correction factor directly. The RFM data only contains signposted speeds, with reference made to this speed in the emission estimation since congestion is less likely to be commonplace in most areas outside of the GMA. The signposted speed was adjusted down slightly to reflect actual travel speeds with fleet-average EFs applied to calculate emissions accounting for the adjusted speed of each road link. EFs were kept constant for speeds above 85 km/h. Emissions explicitly modelled for 2016 and 2021 were used to interpolate emissions for intermediate years.

Comparison with published VKT and emissions data

The total VKT across NSW for freight transport across the 2 models were compared to the VKT published within the ABS SMVU for 2015–16 and 2017–18 (Table 5). The SMVU gives VKT for vehicles based on the state of registration and based on the state of operation, with material differences for articulated trucks. Given the focus on territorial emissions, reference is made to SMVU data given for the state of operation.

Table 5 Comparisons of VKT for freight derived in the study with ABS SMVU data

Freight VKT (billions)	2016	2017	2018	2019
Modelled VKT	5.44	5.54	5.63	5.72
ABS SMVU VKT	5.76	No data	5.81	No data

Freight VKT (billions)	2016	2017	2018	2019
Modelled as % of SMVU	95%		97%	

Total VKT for truck movements across NSW represented 95–97% of freight VKT figures published by the ABS within the SMVU; however, the models produce lower VKT for rigid trucks and higher VKT for articulated trucks (25–30% difference is both cases). This probably indicates a preference within the RFM for using articulated trucks for commodity movement but is also expected to be due to intrazonal trips, which are likely dominated by rigid trips, not being captured in the RFM.

Figure 2 illustrates modelled freight emissions by road link across NSW as a result of this work. Given the legend shows the total emissions by road link, the colour displayed is a function of both the freight volume and the length of the road link. Higher emissions are evident along major freight corridors, such as the Hume Highway (Sydney to Melbourne), Sturt Highway (Hume Highway to Adelaide), Newell Highway (Melbourne to Brisbane via inland NSW), Pacific Motorway (Sydney to Brisbane) and the A32 to Broken Hill.

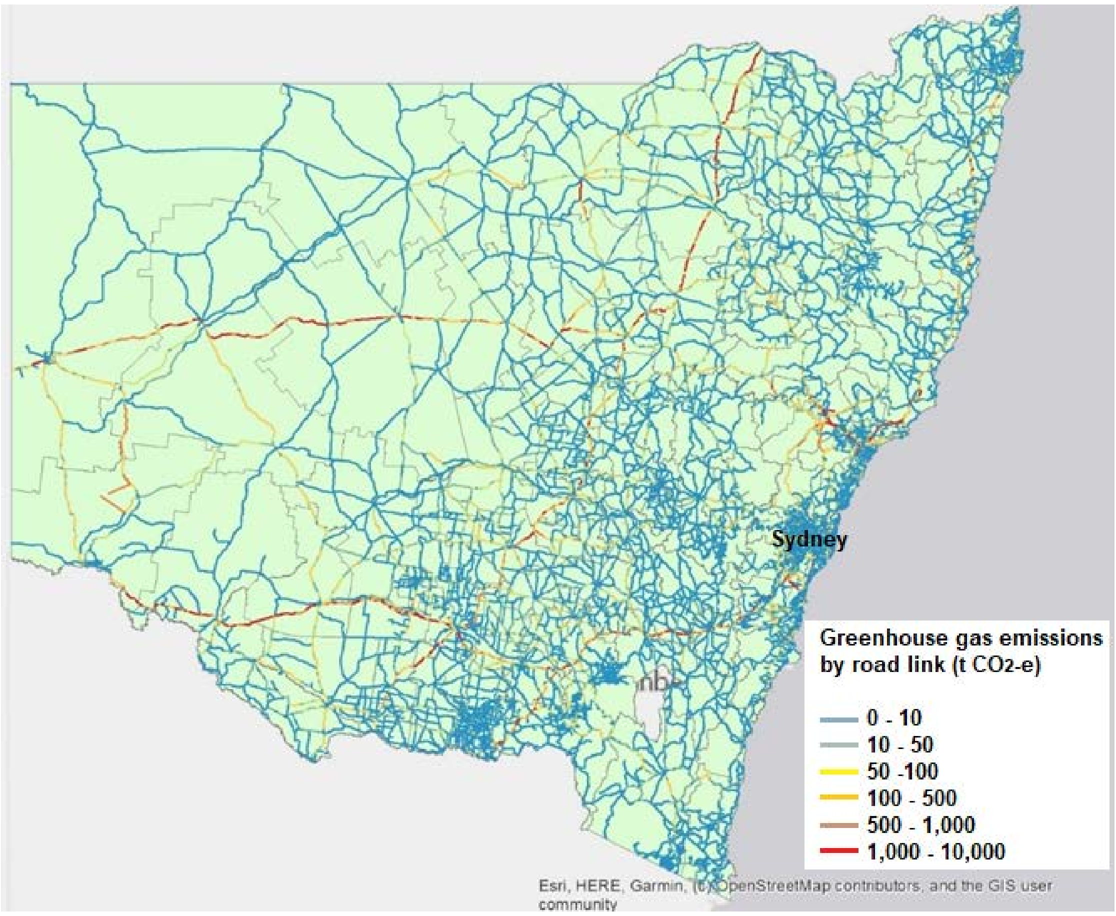

Figure 2 Freight emissions modelled by road link across NSW
The legend shows total emissions by road link, with the colour displayed a function of both the freight volume and the length of the road link.

Truck emissions modelled were estimated to represent 89–94% of the truck-related emission estimates for NSW as inventoried by the Commonwealth Government within the STGGI (Table 6). To account for lower VKT estimates within regional areas due to intrazonal travel not being accounted for in the modelling outside of the GMA, modelled freight emissions were adjusted upwards in regional areas so that the total NSW emissions approximated the published NSW freight emissions within the STGGI.

Table 6 Unadjusted freight emissions for NSW modelled in this study compared with NSW freight emissions from the STGGI

Freight emissions (Mt CO_2-e)	2016	2017	2018	2019
Modelled NSW freight emissions (unadjusted)	4.97	5.03	5.09	5.15
NSW emissions (as published in the STGGI in May 2021)	5.46	5.37	5.57	5.76
Modelled as % of STGGI	**91%**	**94%**	**91%**	**89%**

Data limitations and areas identified for improvement

RFM and FMM data are only available at 5-yearly intervals with data for 2016 and 2021 available to inform the analysis for the years of interest in the spatial study. Whereas 2016 commodity data used in the model were verified by TfNSW against published commodity data, commodity data underpinning modelled truck movements for 2021 are forecast. The 2021 FMM data includes some proposed freeways in the GMA assumed to be finished by 2021 but which are not yet completed. This will be addressed by accessing and integrating model updates as they become available.

The RFM includes road links within the GMA comprising a simpler version of the road network compared to that used in the FMM. The original FMM network also extends beyond the boundary of the GMA. To avoid double counting of truck movements the RFM and FMM datasets were integrated following the advice of TfNSW. RFM data was excluded within the GMA, and RFM data was preferred over FMM in regions near the GMA. For most regions in proximity to the GMA border, total truck flow was higher and better resolved in the RFM. More seamless integration of the FMM and RFM datasets represents an area of focus.

Emission estimates are sensitive to the speed for each road link. Whereas congested speed is available for the GMA within the FMM, only signposted speeds are available for road links within the RFM. Assumptions made to adjust signposted speeds to approximate actual truck speeds represents an area of further work.

The RFM model is based on travel demand resulting from large-scale commodity movements between node locations, and thus does not account for local travel within regional cities and towns, which is likely to be dominated by the use of rigid trucks. Accounting for intrazonal freight movements and verifying the assignment of articulated and rigid trucks within the RFM will support greater coverage and certainty within regional freight emissions.

Light vehicle method

Modelling of VKT and emissions by vehicle type and road link

Light duty vehicle movement outputs were from travel modelling based on the Strategic Travel Model (STM, version 3.8) for the Sydney GMA, and the Regional Travel Model (RTM) covering the whole of NSW but with a lower level of detail. The focus of the RTM is on long distance transport, with trips within SA2 geographical areas not covered.

LDV movements from transport modelling using the STM data include passenger vehicle and LCV movements; however, the LCV data is for business use LCVs with private use LCVs captured within the figures provided for passenger vehicles. Adjustments were therefore made to the data received with the VKT for passenger vehicles split into cars and LCVs to approximate the car/LCV ratios in the SMVU VKT data given for capital cities.

RTM outputs are given as the number of passenger movements rather than vehicle movements, with vehicle trips estimated by assuming an average 1.4 passengers per vehicle based on advice from TfNSW transport modellers. Vehicle movements were split into cars and LCVs based on information on car/LCV ratios from travel modelling studies for regional NSW.

Vehicle trips within the GMA from the STM are given 4 daily time intervals (AM peak, intermediate, PM and evening/overnight). Trips were summed across these periods to provide daily trip values. Daily truck trips were then scaled to yearly values using a factor of 330 (accounting for weekday to weekend trip ratios, on advice from TfNSW). Vehicle trips within the RTM are modelled on a daily basis, with trips scaled to yearly values using a factor of 350 (accounting for weekday to weekend trip ratios, advice from TfNSW).

Road links were allocated to LGAs using ArcGIS. Where road links cross LGA boundaries, all attributes for the road link were duplicated and link lengths recalculated, retaining the assigned vehicle flow. VKT was calculated based on the number of trips for each vehicle type multiplied by the length of the road link, with VKT by vehicle type calculated for each LGA. Modelled VKT for 2016 and 2021 based on the STM were used to interpolate annual VKT for intermediate years for the GMA. The RTM data was only available for 2019, with VKT extrapolated for earlier years.

Emissions by vehicle type were calculated for each LGA by applying the fleet-average EFs by speed class with VKT estimates by speed class for each road link. Emissions were calculated by vehicle type and speed class and then aggregated across speed bins and road links within each LGAs.

Road links in the STM data have ‘congested speed’ as an attribute, and this was used to calculate the speed correction factor directly. The RTM data only contains signposted speeds, with reference made to this speed in the emission estimation since congestion is less likely to be commonplace in most areas outside of the GMA. The signposted speed was adjusted down slightly to reflect actual travel speeds with fleet-average EFs applied to calculate emissions accounting for the adjusted speed of each road link.

Comparison of spatial LDV VKT data with published SMVU VKT data

Light duty vehicle VKT estimates were compared to ABS SMVU 2017–18 data (ABS 2020). The SMVU data for LDVs for 2019–20 was noted to be significantly impacted by COVID-related restrictions that occurred from March 2020 and was therefore not referenced for the years of interest. Given that vehicle travel within SA2 areas outside of the GMA is not accounted for in the RTM data, combined STM and RTM VKT were estimated to account for about 80% of the VKT for cars and 60% of the VKT for LCVs reported within the SMVU (Table 7).

Table 7 Comparison of study VKT for LDVs with SMVU data

	Modelled NSW VKT data (billions) (travel within regional NSW SA2 areas not accounted for)	SMVU VKT (billions) based on state of operation (2017–18)	% of SMVU VKT accounted for
Cars	45.7	56.5	81%
LCVs	8.9	14.7	61%
Total	**54.6**	**71.2**	**77%**

Petrol consumption for 2019 was compared to NSW fuel sales statistics from the APS (DISER 2021b), with petrol consumption for light vehicle travel captured in the STM and RTM models found to comprise about 80% of APS petrol sales (5,675 megalitres)[4].

Accounting for 'missing' LDV VTK and scaling to approximate STGGI emissions

Travel within SA2 areas outside of the GMA were assumed to account for the proportion of light vehicle VKT within the SMVU not accounted for (Table 7). This 'missing' VKT was proportioned to LGAs falling outside of the GMA based on population and associated emissions estimated and included in the LDV emission estimates for these LGAs.

LDV emissions were estimated to be about 90% of the LDV emissions inventoried for NSW by the Commonwealth Government within the STGGI, with LDV emissions scaled across all LGAs to approximate the STGGI estimates for each year (Table 8).

Table 8 NSW LDV emissions with scaling to approximate the STGGI

LDV emissions (Mt CO_2-e)	2016	2017	2018	2019
NSW LDV emissions (with scaling to approximate STGGI emissions for NSW)	16.79	17.80	18.05	17.95

Data limitations and areas identified for improvement

Uncertainties in the emission estimates for LDV emissions, and therefore a focus for further investigation in future studies include:

- estimation of private use LCVs from passenger vehicles within the STM outputs
- estimation of vehicle movements based on modelled passenger movements within the RTM outputs, and allocation of vehicle movements for LCVs and cars
- calculation of emissions accounting for road link speed outputs from the STM and RTM
- accounting for vehicle movements within SA2 areas outside the GMA
- addition of motorcycle emissions.

Aviation (domestic)

Emissions were estimated based on fuel combustion from domestic flights that depart from NSW airports, moving both passengers and freight. The subsector includes all aircraft purchasing aviation fuel in NSW for domestic use including:

- commercial domestic (passenger and freight) flights that depart from NSW
- private aircraft and charter flights departing in NSW.

The following sources are dealt with elsewhere and are excluded from this subsector:

- fuel combustion associated with ground handling operations
- energy consumption associated with airport operations
- military fuel consumption at military airports.

[4] Light duty diesel fuel consumption is unable to be meaningfully compared to the APS due to the very large non-road diesel use and lack of disaggregation in the APS.

Data sources

The data sources used to estimate spatial domestic aviation emissions are given in Table 9.

Table 9 Data sources applied in the estimation of spatial domestic aviation emissions

Data reference	Description	Resolution	Source
AES	Energy consumption (domestic air transport)	Annual	DCCEEW 2022a
APS	Aviation turbine fuel sales for domestic use in NSW	Monthly dataset	DISER 2021b
NGERS facility level reporting	kL of fuel combusted in NSW, GHG emissions	Annual data	Confidential data provided by the CER
STGGI	State GHG emissions for domestic aviation	Annual data	DCCEEW 2022b
BITRE monthly airline performance	Trends in aircraft departures and utilisation	Monthly dataset	BITRE 2022a, 2022b
Climate Active – Qantas, Virgin	Annual emissions per passenger intensity	Public Disclosure Statements	Climate Active 2022a, 2022b
Climate Active – Qantas, Virgin	Airline fuel consumed by route to determine the fuel intensity of passenger flights		Confidential data for quality assurance
CASA aircraft register	Details of aircrafts registered in NSW	Annual	CASA 2022
NIR	EFs	Annual data	DISER 2022

Emission estimation method

Historical NGERS data were compiled for all jet fuel and aviation gasoline (avgas) reported for use in NSW. NGER reporters were classified as commercial, charter, private or special (i.e. military contract). The additional fuel reported under the APS and AES was then assigned to a 'Non-reporters' category. Non-reporters were taken to be private jets, training vessels, small aircraft and small commercial airlines that fall under the NGERS reporting threshold.

Military fuel consumption at military airports[5] is included in the APS/AES fuel consumption data. The NIR allocates 8.2% of aviation turbine fuel and 0.1% of aviation gasoline to military use and this national share allocation is adopted for NSW and removed from the total fuel consumption.

BITRE flight movements and passenger revenue data were used to apportion fuel consumption to main airports[6] and regional airports[7] in NSW, based on the proportion of revenue passengers.[8]

---

[5] Military airports: Dochra Airfield, HMAS Albatross, Holsworthy Barracks, RAAF Base Glenbrook, RAAF Base Richmond, RAAF Base Wagga and RAAF Base Williamtown.

[6] Main airports: Sydney, Newcastle, Albury, Armidale, Ballina, Coffs Harbour, Dubbo, Port Macquarie, Tamworth and Wagga Wagga.

[7] Regional airports: Bathurst, Broken Hill, Griffith, Inverell, Lismore, Lord Howe Island, Merimbula, Moree, Moruya, Narrandera, Orange, Parkes and Wollongong.

[8] Analysis of confidential Climate Active data indicated that for commercial airlines revenue passengers is more reflective of fuel consumption than flight movements.

For non-reporters, the number of vessel registrations for postcodes closest to each minor regional and private airport (~58 airports) was reviewed. Apportionment of emissions based on vessel registrations was found to overestimate emissions for such airports; for example, some private airports are associated with vessel registrations for historical restoration societies, with vessel registrations being disproportionate to the expected fuel consumption and emissions. It was decided to apportion fuel use and emissions to the main metropolitan and regional airports for the Stage 1 NSW local-scale emissions.

Emissions are estimated based on NGERS fuel consumption (for commercial, charter, private, special) and based on AES (for non-reporters), using the EFs reported in the NIR 2020 (DISER 2022, Table 3.2 for CO_2 EFs and Table 3.18 for non-CO_2 EFs).

Verification

AES are derived from facility level reporting under NGERs and monthly APS, and are considered the most appropriate source of activity data for estimating emissions of non-reporters. Using AES fuel consumption, estimated emissions were found to be marginally higher than STGGI estimates for 2016 and marginally lower for 2017, 2018 and 2019; however, for the most part STGGI emissions estimates for 2016–2019 could be reproduced using AES data (Figure 3).

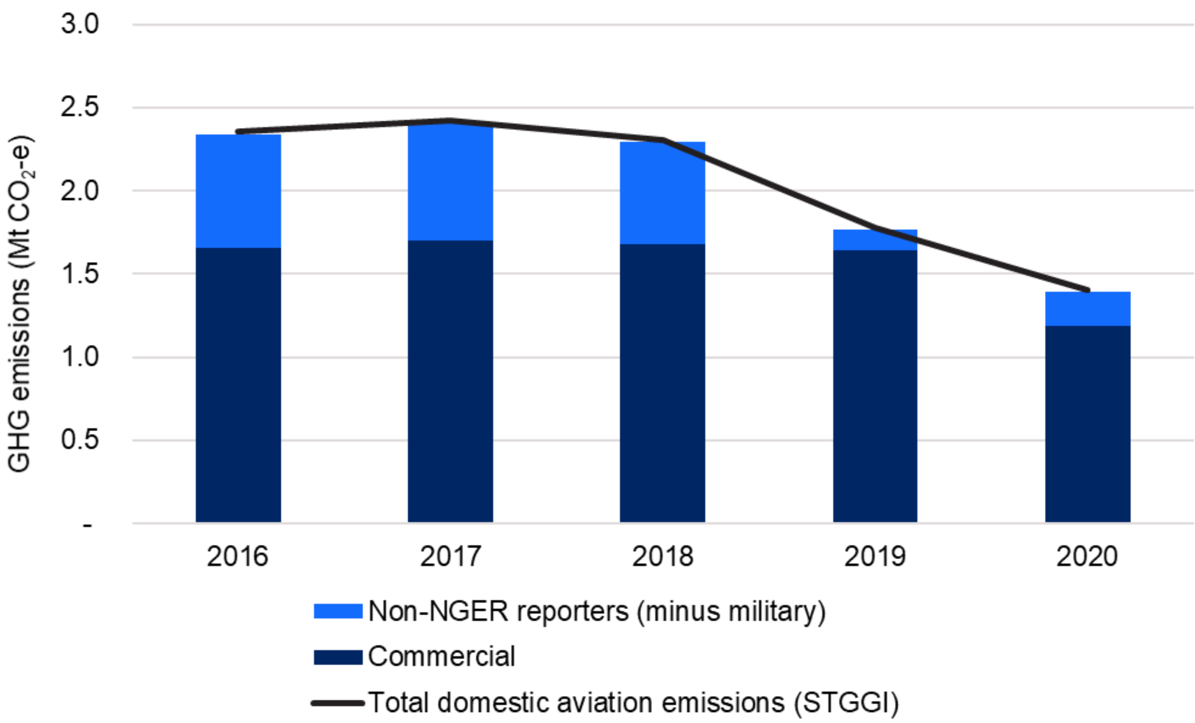

Figure 3 Estimated domestic aviation emissions using AES fuel for non-reporters and compared with total STGGI emissions for NSW aviation

Special and charter aviation emissions were estimated to be less than about 0.01 Mt CO2-e and are therefore not shown in the graph.

Data limitations and quality

Emissions are apportioned to the main metropolitan and regional airports only, due to the lack of passenger and flight movement data for private and minor regional airports. This will be the focus for improvement in the next update of aviation emissions for the NSW local-scale emission accounts. Fuel apportionment for military airports will also be reviewed to verify the use of the national average to indicate military fuel consumption in NSW.

Railways

Rail is the third largest transport emission source after on-road and aviation. The major players in NSW include Sydney Trains, Australian Logistics Acquisition Holdings, NSW Trains, Aurizon Holdings Ltd, Asciano Limited, GWI Holdings, QUBE Holdings and One Rail Australia.

This section addresses scope 1 emissions associated with the transport of goods or people by rail within NSW, including passenger (urban, regional and tourism) and freight (bulk, coal, and commodity) rail transport. It excludes energy consumed in ancillary rail services and in the operation of train stations.

Scope 2 emissions associated with the consumption of grid electricity are addressed in the section related to electricity consumption.

Data sources

Data sources used to estimate railway emissions by LGA are given in Table 10.

Table 10 Data sources applied in the estimation of spatial railway emissions

Data reference	Description	Resolution	Source
AES	Total energy consumption (rail)	Annual	DISER 2020
BITRE rail statistics	Kilometres travelled	Annual data	BITRE 2021b
ARTC and TfNSW – rail network data	Gross tonne kilometres (GTK)	Annual	NSW rail network data provided by the Australian Rail Track Corporation (ARTC) and TfNSW (not public)
NGERs facility level reports	kL of fuel combusted in NSW, emissions by type	Annual data	Confidential data provided by the CER
STGGI	State GHG emissions for rail	Annual data	DCCEEW 2022b
TfNSW	Utilisation of passenger trains to allow for energy usage adjustment for passenger numbers	Biannual dataset	TfNSW 2022d
TfNSW	Train patronage – monthly figures	Monthly	TfNSW 2022c
NIR	EFs	Annual data	DISER 2022

Emission estimation method

The STGGI scope 1 emissions for railways were disaggregated based on diesel–electric rail activity, expressed as GTK[9], in each LGA. NSW rail network data was provided by ARTC and TfNSW as GTK freight activity within individual track segments of the NSW rail network, distinguishing between freight and passenger rail.

[9] The unit of measure representing the movement over a distance of 1 km of 1 t of vehicle and content.

NGERS-reported diesel oil consumption, reported by rail operators for each year, and given separately for freight and passenger rail, was used to apportion annual STGGI emissions into freight and passenger rail emissions over the 2016–2019 period. Diesel consumption by rail freight was calculated to account for 91–92% of total diesel use for rail transport each year.

Estimated freight rail emissions were disaggregated by LGA based on the proportion of total GTK freight activity occurring in the LGA. Passenger rail emissions were similarly disaggregated based on the proportion of total GTK passenger activity in the LGA. Emissions from freight and rail were summed for each LGA to provide a single rail emissions estimate by LGA for each year.

Verification

STGGI rail emissions are reproduced using AES diesel consumption for rail transport and EFs for rail from the NIR 2020 (DISER 2022, Table 3.2 for CO_2 and Table 3.20 for non-CO_2 gases).

Data limitations and quality

ARTC and TfNSW GTK activity is provided for individual track segments of the NSW rail network. GTK activity by track segment has been assigned to individual LGAs within the GMR, which accounts for approximately 60% of NSW freight GKT and approximately 42% of NSW passenger GKT. Therefore, 60% of estimated freight emissions and 42% of the estimated passenger emissions (the GMR component) are spatially allocated based on the fraction of the GKT for each track segment in an LGA to the total GMR GKT.

For areas outside the GMR, where individual track segments have not been assigned to individual LGAs, a simplified approach is taken whereby track segment origins and destinations are matched to LGA suburbs, with GKT then summed to derive an LGA total (i.e. the proportion of track length in each LGA is not taken into account). This is done separately for passenger and freight with emissions then spatially allocated based on the fraction of the GKT for an LGA to the total GKT. This analysis is done for the ARTC interstate network only and does not include TfNSW's Country Regional Network, which accounts for only a small percentage of the freight task. Improvements to the spatial allocation for non-GMR LGAs will be a focus of the next update.

Navigation (domestic)

This subsector includes scope 1 emissions associated with all civilian (non-military) marine transport of passengers and freight. Domestic navigation consists of coastal shipping (freight and cruises), interstate and urban ferry services, and other vessels and small pleasure craft movements in NSW.

The following activity is included for this subsector:

- coastal shipping – domestic freight that leaves from NSW
- coastal shipping – domestic cruises that leave from NSW
- port towage vessels
- ferry services – public
- ferry services – private
- small pleasure craft movements
- other small vessels/craft.

Excluded from the scope:

- fuel use in military vessels
- international shipping/freight
- energy usage at ports, marinas, and other ancillary marine functions (addressed within other IPCC sectors).

Data sources

Data sources used to estimate domestic navigation emissions are given in Table 11.

Table 11 Data sources applied in the estimation of spatial domestic navigation emissions

Data reference	Description	Resolution	Source
AES	AES data for domestic (coastal) water transport fuel consumption – fuel oil, marine diesel and gasoline	Annual	DISER 2020
NGERs facility level reporting	kL of fuel combusted in NSW, GHG emissions	Annual data	Confidential data provided by the CER
STGGI, 2020	Domestic navigation for NSW	Annual	DCCEEW 2022b
BITRE	Port based maritime activity		Publicly available: BITRE 2022c
Opal	Public transport on ferries trip data		TfNSW 2022b
Australian Maritime Safety Authority (AMSA)	Vessel registrations		AMSA 2022
Recreational vessel registrations	Registration by postcode for spatial modelling		TfNSW 2022a

Emission estimation method

NGERS data was extracted for ANZSIC codes 'water passenger transport', 'water freight transport' and 'water transport support services' and apportioned as follows:

- 'Water freight transport' and 'water transport support services' were assigned to the coastal shipping category. Energy consumption for these NGERS categories is reported for fuel oil, diesel and gasoline.
- 'Water transport services' were assigned to the ferry services category, with energy consumption reported for diesel and a small amount of gasoline.

Fuel consumption statistics for domestic 'water transport' from AES were used to estimate emissions for non-reporting vessels, with the following assumptions applied:

- The difference between NGERs and AES fuel oil consumption was apportioned to non-reporting vessels in the coastal shipping category.
- The difference between NGERs and AES diesel oil consumption was apportioned to all other non-reporting vessels, with NGERS assumed to capture all ferries.
- The difference between NGERs and AES gasoline consumption was apportioned to non-reporting pleasure craft and other small vessels, noting that a small proportion is reported under the NGERS for ferries.

Estimated domestic navigation emissions were disaggregated by LGA based on the proportion of relevant activity occurring in each LGA, as follows:

- Emissions for coastal shipping were apportioned spatially based on the number of port calls, obtained from BITRE marine activity statistics for the main operating ports of Sydney, Newcastle and Port Kembla. The total number of port calls for Newcastle Port was assigned to the Newcastle LGA while the total number of port calls for Port Kembla was assigned to the Wollongong LGA. For Sydney, the total number of port calls was split between operating areas of Sydney harbour as follows:
    - Port Botany is one of Australia's largest container ports with approximately 1,600 ships visiting the port each year (Port Authority of NSW 2022). This accounts for approximately 80% of the total BITRE reported port calls for Sydney. Port Botany operates container terminals in both Bayside and Randwick LGAs, and emissions are split evenly between these 2 LGAs.
    - The remaining reported port calls are split evenly between the other operating areas of Sydney Harbour, equating to about 2 ships a week for each of the following:
        - Gore Bay contains the fuel import terminal for Viva energy and is assigned to North Sydney LGA
        - Glebe Island contains a bulk import terminal for dry goods (i.e. cement) and is assigned to the Inner West LGA
        - White Bay contains the main cruise ship terminal for Sydney and is assigned to the Inner West LGA
        - Kurnell (also in Botany Bay) contains a fuel import terminal and is assigned the Sutherland Shire LGA.
- Emissions for ferries were apportioned based on Opal data for ferry trips and distances (TfNSW 2022b), and apportioned to LGAs that are included in each ferry route.
- Emissions for diesel consumption in other non-reporting vessels were apportioned based on the AMSA list of registered ships (i.e. larger vessels) (AMSA 2022). The total number of vessels (ferries and fishing vessels excluded) were grouped by home port and assigned to the relevant LGA for each home port.
- Emissions for gasoline consumption in pleasure craft and other small vessels were apportioned to LGAs based on NSW boat licence registrations (TfNSW 2022a). Post codes for each registration were mapped to LGAs and apportioned based on the percentage of LGA registrations by total number of registrations.

Verification

Using AES fuel consumption to estimate residual emissions from non-reporters, emissions are marginally higher than STGGI estimates for 2017 and 2018 and marginally lower for 2016, 2019 and 2020; however, STGGI emissions estimates for 2016–2019 are reproduced to within a few percent using AES data (Figure 4).

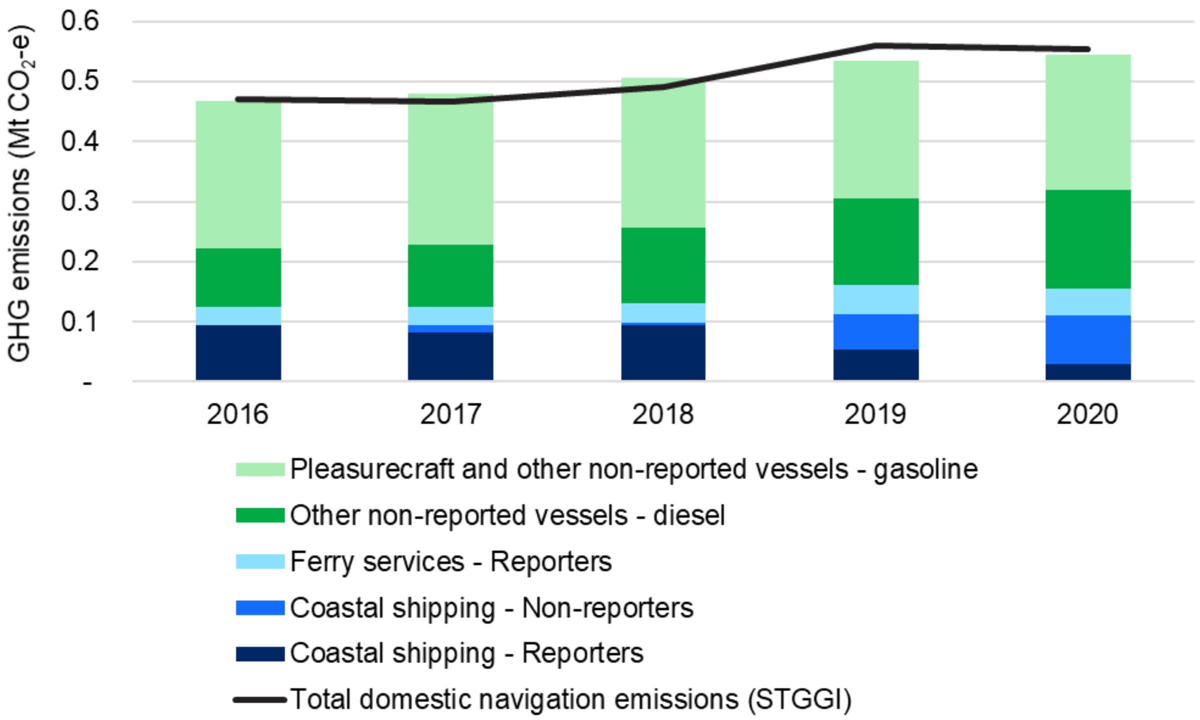

Figure 4 Domestic navigation emissions estimated using AES 2021 and compared with total STGGI emissions

Data limitations and quality

The spatial allocation for coastal shipping is based on the total number of port calls for both domestic and international shipping, as no disaggregation is provided for port calls in the BITRE data. While disaggregation (domestic and international) is provided for freight tonnes, this does not include other coastal shipping (i.e. cruise ships). Furthermore, the number of port calls is provided for Sydney only and not split across the Sydney Ports and cruise ship terminals. Improving this spatial allocation will be the focus of the next update.

Other transportation

The 2 categories included in the Other Transportation subsector are:

- pipeline transport
- off-road vehicles.

Pipeline transport

This sector includes combustion related emissions from use of pipelines to transport gases, liquids, slurry and other commodities. The sector is dominated by natural gas pipelines. (Note that fugitive emissions from natural gas pipelines are addressed separately under A.B.2.b.4 natural gas transmission and storage; refer to the Fugitive Emissions from Fuels sector.)

Data sources

The data used in the estimation of pipeline transport emissions are summarised Table 12. Refer to Appendix A for information on approaches applied in the study to ensure NGERS data confidentiality requirements are met when publishing local-scale emissions.

Table 12 Data used in the estimation of pipeline transport emissions

Data reference	Description	Resolution	Source
STGGI	NSW emissions from other transportation – 1.A.3.e	Total NSW emissions disaggregated by IPCC category and subcategory	DCCEEW 2022c
NGERS facility data	NSW emissions for pipelines and other transport	Facility-specific emissions data reported under the NGERS	NGERS data
AES	AES Table F – energy consumption for 'Other transport, services and storage'	Energy consumption by fuel type	DCCEEW 2022a
Gas and pipeline network	Length of gas network pipes – GIS data and shapefiles		Geoscience Australia 2017

Emission estimation method

AES energy consumption for 'Other transport, services and storage' is not disaggregated for pipeline transport. Emissions estimated from AES fuel consumption are more than 3 times higher than STGGI emission totals for pipelines (on average from 2016–2019).

NGERS reported fuel consumption and emissions were compiled for the ANZSIC group 'pipelines and other transport'. NGERS data for the period 2016–2019 comprise, on average, 55% of the STGGI emissions totals for the same period. The combustion of natural gas makes up approximately 90% of the reportable scope 1 emissions from the sector and 2 reporters alone comprise 100% of the reportable natural gas consumption for the sector.[10] The combustion of diesel or fuel oil makes up most of the remaining reportable scope 1 emissions from the sector, with much of this diesel use reported for fleet vehicles.

Emissions for pipeline transport are therefore estimated based on STGGI totals for the category, with total state emissions disaggregated spatially based on the gas distribution network only (which accounts for the majority of the reportable emissions for the sector).

Emissions are spatially allocated based on the proportion of total pipeline length that is located within each LGA.

Verification

NGERS data for the period 2016–2019 comprise, on average, 55% of the STGGI emission totals for the same period. The difference between NGERS and STGGI emissions is expected to be from a number of smaller facilities below the reporting threshold using diesel fuel in pumping stations for the transport of liquids, slurries and other commodities.

Data limitations and quality

Spatial allocation is currently based on the gas distribution network only, based on the proportion of pipeline within each LGA. It is expected that most emissions would occur at compressor/ pumping stations and therefore improving this spatial allocation will be the focus of the next update.

[10] Based on NGERS data for 2016–2019

Off-road recreational vehicles

This sector includes combustion related emissions from the use of off-road mobile sources, such as unregistered trail bikes, recreation vehicles and competition vehicles.

The following sources are dealt with elsewhere and are excluded from this subsector:

- off-road vehicles that are classified in 1.A.4 Other Sectors, for example:
  - commercial/institutional off-road vehicles
  - residential off-road vehicles such as lawn mowers
  - agricultural forestry and fishing off road vehicles
  - military transport.

Data sources

Data used in the estimation of off-road recreational transport emissions are given Table 13.

Table 13 Data used in the estimation of off-road recreational transport emissions

Data reference	Description	Resolution	Source
STGGI	NSW emissions from other transportation – 1.A.3.e	Total NSW emissions disaggregated by IPCC category and subcategory	DCCEEW 2022c
AES	AES Table F – energy consumption for 'Road transport'	Energy consumption by fuel type	DCCEEW 2022a
APS	Automotive gasoline sales for domestic use in NSW	Monthly fuel sales by sector/industry	DISER 2021b
Trail and motocross tracks NSW	Number of tracks per LGA		Trackfinder 2022
Racing circuits	Number of circuits per LGA		Motorsport Australia NSW Supersprints 2022

Emission estimation method

AES energy consumption for road transport (gasoline) and APS automotive gasoline sales can be apportioned to off-road vehicles based on the allocated share for off-road vehicles reported in the NIR (0.1%) (DISER 2021c). A comparison of the estimated fuel consumption for off-road recreational vehicles, based on AES, APS and STGGI emissions, is presented in Table 14. The STGGI estimate is back-calculated from the annual emissions using an EF for automotive gasoline (expressed in tonnes per kilolitre).

The estimated fuel consumption compares across all 3 data sources, which are all within a few percent of each other.

Table 14 Comparison between AES, APS and STGGI estimated fuel consumption (kL) for off-road recreational vehicles

Source	2016	2017	2018	2019
AES (0.1% of road transport gasoline)	5,349	5,529	5,506	5,393
APS (0.1% of automotive gasoline sales)	5,737	5,815	5,811	5,680
STGGI (back calculated from emissions)	5,244	5,370	5,365	5,259

Emission estimates for off-road transport are based on STGGI totals for the category with total state emissions disaggregated spatially based on a combination of population density and the number of racing circuits and trail/motocross tracks within each LGA. The number of circuits/tracks within each LGA is summed and a proportion of the total circuits/tracks is derived for each LGA. This is then applied to the population for these LGAs to derive a track weighted population, which is then used to apportion emissions across each LGA based on the fraction of the track weighted population across the state.

Verification

STGGI emissions can be reproduced using the AES or APS estimated fuel consumption and EFs reported in the NIR (DISER 2022, Table 3.2 for CO_2 EFs (automotive gasoline) and Table 3.25 for non-CO_2 EFs (petrol recreational vehicles). There are no NGERS reported data under this category.

Fugitive emissions from fuels

Fugitive emissions refers to GHG released in connection with, or as a consequence of, the extraction, processing, storage or delivery of fossil fuels This excludes combustion of fuels for the production of useable heat or electricity.

Data sources

Data sources applied to develop fine-scale emissions for this sector are as follows:

- NGERS data for NSW facilities for 2015–16, 2016–17, 2017–18 and 2018–19
- NSW Greenhouse Gas Inventory (STGGI) data for category 1B subsectors for 2015–16, 2016–17, 2017–18 and 2018–19.

Refer to Appendix A for the approaches applied in the study to ensure NGER data confidentiality requirements are met when publishing local-scale emissions.

Emission estimation method

The calculation of GHG emissions from fugitive emissions associated with fuel production is divided into 2 categories as per the NIR 2019 (DISER 2021c):

- 1B1 solid fuels
- 1B2 oil and natural gas.

Category 1B1 covers fugitive emissions from the production, transport and handling of coal from surface and underground mining, and emissions from decommissioned underground mines. A significant contribution arises from ventilation air CH_4 from underground coal mines. GHG emissions from flaring and post-mining activities (i.e. GHGs desorbing from surface coal stockpiles) are included.

NGER category 1B1 data were compiled and further subdivided into underground mines (1B1a i), surface (or open cut) mines (1B1a ii) and other – decommissioned mines (1B1c). Emissions in each of the 3 categories were then summed and compared to NSW STGGI subsector emissions.

Category 1B2 covers fugitive emissions from the oil and gas industry. Over the years of interest, all emissions in this category arose from gas exploration, production, transmission and distribution. According to the STGGI, there have been no emissions from oil refining in NSW since 2014, with emissions from this subsector therefore excluded.

Fugitive emissions from the gas industry include:

- vented emissions as a result of process or equipment design or operational practices
- flared emissions from the disposal of gas through combustion for non-energy purposes
- leaked emissions from unintentional equipment leaks from valves, flanges, pump seals, compressor seals, relief valves and other leakage sources from pressurised equipment not defined as a vent.

NGER category 1B2 emissions were compiled under the general category of natural gas, with emissions then summed and compared to NSW STGGI subsector emissions for natural gas.

Verification

For category 1B1 (underground mines), the agreement between NGER and STGGI emissions was generally very good. NGER emissions were higher than STGGI emissions by 6% in 2015–16. In 2016–17, 2017–18 and 2018–19, NGER emissions were higher than STGGI emissions by ≤1%.

For 1B1 (open cut mines) the agreement between NGER and STGGI data was also very good, being within 2%. Emissions were improved by obtaining more accurate estimates from the national emissions inventory team of the GHG emissions intensity of run-of-mine (ROM) production for 4 mines reporting under the NGERS based on Method 1. Method 1 provides a fixed emission intensity for open cut coal mines in NSW of 0.061 tonnes CO_2-e/tonne ROM coal, which tends to over-estimate the fugitive emissions from open cut mines.

The then Commonwealth Department of Industry, Science, Energy and Resources (DISER) provided revised intensities for these mines as follows (pers. comm., Glen Whitehead, DISER, 28 July 2020):

- Mount Pleasant Mine: 0.003 tonnes CO_2-e/tonne ROM coal[11]
- Maules Creek Mine: 0.001 tonnes CO_2-e/tonne ROM coal
- Namoi Open-Cut Mine (Sunnyside): 0.001 tonnes CO_2-e/tonne ROM coal.

For 1B1 (decommissioned mines) emissions from NGERS was at most 25% lower than NSW STGGI emission estimates. In 2016–17 the NGER data was 3% higher than the STGGI data.

When all 3 coal mining categories were added and compared with the NSW total from the STGGI, the agreement was better than ±5%. This is due to the good agreement between NGERS and STGGI emissions for underground mines, with such mines comprising between 78% and 88% of total fugitive emissions. Open cut mining contributed 10–16% and decommissioned mines 2–6% of fugitive emissions.

For category 1B2 (natural gas), there were only 15 facilities reporting fugitive emissions from the natural gas sector in NSW under NGERS. These were mostly gas transmission and distribution pipeline operators, with minor emission contributions from gas exploration. The agreement between NGERS and the STGGI emission totals was good, differing by at most 4% (with NGERS emissions slightly higher than STGGI emissions).

To spatially resolve the emissions from gas pipelines, a separate procedure was adopted. Under NGERS Method 1, pipeline emissions are calculated based on the length of the pipeline. Using this approach, pipeline lengths were estimated by LGA using GIS mapping and emissions apportioned based on the percentage of the length of total pipelines in each LGA.

About 96% of NSW fugitive emissions are from coal mining with 4% associated with natural gas.

[11] For the Mount Pleasant Optimisation Project, the proponent MACH Energy submitted a GHG Environmental Impact Statement (EIS) in January 2021. The fugitive emission intensity was reported in EIS documentation to be 0.012 tCO_2-e/t ROM based on NGERS Method 2. This information will be considered in future NSW spatial account updates.

Data limitations and quality

Uncertainties and data limitations

Emissions from decommissioned mines are a source of uncertainty. This may be a result of mismatches in the designation of mines as being in care and maintenance or decommissioned within the NGERS and the STGGI. Mines under care and maintenance are usually classified as active but may have been classified as decommissioned in the STGGI (and vice versa). This is being investigated with the support of the national emissions inventory team.

For natural gas fugitives, the spatial allocation of pipeline emissions based on the lengths of pipelines within LGAs may be an over-simplification.

Data quality

The quality of the data is considered high and can be further improved by addressing the areas discussed above.

Industrial processes and product use

The industrial processes and product use (IPPU) sector includes direct GHG emissions from the chemical and/or physical transformation of fossil fuel (or fossil fuel derived) feedstocks in an industrial process and the use of synthetic GHGs such as halocarbon refrigerants.

Data sources

Data sources applied to develop fine-scale emissions for this sector are given in Table 15. NSW facilities falling under IPPU categories 2A–2C are addressed using NGERS data, with reference also made to data supplied by DISER for 2B (N_2O used in aerosols and anaesthetics).

Emissions were taken directly from the STGGI for 2D (lubricants), 2F (synthetic gases, e.g. fluorocarbon and hydrofluorocarbon as replacements for ODS), 2G (other product use and manufacture) and 2H (other) as emissions arose mostly from facilities falling under the NGER reporting threshold.

Approaches applied in the study to ensure NGER data confidentiality requirements are met when publishing emissions are documented in Appendix A.

Table 15 Data used in the estimation of industrial process and product use emissions

Data reference	Description	Resolution	Source
NGER facility data	NGERS data for NSW facilities under IPCC categories 2A–2C	Facility-specific industrial process and product use emissions data reported under the NGERS	Confidential data received from the CER
STGGI	NSW data from the STGGI	Total NSW emissions disaggregated by IPCC category and subcategory	NSW data published by the Commonwealth Government within the STGGI (DISER 2021e)
DISER IPPU emissions time series data spreadsheets	• Mineral products by facility • Chemical products by facility; includes N_2O use in NSW • Metal products by facility • ODS replacement trade data for Australia pro rata for NSW. Refrigerant import data is collected by DISER under the Ozone Protection and Synthetic Greenhouse Gas Management Act	Facility-specific emissions data for all except ODS replacements, N_2O use, non-energy products, other product manufacture and other The minerals, chemicals and metals data from DISER used to cross-check NGERs data for 2A–2C	DISER data for 2017–18 and previous years (received June to August 2019)
Australian Statistical Geography Standard (ASGS) 2019	Resident population estimates by LGA	Estimated resident population by LGA from 2015–16 to 2018–19	NSW 2019 Population Projections – ASGS 2019 LGA projections

Emission estimation

The calculation of GHG emissions from industrial processes and product use is divided into 8 categories as per the NIR 2019 (DISER 2021c):

- 2A Mineral Industry (cement clinker and lime production)
- 2B Chemical Industry (ammonia and nitric acid production)
- 2C Metal Industry (iron and steel and aluminium production)
- 2D Non-energy products from fuels and solvents (lubricant oils not used for fuels)
- 2E Electronic industry (not reported in NSW and not discussed further)
- 2F Product uses as ODS substitutes (fluorocarbons and hydrofluorocarbons used in refrigeration and air conditioning equipment, fire retardants and aerosols)
- 2G Other product use and manufacture (SF_6 used in switchgear)
- 2H Other (CO_2 used in food production).

For 2A–2C, data is reported on a facility basis in the NGERS which allows each facility to be mapped to an LGA. (Refer to Appendix A for the approaches applied in the study to ensure NGER data confidentiality requirements are met when publishing emissions.)

For 2D, 2F, 2G and 2H many of the sources of emissions are below the NGERS facility threshold and are not reported. For 2F, emissions data for NSW was obtained from the STGGI and further subdivided into LGAs based on the fraction of the NSW population in each LGA. The 2D, 2G and 2H subsectors represent relatively small sources of emissions. Since no detailed facility data is available under NGERS, the STGGI data was used and disaggregated based on population.

Verification

Facility level IPPU emissions were obtained from NGERS for 2A–2C. The NGERs facility data accounts for about 100% of the STGGI emissions data for all 3 categories over each year of interest. For 2D, 2F, 2G and 2H the data from the STGGI was used without change and hence could not be independently verified.

Data limitations and quality

The emissions reported under 2A–2C accounted for 70% of IPPU emissions in 2016–17. The category totals based on NGERS data are in very good agreement with the STGGI data. The emissions data for 2A–2C is considered complete.

For the 2D, 2F, 2G and 2H, much of the emissions arise from area sources rather than from facility/point sources. This data is not captured under the NGERS and STGGI estimates rely on the use of stock models with emissions apportioned by population. The emissions could not be independently verified. This is of note particularly for category 2F given that the emissions from ODS replacements represented 28% of NSW's IPPU emissions in the 2016–17 inventory.

Areas requiring improved data or methods

Uncertainties in the NSW emissions IPPU inventory may be reduced by sourcing independent emissions data for ODS replacements such as through a NSW-specific stock model. Development of such a stock model would however require substantial work to track the flows of refrigeration, mobile and stationary air conditioning equipment, and fire retardants, by gas type in NSW.

Emissions in categories 2D, 2G and 2H together constitute about 2% of the IPPU inventory and improving emission estimates for these categories is therefore assigned a lower priority.

Data quality

The quality of the data for the primary inventory year is considered high for 2A–2C and moderate for 2D and 2F–2H. Improvements are possible by addressing the areas discussed above.

Agriculture

The agriculture sector comprises emissions from livestock and crop production. It includes emissions from enteric fermentation, manure management, and agricultural soils. These emissions are predominantly N_2O and CH_4.

Data sources

Data used in the estimation of agricultural emissions are given in Table 16, with 2015–16 being the primary inventory year. The main source of agricultural activity data was the ABS Agricultural Census, which provided the agricultural commodities dataset (ABS 2018). It is collected once every 5 years; the most recent was collected in 2015–16 with the next survey for 2020–21 not yet published (as at July 2022). The survey collects data at SA2 and LGA level. In between the Agricultural Census years, there is an annual Rural Environment Agricultural Commodities Survey (REACS). This survey has a lower reporting threshold (a smaller sample size) and collects less granular data at the SA4 level.

Table 16 Data used in the estimation of agricultural emissions

Data reference	Description	Resolution	Source
Activity data	Agricultural commodities 2015–16	SA2	ABS/ABARES (ABS 2018)
Activity data	Water use on Australian farms 2015–16	SA2	ABS/ABARES (ABS 2019)
Activity data	NSW Landuse 2017 v1.2	Spatial layer	SEED, NSW DPIE (DPIE 2020b)
STGGI	NSW emissions data from the STGGI for 2016–2019 as reported in the NIR 2019	State	DISER 2021e

Emission estimation method

Emission categories and sources addressed

Emissions from livestock and crops are addressed in the analysis (Table 17). The GHG emissions from agriculture were provided as crop and livestock – beef cattle, dairy cattle, sheep, swine, poultry, goats and other livestock. This approach aggregated the categories from the NIR (DISER 2021c) to provide insights on the emissions from the agricultural economic sectors or commodities. Commodity emissions presented at LGA level are rounded up to the nearest 10 tonnes of CO_2e in this analysis (refer to section on method validation and uncertainty analysis).

Other agricultural subsectors were excluded due to the lack of suitable fine-scale activity data to spatially disaggregate the state-level emissions. CO_2 emissions were excluded. Emissions from liming and urea, which together contributed 3–4% of NSW's annual agriculture emissions from 2015–16 to 2018–19 were excluded. Despite the small contribution to NSW agricultural emissions, liming and urea emissions may be larger contributors in some cropping regions. Within agricultural soils, N_2O emissions from organic fertilisers (sewage sludge), and emissions associated with mineralisation due to loss of soil carbon were also excluded from the Stage 1 spatial dataset. Emissions associated with sewage sludge and mineralisation contributed less than 0.4% of NSW's annual agriculture emissions from 2015–16 to 2018–19.

Table 17 Emission categories and sources considered and not considered in the calculations

Emission categories	2015–16	2016–17	2017–18	2018–19
Livestock – 3.A. enteric fermentation	✓	✓	✓	✓
Livestock – 3.B. manure management	✓	✓	✓	✓
Livestock – 3.D. agricultural soil	✓	✓	✓	✓
Livestock – 3.D.A.2.a and 3.D.A.3. organic fertilisers	✓	✓	✓	✓
Crop – 3.D. agricultural soil	✓	✓	✓	✓
Crop – 3.F. field burning of agricultural residues	✓	✓	✓	✓
Crop – 3.C. rice cultivation	✓	✓	✓	✓
3.H. Urea application	X	X	X	X
3.G. Liming	X	X	X	X
3.D.A.2.b. Sewage sludge applied to land	X	X	X	X
3.D.A.5. Mineralisation due to loss of soil carbon	X	X	X	X

Spatial redistribution of activity data and emission calculation by LGA

Emissions were calculated for each LGA on the basis of SA2 level activity data from the agricultural commodities dataset (ABS 2018). Activity data is given as area or yield for cropping and as numbers of livestock, unless otherwise stated. LGA boundaries are subject to adjustment over time, and it is necessary to redistribute the activity data based on LGA boundaries selected for the study (ABS 2018 LGA boundaries) before calculating emissions.

The 2015–16 activity data was available at SA2 level with the boundaries dating back to 2011. A geometric intersection of the 2011 SA2 boundaries and the 2018 LGA boundaries was used to redistribute the activity data. In some instances, the SA2 feature can intersect multiple LGA features (Figure 5). The activity data was then attributed to the LGA by the proportional area of the SA2 feature that occurred within the LGA boundary; for example, the 2011 SA2 feature of Braidwood occurs in two 2018 LGA areas with 89% in Goulburn–Mulwaree and the remaining 11% in Queanbeyan–Palerang. As a result, 89% of the SA2 level activity data is attributed to the Goulburn–Mulwaree LGA and the remainder to Queanbeyan–Palerang. This approach mirrors the method used by the ABS to attribute SA2 level data to LGAs and this dataset was used to validate our redistributed activity data (refer to the section on data limitations and quality).

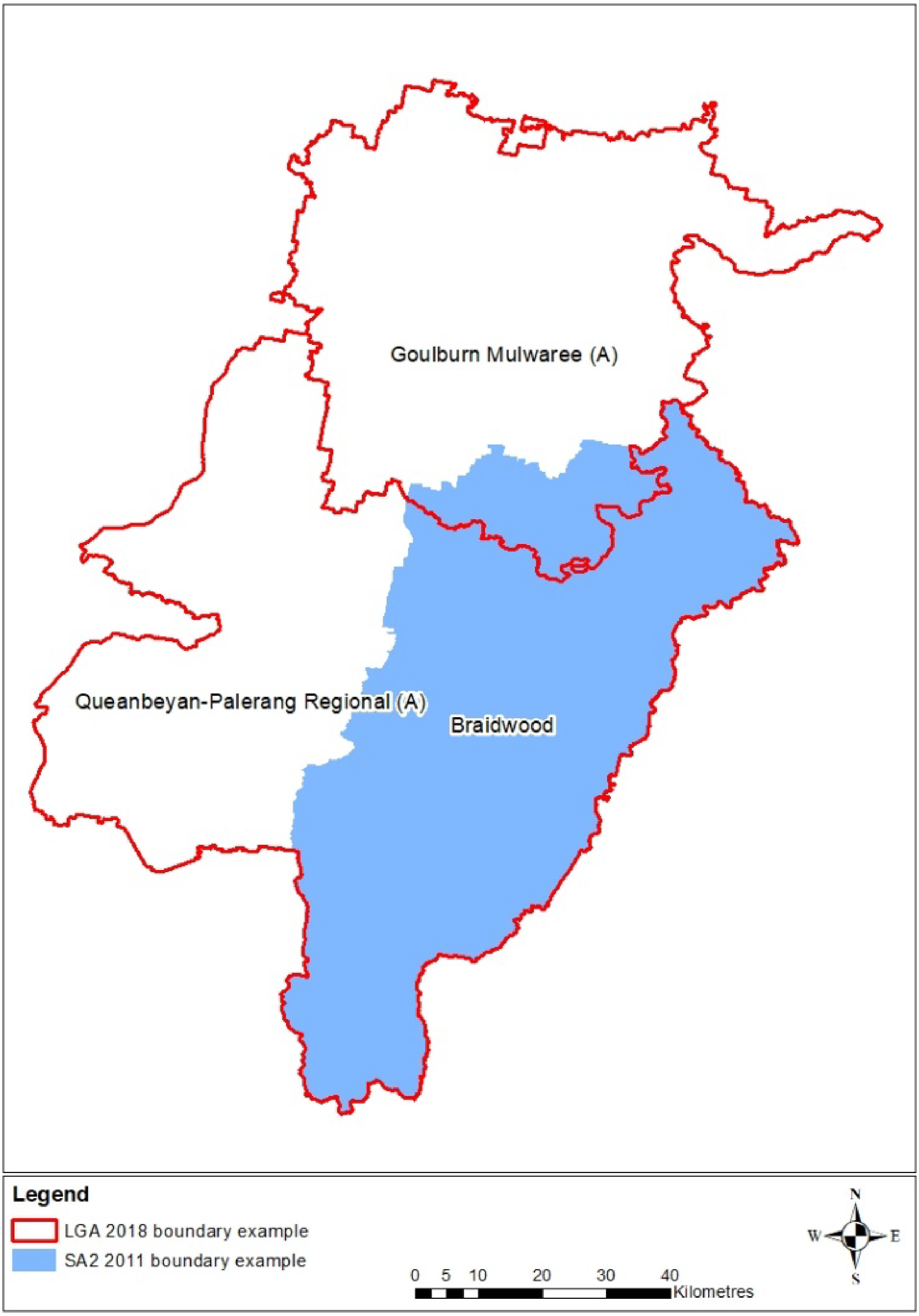

Figure 5 Example of the alignment of SA2 and LGA boundaries

To adapt the inventory data for the state to LGA boundaries, a series of scaling factors were applied following a top-down approach. For cattle, sheep, pigs and goats, the emissions for the subsectors agricultural soil (this included animal waste applied to soil), enteric fermentation and manure management were calculated as follows. For each livestock species *i* and LGA *j*:

$$E\_ls_{i,j} = \frac{(E\_soil_{i,NSW} + E\_ef_{i,NSW} + E\_mm_{i,NSW}) * N_{i,j}}{N_{i,NSW}}$$

where:

$E\_ls_{i,j}$ = emissions from livestock (tonnes CO_2-e)

$E\_soil_{i,NSW}$ = emissions from agricultural soils (tonnes CO_2-e)

$E\_ef_{i,NSW}$ = emissions from enteric fermentation (tonnes CO_2-e)

$E\_mm_{i,NSW}$ = emissions from manure management (tonnes CO_2-e)

$N_{i,j}$ = number of livestock in LGA

$N_{i,NSW}$ = number of livestock in NSW.

Emissions for poultry were calculated as per the above but without enteric fermentation subsector emissions as such emissions are not applicable. Emissions from all other livestock were aggregated (alpaca, buffalo, camels, deer, donkeys and mules, horses, ostriches and emus) as the activity dataset from the ABS provided only the aggregated number of these livestock. Emissions from all other livestock were calculated as per cattle above using the 3 subsectors.

Crop emissions were aggregated into 16 categories (Table 18) and the emissions from crop residues at LGA level were calculated as follows. For each crop species *i* and LGA *j*:

$$E\_cr_{i,j} = \frac{(E\_soil_{i,NSW} + E\_burn_{i,NSW}) * Y_{i,j}}{Y_{i,NSW}}$$

where:

$E\_cr_{i,j}$ = emissions from cropping (tonnes CO_2-e)

$E\_soil_{i,NSW}$ = emissions from agricultural soils due to crop residues (tonnes CO_2-e)

$E\_burn_{i,NSW}$ = emissions from field burning of agricultural residues (tonnes CO_2-e)

$Y_{i,j}$ = yield for crop in LGA (in tonnes)

$Y_{i,NSW}$ = yield for crop in NSW (in tonnes).

$$E\_ricecultivation_{j} = \frac{(E\_floodedfield_{NSW}) * A_{j}}{A_{NSW}}$$

where:

$E\_ricecultivation_{j}$ = emissions from rice cultivation (tonnes CO_2-e)

$E\_flooded\ field_{NSW}$ = emissions from flooded fields (tonnes CO_2-e)

A_j = area of flooded fields in LGA (in ha)

A_{NSW} = area of flooded fields in NSW (in ha).

Emissions at LGA level for rice was the sum of the CH_4 and N_2O emissions from crop residues (agricultural soils and field burning) and CH_4 emissions from rice cultivation in flooded fields. The scaling of emissions for financial years 2017, 2018 and 2019 was based on activities from financial year 2016 to reference the granular SA2 level data for that year.

To partition emissions from pasture, a spatial analysis was required to first determine the area of pasture in NSW. Pasture was identified by the ALUM (Australian Land use and Management) classifications: grazing modified pastures and irrigated grazing modified pastures in the NSW Landuse 2017 layer (DPIE 2020b) (Figure 6). Pasture also included areas identified as non-woody grazing native vegetation outside of the arid and semi-arid rangelands. The non-woody vegetation and the rangelands boundary were sourced from DEE (DEE 2018) and ACRIS (ACRIS 2013) respectively. This approach was chosen to emulate the NIR methods used to determine the nation-wide emissions from pastures (DISER 2021c).

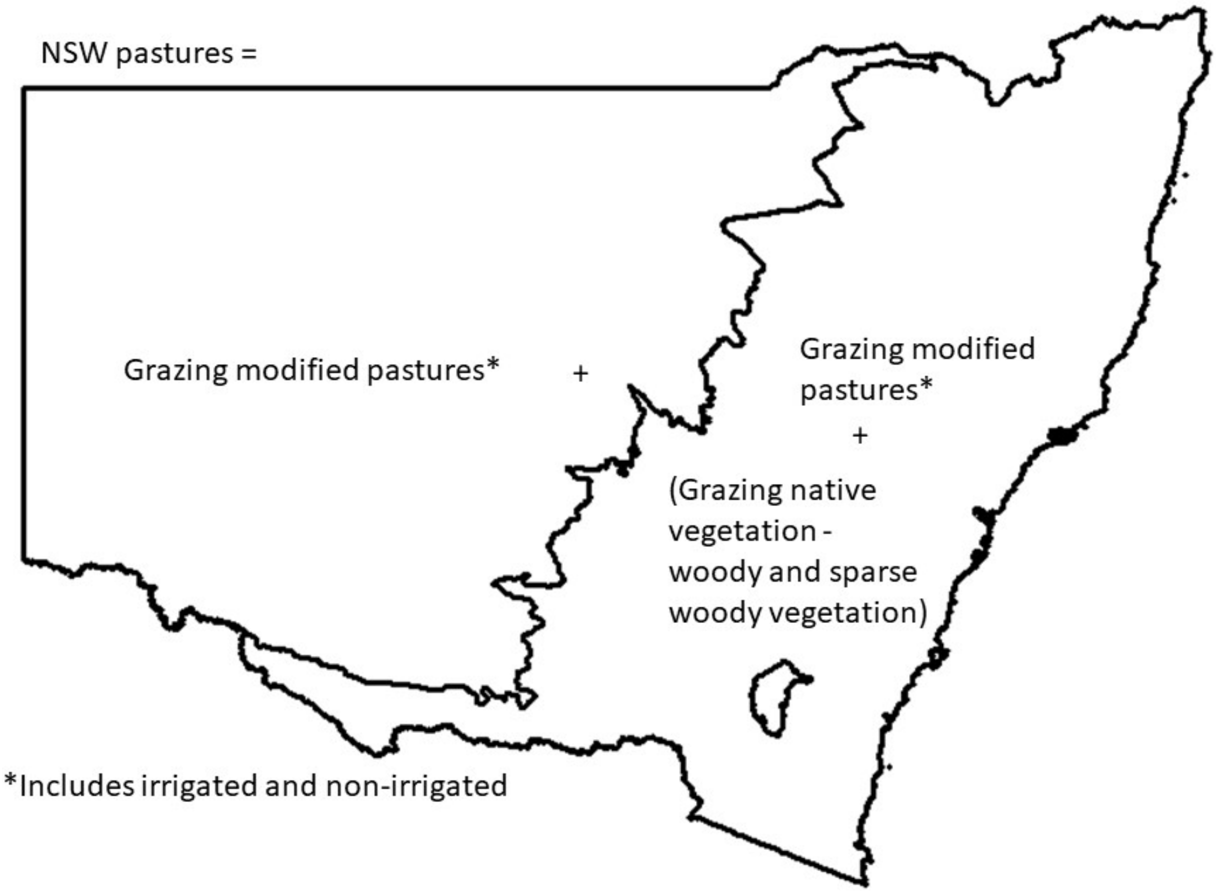

Figure 6 Estimation of pasture activity area using NSW Landuse 2017 and national forest and sparse woody vegetation data

Inorganic fertiliser emissions were based on the Water use on Australian farms activity dataset (ABS 2019), with this data used to provide an estimate of area of irrigated commodities. This approach was used for irrigated pasture, irrigated cropping, non-irrigated cropping, cotton, sugar cane and horticulture. While the area of cotton, sugar cane and horticulture can be identified from the ABS agricultural commodities dataset, water use activity data were found to be more closely aligned to the Australian Greenhouse Gas Emissions Inventory System (AGEIS) activity data (refer to the data limitations and quality section). The area of non-irrigated pasture was identified using the area classified as grazing modified pastures in the NSW Landuse 2017 dataset (Figure 7) to emulate the method described in the NIR (DISER 2021c). This top-down approach assumed the fertiliser application rate for a given cropping category or commodity was consistent across the state, as reported in the NIR, Volume 1. For crop or pasture category i and LGA j:

$$E\_fert_{i,j} = \frac{E\_soil_{i,NSW} \ * A_i}{A_{i,NSW}}$$

where:

$E\_fert_{i,j}$ = emissions from fertiliser use (tonnes CO_{2}-e)

$E\_soil_{i,NSW}$ = emissions from inorganic fertiliser use on agricultural soils (tonnes CO_{2}-e)

A_j = area for fertilised crops or pasture in LGA (in ha)

$A_{i,NSW}$ = area for fertiliser crops or pasture NSW (in ha).

Table 18 Crop categories and sources of emissions included in the analysis

Commodity category	ABS commodity census activity data	STGGI emissions data	
		Subsector	Sources of emissions
Wheat Oats Barley Triticale Sorghum Maize Peanuts in shell Oilseeds All other cereals Roots and tubers Sugar cane	Yield of wheat Yield of oats Yield of barley Yield of triticale Yield of sorghum Yield of maize Yield of peanuts in shell Yield for canola and other oilseeds Yield of all other cereals not for grains, and all other cereals Yield of potatoes and carrots Yield of sugar cane	3.D. Agricultural soils	3.D.A.4. Direct soil emissions from crop residue
		3.D. Agricultural soils	3.D.B.2. Indirect soil emissions through nitrogen leaching and run-off from crop residue
		3.F. Field burning of agricultural residues	
Cotton Forage crops	Yield of irrigated and non-irrigated cotton Area of cereals and other cereals fed-off, grazed or used as green manure	3.D. Agricultural soils	3.D.A.4. Direct soil emissions from crop residue
		3.D. Agricultural soils	3.D.B.2. Indirect soil emissions through nitrogen leaching and run-off from crop residue
Rice	Yield of rice	3.D. Agricultural soils	3.D.A.4. Direct soil emissions from crop residue
		3.D. Agricultural soils	3.D.B.2. Indirect soil emissions through nitrogen leaching and run-off from crop residue
		3.F. Field burning of agricultural residues	
	Area of rice	3.C. Rice cultivation	

Commodity category	ABS commodity census activity data	STGGI emissions data	
		Subsector	Sources of emissions
Pulses	Yield of lentils, lupins, chickpeas, mung beans, faba beans and other pulses	3.D. Agricultural soils	3.D.A.4. Direct soil emissions from crop residue
		3.D. Agricultural soils	3.D.B.2. Indirect soil emissions through nitrogen leaching and run-off from crop residue
		3.F. Field burning of agricultural residues	
Pasture	Area of irrigated and non-irrigated grazing modified pastures Area of non-woody grazing native vegetation outside of NSW rangelands	3.D. Agricultural soils	3.D.A.4. Direct soil emissions from crop residue of annual grasses, grass clover mixture, lucerne, other legume pasture and, perennial pasture
		3.D. Agricultural soils	3.D.B.2. Indirect soil emissions through nitrogen leaching and run-off from crop residue of annual grasses, grass clover mixture, lucerne, other legume pasture and, perennial pasture
Fertilisers	Total area and area watered of irrigated and non-irrigated pasture Total area and area watered of irrigated cropping and non-irrigated cropping Total area and area watered of irrigated and non-irrigated cotton Total area of cut flowers, fruits, nuts and vegetables Total area of sugar cane	3.D. Agricultural soils	3.D.A.1. Direct soil emissions from inorganic fertilisers
		3.D. Agricultural soils	3.D.B.2. Indirect soil emissions through nitrogen leaching and run-off from fertiliser, and 3.D.B.1. atmospheric deposition from fertiliser

Method validation and uncertainty analysis

Total emissions from all LGAs were compared to emissions from the STGGI for the subsectors accounted for in this analysis and found to be less than 1% lower (Table 19).

Total emissions from all LGAs were compared to total agricultural emissions for NSW from the STGGI and found to be around 4% lower than the annual STGGI totals (Table 19). Liming and urea emissions, which were omitted, accounted for most of the 4%.

Table 19 Total emissions accounted by the spatial accounts compared with STGGI

Year	Absolute difference from STGGI total (kt CO_2-e /yr)	% difference from STGGI total	Absolute difference from accounted STGGI sectors (kt CO_2-e/ yr)	% difference from accounted STGGI sector
2016	–760	–3.83	–131	–0.68
2017	–926	–4.31	–167.0	–0.80
2018	–768	–4.00	–140.0	–0.75
2019	–656	–4.03	–67.0	–0.43

For the top-down approach, we explored the possibility of using area and yield to apportion the emissions at state level to LGAs (Figure 7). The results for 10 crop types (wheat, oats, barley, triticale, sorghum, maize, other cereals, oilseed, peanuts and pulses) are provided here. Using emissions from crop residues, which included field burning of crop residues and direct and indirect soil emissions from crop residues, we expected a ratio of one if area performed as well as yield for estimating emissions from the crop. The coefficient of determination, R^2 of 0.955 indicated a good linear fit (emission based on area = 0.96 * emission based on yield) and small difference between emissions based on yield and emissions based on area. Around 57% (n=308) of the results were within 25% of the expected ratio of one (Figure 9). A sense check was conducted with some of the extreme ratios by calculating the crop productivity (i.e. yield per unit area). These productivities were found to far exceed (i.e. either too low or too high) the normal range or national average of crop productivity for the specific crop.

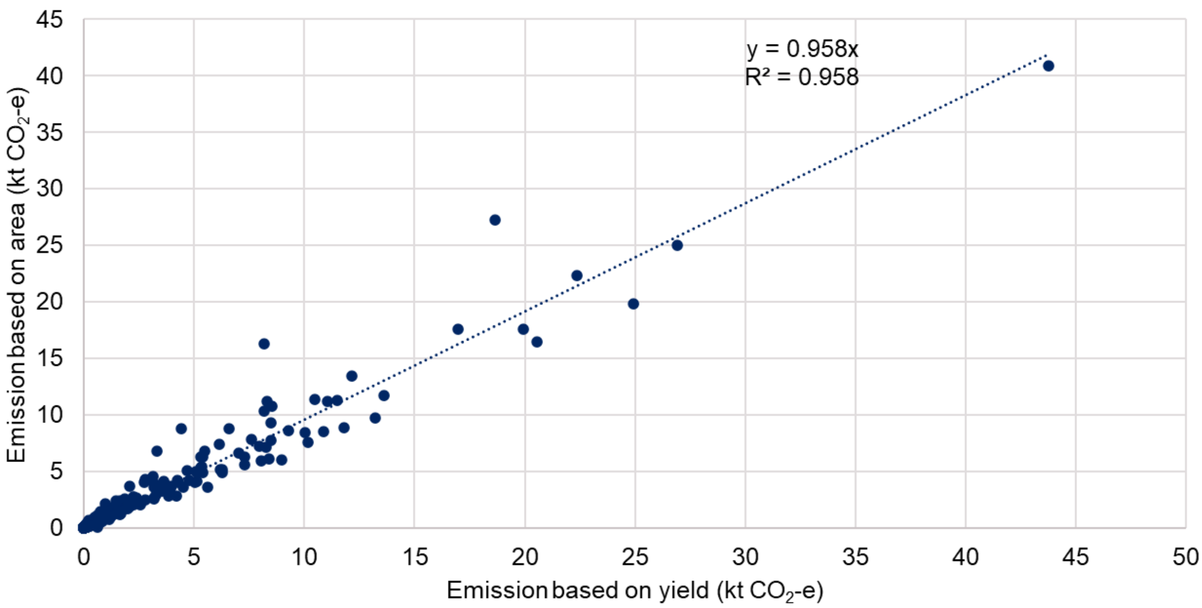

Figure 7 Comparing top-down emissions calculated based on area and yield for 2016

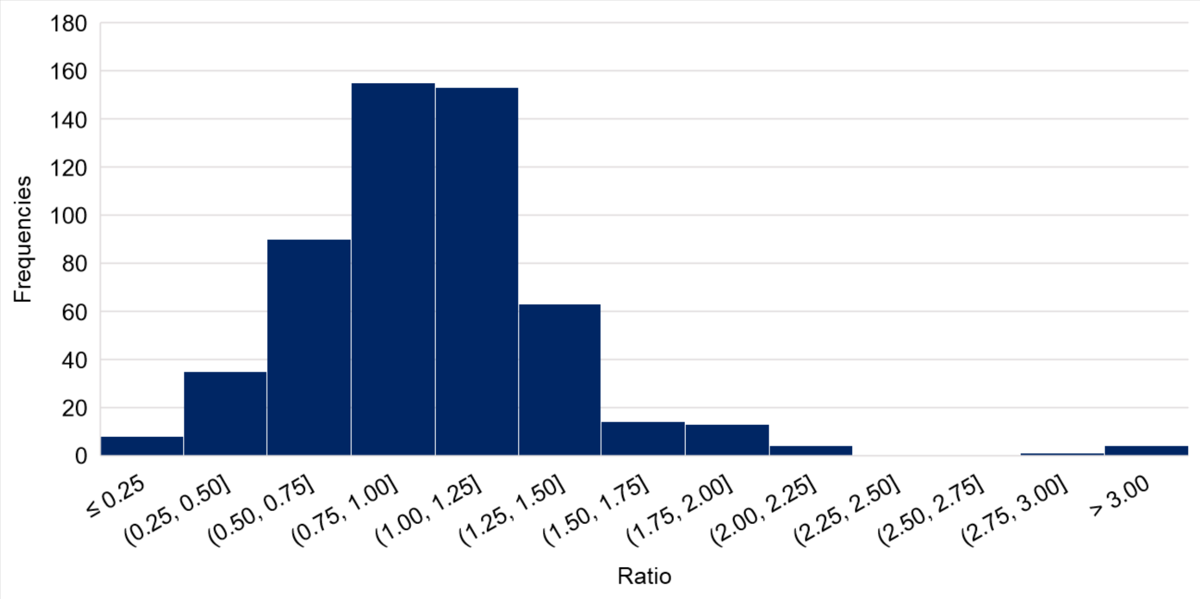

Figure 8 Frequencies of ratio of emissions based on area to emissions based on yield

As a result of spatial interpolation, some activities may be assigned to neighbouring areas without such activity. In most instances, this results in small emissions less than 5 tonnes of CO_2-e. As such, all emissions were rounded to the nearest 10 tonnes of CO_2-e in this analysis so that emissions less than 5 tonnes were rounded to zero. This approach also assumed that agricultural activities are uniformly distributed over the SA2s, when in fact the activities would vary with topography, climate and land use.

The top-down approach using yield was compared to a bottom-up approach of emissions being calculated using IPCC tier 2 equations with country-specific crop information reported in the NIR 2018, Volume 1 (Figure 9). The R^2 of 0.998 indicated a good linear fit (bottom-up emission = 1.08 * top-down emission) and small difference between top-down emissions and bottom-up emissions based on yield. All the data points (n=545) were within 20% of the expected ratio of one (Figure 10). Both the R^2 and histogram indicated that using the top-down approach of emission estimation with yield would provide a reasonable approximation of the emissions at the LGA level compared to the bottom-up approach. The use of the top-down approach would also enable us to apportion state emissions in those years where activities data were not collected at sufficiently fine scale. We assumed that the proportion of activity at LGA relative to state total activity remained stable from 2016–2019.

When these results were considered in combination with the results from the comparison of top-down emissions calculated based on area and yield, the extreme ratios were likely to be associated with errors in the area activity data.

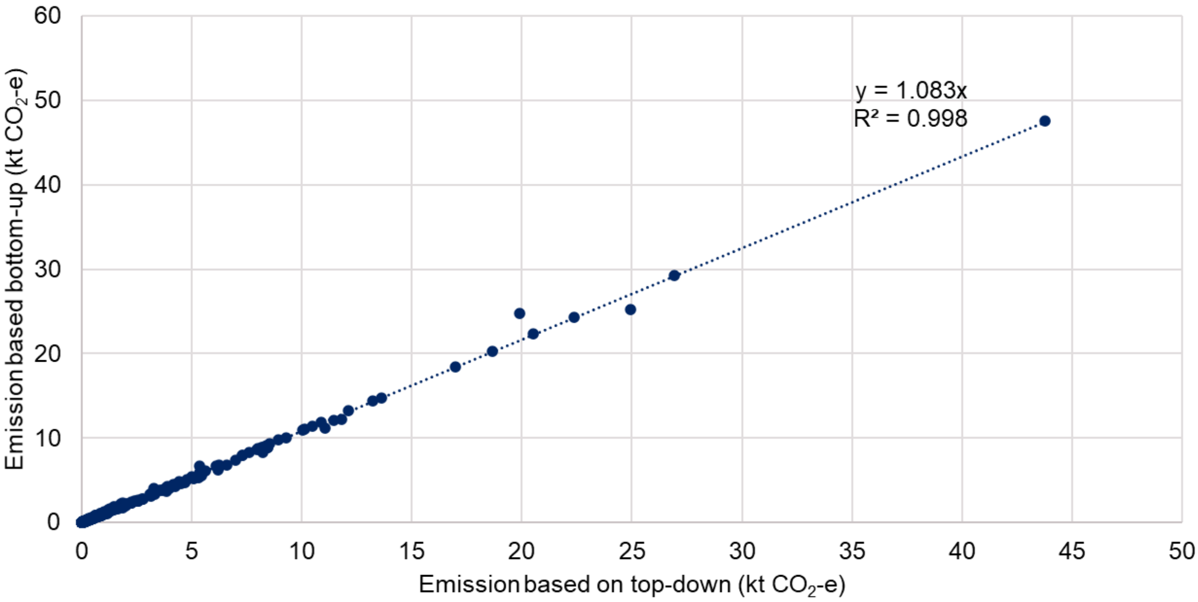

Figure 9 Comparing top-down and bottom-up emissions calculated based on yield for 2016

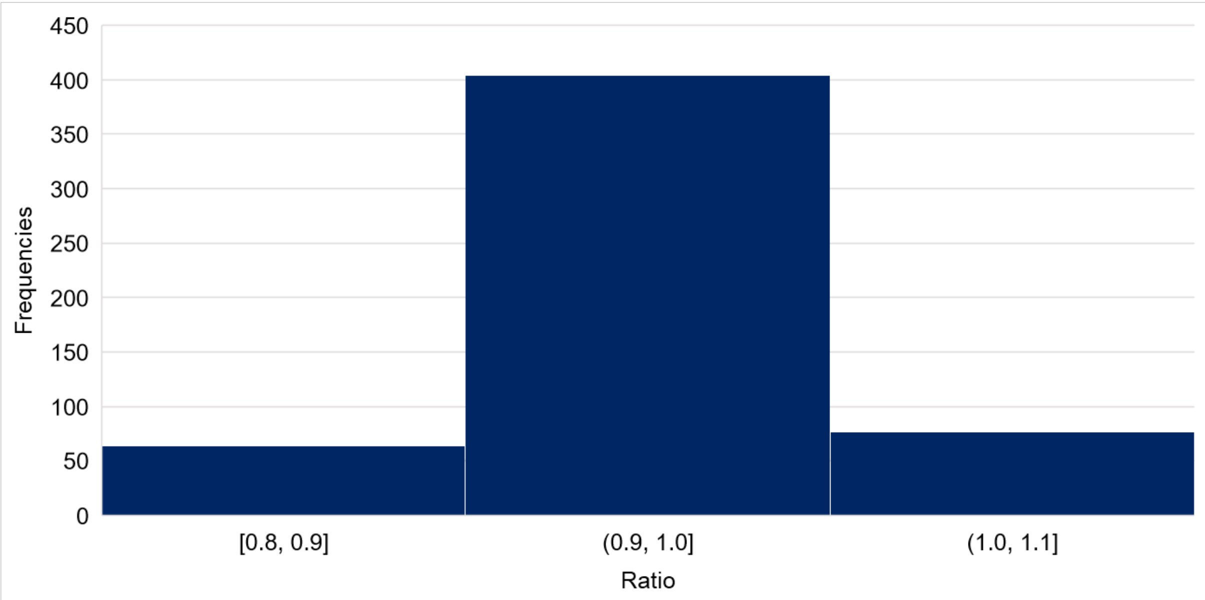

Figure 10 Frequencies of ratios of emissions calculated using top-down approach to emissions calculated using bottom-up approach

Emissions calculated based on the bottom-up approach were also compared with the state total for various crops (Table 20). For this comparison, emissions from rice included CH_4 from flooded rice cultivation, but otherwise covered field burning of residues and agricultural soil emissions as per the comparisons above for other crops. The differences were greatest for pulses (30%) and sugarcane (22%), which reflected the greater differences in these activity data used in the calculations compared to AGEIS activity data (Table 21). These provided indications of the uncertainties surrounding crop emissions introduced by our methodology. The NIR estimated overall uncertainties calculated with approach 1 propagation of error method for agricultural soils to be in the order of 56%. The uncertainties were introduced by both activity data and EFs.

Table 20 Total emissions from bottom-up calculation compared with NSW emissions reported in the National Greenhouse Gas Inventory (NGGI) for various crops

Crop	Emissions (based on bottom-up calculation)	Emissions (based on NGGI)	Absolute difference from NGGI	% difference from NGGI
Wheat	436	385	52	13%
Oats	24	24	0	0%
Barley	139	132	7	6%
Triticale	4	4	0	4%
Sorghum	34	32	3	8%
Maize	6	5	1	11%
Other cereals	1	0.6	0	7%
Oilseed	116	106	10	10%
Peanuts	0.03	0.02	0	10%
Pulse	65	50	15	30%
Rice	113	123	–10	–8%
Cotton	38	38	0	–0.3%
Sugarcane	10	9	2	22%
Tubers and roots	0.2	0.2	0	1%

Table 21 Total crop yield after spatial interpolation of ABS census data compared with AGEIS activity data

Crop	Absolute difference from NGGI (Gg/yr)	% difference from NGGI
Wheat	150	2%
Oats	23	6%
Barley	67	3%
Triticale	2	3%
Sorghum	18	3%
Maize	1	1%
Other cereals	1	10%
Oilseeds	0.43	<<0.1%
Peanuts	0	0%
Pulses	–137	–21%
Rice	13	5%
Cotton	1	0.3%
Sugarcane	184	8%
Tubers and roots	–2	<<0.1%

Data limitations and quality

Data categorical, temporal and spatial resolution

The activity datasets available were of coarser resolution compared to emissions data; for example, emissions from cattle can be divided into 3 subsectors – enteric, agricultural soil and manure management (Table 22). Within each subsector, emissions data are further subdivided into multiple categories; for example, emissions from manure management can be directly from the manure or indirectly via atmospheric deposition or nitrogen leaching and runoff. Enteric fermentation emissions were further divided into age groups, gender and feeding regimen. In comparison, the activity data at LGA level was provided only as 3 categories by the ABS.

By using the activity data for 2015–16 to approximate the spatial distribution of emissions for the subsequent 3 years, the proportion of activity in each LGA relative to the state is assumed to be constant. An alternative approach may be to use long-term averages in the spatial distribution of activity data. Once the SA2 level activity data is published for 2020–21, interpolated activity data for intermediate years could also be applied on the basis of the data for 2015–16 and 2020–21.

Table 22 Cattle data resolution available for activity and emissions datasets

Cattle categories under ABARES activity data	Cattle categories under emissions data	
Meat cattle – calves less than 1 year	Enteric	Domestic
Meat cattle – cows and heifers 1 year and over		Export long-fed
Meat cattle – all other meat cattle		Export mid-fed
		Bulls >1 year
		Bulls <1 year
		Cows <1
		Cow >2
		Cows 1–2
		Steers >1
		Steers <1
	Agricultural soil	Beef cattle – feedlot
		Beef cattle – pasture
	Manure management	Domestic
		Export long-fed
		Export mid-fed
		Bulls >1 year
		Bulls <1 year
		Cow >2
		Cows <1
		Cows 1–2
		Steers >1
		Steers <1

To determine emissions from pasture, a spatial analysis was required to first determine the area of pasture in NSW. Multiple approaches were applied to spatially disaggregate the pasture area, with the activity data compared to the data from AGEIS (Table 23). While the approach applied emulated the methods used to determine the nation-wide emissions from pastures (DISER 2021b), the total area of pasture found in NSW could not be replicated (10 million hectares vs 15 million hectares). The current approach distributed the state's emissions from pasture to the 10 million hectares identified. Further analysis will be undertaken to review reasons for the differences in the area of pasture in NSW in the next update of the NSW local-scale emissions.

Table 23 Comparison of fertiliser activity (Gg nitrogen applied) for 2015–16 derived from 3 sources

Crop	ABS water use	ABS agricultural commodities	AGEIS
Horticulture	10.7	10.2	15.8
Sugar cane	4.3	7.1	2.9
Cotton	45.9	45.9	46
Irrigated crop	18.0	*	21.3
Irrigated pasture	16.8	*	16.7

* not possible to determine from ABS agricultural commodities dataset.

Activity data anomalies

The quality of the activities data was evaluated by comparing the activity data with the NSW Landuse 2017 layer (DPIE 2020b). The classes in the NSW Landuse layer were used as proxies for arable land within each SA2 boundary and compared with the activity values to identify anomalies. Where land-use type and activity data did not agree, high resolution aerial imagery was used to verify if the activity could have taken place. Through this approach, several anomalies were detected in the activity data from the ABS agricultural commodities dataset, whereby livestock or crop activity were detected within LGAs where such activities could not have occurred. The problematic SA2 boundaries were mostly limited to inner city suburbs of Sydney, where it was likely the addresses used in the farm census did not match with the location of the activity. SA2 features that were identified as erroneous were put into an 'unallocated' category rather than an LGA (Table 24). This approach maintained the original NSW total activity data for the calculation of the EFs so there was no inflation of the EFs.

Table 24 Activity data identified as erroneous and the impact on NSW totals

	Cattle	Sheep	Cropping
Activity identified as erroneous	27,710 (no.)	24,080 (no.)	11,182.45 ha
Total activity in NSW	4,997,700 (no.)	25,968,193 (no.)	6,598,973 ha
Percentage of total	0.55%	0.09%	0.17%

Issues with topology and geometric intersections

The geometric intersection of the 2011 SA2 and 2018 LGA boundaries produced small features or 'slithers' in the dataset because of the misalignment of the line features (Figure 11). This may result in small values of activity data from an SA2 feature being represented in an LGA feature where it did not actually occur. In subsequent stages of developing the NSW spatial accounts, cluster tolerance for the topology rules of line features will be considered to correct for this issue.

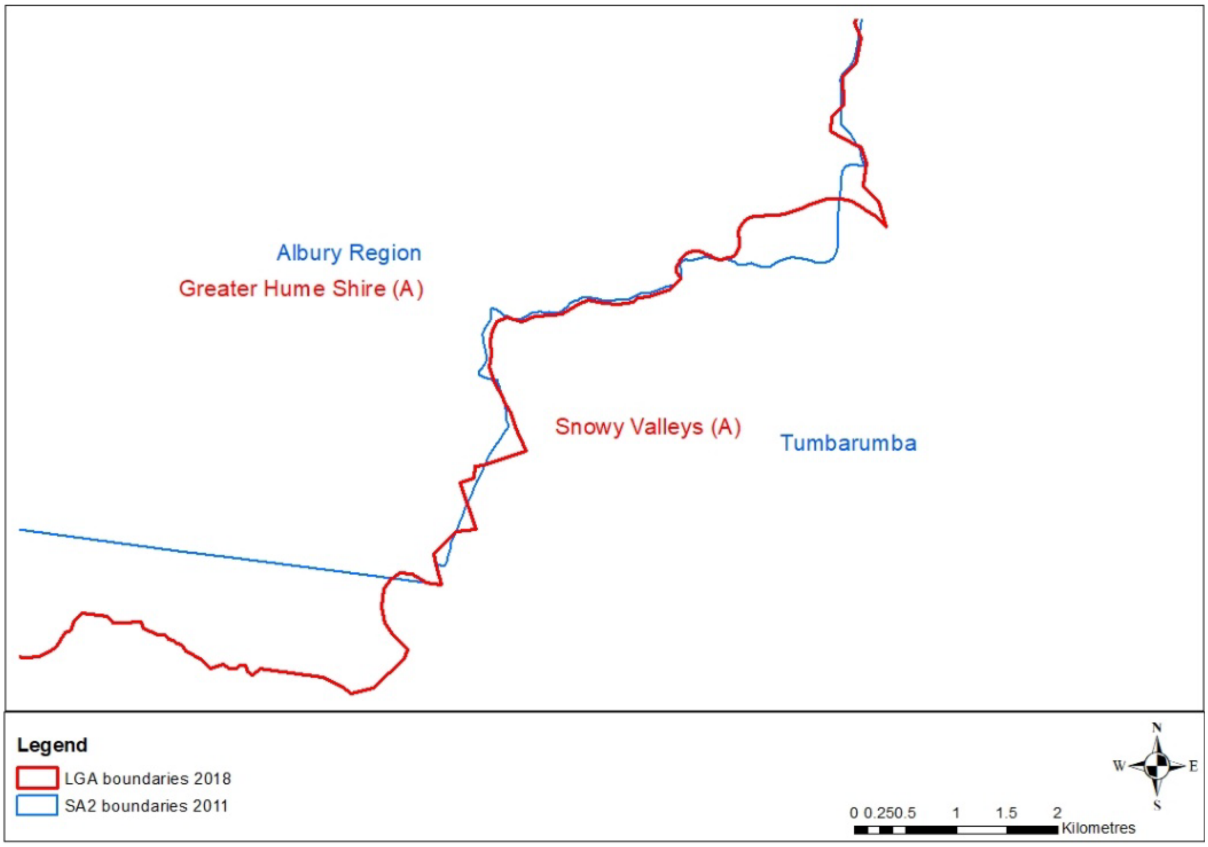

Figure 11 Example of the misalignment of line features when defining jurisdictional boundaries

Land use, land-use change and forestry

The land use, land-use change and forestry (LULUCF) sector accounts for emissions from and removals by forest lands, croplands, grasslands, wetlands and settlements. It includes emissions from events of land clearing, timber harvesting, wildfires and prescribed fires. It also includes removals by harvested wood products and forest growth from the aforementioned events. Management activities on cropland and grassland that contribute to emissions and removals are also accounted for in this sector.

Data source

Annual flux of emissions from LULUCF is simulated using the Full Carbon Accounting Model (FullCAM). Details of FullCAM model parameterisation are provided in the NIR (DISER 2021d). Emissions data for financial years 1990–2019 were generated and exported from the FullCAM spatial simulator at LGA level.

Emissions that are included in this analysis are detailed in this section (Table 25). Emissions that are not spatially simulated are excluded (refer to the section on data gaps and limitations).

Forest land remaining forest land covers emissions and removals in areas of state native forestry and plantations established prior to 1990. The changes that drive carbon fluxes in these areas are log harvesting, prescribed burns, and wildfires.

Plantations and natural regeneration cover plantations and native environmental plantings put in place since 1990, and emergence of native forest in protected areas since 1972. The anthropogenic changes that drive carbon fluxes in these areas are log harvesting, prescribed burns, and wildfires.

Regrowth on deforested land covers cropland, grassland or settlement converted to forest. The changes that drive carbon fluxes in these areas are woody vegetation gains, wildfires, and prescribed burns.

Cropland remaining cropland covers soil carbon fluxes on cropland. The changes that drive carbon fluxes in these areas are land management activities such as crop type and rotation, stubble management, tillage techniques, fertiliser application and irrigation, use of green manure and/or application of soil ameliorants such as compost, manure or biochar.

Land converted to cropland covers cropland that has had at least one land clearing event since 1972. It includes primary conversion, which means a loss of forest cover in an area that has been forest since 1972. It also includes secondary conversion, which means all other losses of forest cover. The changes that drive carbon fluxes in these areas are removal of woody vegetation, burning of cleared vegetation and the subsequent soil carbon and debris decay.

Grassland remaining grassland covers soil carbon fluxes on grasslands. For herbaceous grass, living biomass and dead organic matter are considered by IPCC guidelines to be net zero as increases in one year may equal losses from harvest and mortality in the next year. The changes that drive carbon fluxes on grassland remaining grassland are pasture and grazing management.

Land converted to grassland covers grassland that has had at least one land clearing event since 1972. It includes primary conversion, which means a loss of forest cover in an area that has been forest since 1972. It also includes secondary conversion, which means all other losses of forest cover. The changes that drive carbon fluxes in these areas are losses in woody vegetation, burning of cleared vegetation and the subsequent soil carbon and debris decay.

Land converted to settlement covers settlement that has had at least one land clearing event since 1972. It includes primary conversion, which means a loss of forest cover in an area that has been forest since 1972. It also includes secondary conversion, which means all other losses of forest cover. The changes that drive carbon fluxes in these areas are losses in woody vegetation, burning of cleared vegetation and the subsequent soil carbon and debris decay.

For all the land uses simulated, climate is an underlying variable that has a big influence on both vegetation growth and soil carbon fluxes.

Table 25 Details of LULUCF simulation model applied, categories included in this analysis and completeness of the estimations

Land use, land-use change and forestry	Simulation model name[12]	Inclusion [13]	Completeness [14]
A. Forest land			
1. Forest land remaining forest land	Harvested Native Forest, FrF (fires), Pre-1990 plantations	✓	X
2. Land converted to forest land			
Plantations and natural regeneration	Afforestation/Reforestation (New plantings), Additional land converted to forest (Natural regeneration), ERF (New plantings)	✓	✓
Regrowth on deforested land	Deforestation	✓	✓
B. Cropland			
1. Cropland remaining cropland	CrC	✓	✓
2. Land converted to cropland	Deforestation	✓	X
C. Grassland			
1. Grassland remaining grassland	GrG	✓	X
2. Land converted to grassland	Deforestation	✓	X
D. Wetland			
1. Wetland remaining wetland	Tier 2	X	X
2. Land converted to wetland	Tier 1	X	X
E. Settlements			
1. Settlements remaining settlements	Tier 2	X	X
2. Land converted to settlements	Deforestation	✓	X
G. Harvested wood products	Tier 2	X	X

Note: Details of Tier 1 and Tier 2 methods are provided in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006a). In brief, estimate methods differ in the level of details, with Tier 1 being the default method to Tier 3 being the most detailed method.

[12] The simulation model and corresponding inventory subcategory (in bracket) as per the NIR.

[13] LULUCF emissions included based on inventory categories listed in the first column.

[14] The completeness of the estimation for each category as compared to the NIR.

Verification

The emissions calculated at LGA level are aggregated and compared to the STGGI for NSW for each category (Table 26). The annual emissions are generally lower compared to the STGGI as expected, mainly due to the gaps in LGA-level spatial data for some of the emissions (refer to the data gaps and limitation section).

Table 26 Comparison of emissions from the NSW spatial accounts with STGGI estimates by category and year

Categories	Year	Spatial account (kt CO_2-e)	STGGI (kt CO_2-e)	Abs. diff (kt CO_2-e)	Percent difference
Forest land remaining forest land	2016	–1,939	–2,452	513	–21
	2017	–1,982	–2,280	298	–13
	2018	–5,273	–5,640	366	–7
	2019	–5,292	–4,706	–587	12
Plantation and natural regeneration	2016	–5,178	–5,067	–110	2
	2017	–4,549	–4,609	60	–1
	2018	–3,091	–3,289	198	–6
	2019	–2,631	–2,878	247	–9
Regrowth on deforested land	2016	–5,955	–5,948	–6.8	0.1
	2017	–5,500	–5,485	–14.7	0.3
	2018	–5,627	–5,626	–0.5	0.0
	2019	–4,918	–4,919	1.1	0.0
Cropland remaining cropland	2016	–87	–2	–84	3417
	2017	–10	362	–371	–103
	2018	2,468	2,426	42	2
	2019	671	2,643	–1,972	–75
Land converted to cropland	2016	162	199	–37	–18
	2017	377	411	–34	–8
	2018	344	379	–35	–9
	2019	331	368	–36	–10
Grassland remaining grassland	2016	–2,310	–2,812	501	–18
	2017	–3,611	–5,131	1,520	–30
	2018	–517	–776	258	–33
	2019	–1,854	–1,954	100	–5
Land converted to grassland	2016	6,906	7,059	–153	–2
	2017	8,141	8,377	–236	–3
	2018	10,291	10,627	–336	–3
	2019	7,256	7,614	–358	–5
Land converted to settlement	2016	297	307	–10	–3
	2017	315	329	–14	–4
	2018	201	209	–9	–4
	2019	144	151	–7	–5

Data gaps and limitations

Emissions excluded from the Stage 1 NSW local-scale emissions due to the National Inventory emission estimation methodology not being spatially explicit are:

- wetlands converted to croplands and grasslands
- woody horticulture
- sparse woody vegetation on grasslands, wetlands and settlements
- emissions and removals associated with grassland fires
- mangroves and tidal marsh
- harvested wood products
- private native forests
- fuelwood consumed.

Some of the simulations (e.g. cropland remaining cropland or CrC, and grassland remaining grassland or GrG) showed large variation compared to the STGGI for some years even when gaps in spatial data were excluded. Further improvements to the NSW spatial emission accounts will seek to address these issues.

Waste

The waste sector includes emissions from solid waste disposal and treatment, and domestic, commercial and industrial wastewater treatment and discharge.

Solid waste

For accounting purposes under the GPC, emissions from landfilled solid waste are categorised as follows (Figure 12).

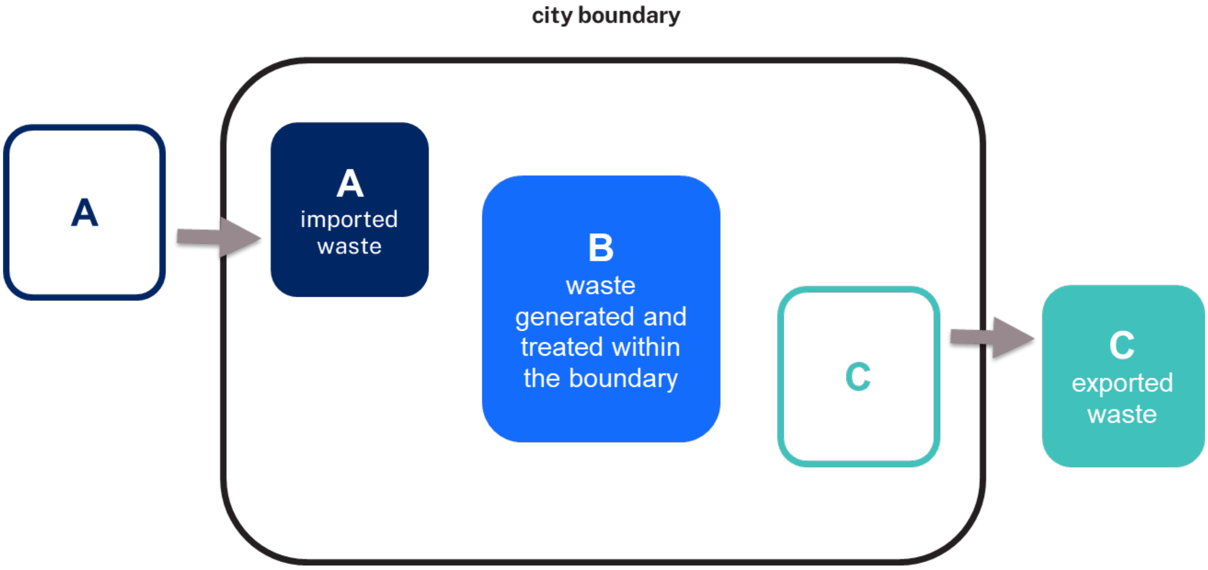

Figure 12 GPC defined boundaries for imported and exported waste
Source: World Resources Institute (2014), p.86.

The GPC categorises the waste flows:

- A – waste generated outside of the LGA boundary and treated within the boundary
- B – waste generated and treated within the LGA's boundary
- C – waste generated inside the boundary and treated outside of the boundary.

The GPC provides the following definitions in terms of emissions scopes:

- scope 1 (or territorial) emissions = emissions from A+B (all emissions generated within the LGA boundary)
- scope 3 emissions = emissions from C.

The Stage 1 NSW local-emissions dataset includes scope 1 (territorial) emissions from the disposal of each in each LGA. Area-induced and scope 3 emissions will be considered for inclusion in a future update.

Scope 1 emissions were inventoried at LGA resolution for the entire state, so aggregated emissions approximate total NSW STGGI emissions for the solid waste disposal subsector.

Territorial scope 1 emissions from solid waste disposal at landfills

Landfilling of solid waste is the primary waste management practice in Australia. The anaerobic decomposition of organic matter in a landfill is a complex process that requires several groups of microorganisms to act in a synergistic manner under favourable conditions. GHG emissions are created from solid waste deposited over a long period (more than 50 years according to the National GHG Emissions Inventory). The emissions from the anaerobic decomposition of organic matter are CH_4 and CO_2. Emissions of CO_2 generated are considered to be biogenic and are not included in the inventory. CO_2 produced from the flaring of CH_4 from waste is also considered to be of biogenic origin (DISER 2021d).

According to the NIR (DISER 2021d) ‘a relatively small number of sites are responsible for the bulk of the waste received in Australia’, ‘50 per cent of Australia’s waste disposal occurs in the 21 largest landfills. Of the landfills reporting under NGERS, 18 process more than 200 kt of waste per year, 12 process between 100 kt and 200 kt per year, 18 process between 50 kt and 100 kt per year, 12 process between 25 kt and 50 kt per year, 4 process between 10 kt and 25 kt per year and the remainder (25 landfills, or around 28 per cent of the total number of landfills) process less than 10 kt each per year.’

Further, 11% of landfills have a landfill gas collection system in place; however, in the larger-scale landfills this practice is more common, meaning that around 43% of the CH_4 generated is collected for either flaring or energy generation (DISER 2021d).

The method for calculating territorial scope 1 emissions from solid waste is based on a first order decay (FOD) model produced by the CER, namely the Solid Waste Calculator (CER 2020). The department has developed in-house software based on the CER’s calculator to make calculations easier to perform. The model tracks the stock of carbon estimated to be present in the landfill at any given time. Emissions are generated by the decay of the carbon stock and reflect waste disposal activity over many decades.

The department model is driven by landfill facility waste stream data obtained from the Commonwealth Government’s national emissions inventory team and augmented with recent waste data from the NSW EPA Waste and Resource Recovery Portal (WARRP) system. Specifically, the Commonwealth Government’s landfill masses are used for 1940–41 to 2014–15. NSW EPA WARRP data is used from 2015–16 onwards; this data includes tonnes per annum of municipal solid waste (MSW), commercial and industrial (C&I) waste and construction and demolition (C&D) waste for each landfill.

In total there are about 300 landfills in NSW that currently report under the WARRP. These landfills accept 100 tonnes or more waste each year. Landfills accepting less than 100 tonnes per year were excluded (approximately 40 sites). The WARRP dataset gives the location of each participating landfill in NSW.

Data sources

Foundational datasets used in the estimation and disaggregation of emissions from solid waste disposal are listed in Table 27.

Table 27 Data used in the estimation of solid waste disposal emissions

Data reference	Description	Resolution	Source
NGERS facility data	Landfill emissions	Site-specific waste and emissions data for waste disposal sites reporting under the NGERS	NGERS reporting data for NSW solid waste disposal facilities, 2015–16, 2016–17, 2017–18 and 2018–19
NSW STGGI 2018–19	NSW solid waste disposal emissions	Total NSW emissions disaggregated by IPCC category and subcategory	STGGI data for category 5B (Solid waste disposal) (NSW GHG 2018–19 dataset as received May 2021)
DISER solid waste disposal data	Waste tonnes (MSW, C&I, C&D) CH_4 transfer and capture data	Site-specific waste disposal data for facilities reporting under the NGERS and 'residual NSW'	DISER modelled estimates of landfill emissions for 2018–19 and prior years (DISER solid waste disposal modelling dataset, as received July 2020). Used as a check on the emissions calculated by the department model
NSW EPA WARRP data 2015–2019	Waste tonnes (MSW, C&I and C&D) per landfill	Waste disposal information for all levy liable landfills by LGA	NSW EPA waste data for 2015–16 to 2018–19. All licence holders of levy liable waste facilities such as landfills must report to the WARRP. Data is confidential

The following was noted when compiling the data to support modelling for landfills:

- Most local councils are not constitutional corporations and therefore do not report under NGERS. The NIR (DISER 2021c)[15] indicates 65% of total Australian waste disposal is covered by NGER facility data. The residual disposal not covered by the NGERS data is estimated by DISER as the total waste disposal reported for NSW minus the sum of disposal reported by facilities under the NGERS.
- The NSW EPA WARRP data includes waste disposal information for all levy liable landfills, with the total waste disposal figures for 2015–16 to 2018–19 being 1.5–2.0 million tonnes higher than estimated by DISER. This is due to different datasets being used and due to Virgin Excavatable Natural Materials (VENM) being included in WARRP data but excluded from DISER's inventories. VENM refers to quarried natural materials such as clay, gravel, sand, soil or rock fines, which is largely inert and therefore not likely to materially affect inventory estimates. More relevant are the differences in waste data noted when comparing individual landfill waste mix stream masses (especially MSW and C&I) at larger landfills. Irrespective of differences in individual landfill waste composition, the NSW WARRP waste mass data was adopted over the DISER data from 2015–16 onwards.
- Data reported under the NSW WARRP only extends back to 2015–16. FOD modelling requires the inclusion of data for prior years, with reference therefore made to historical waste data from DISER that extends back several decades. According to the IPCC, reasonably accurate estimation of landfill gas emissions using FOD modelling requires 3–5 half-lives of data (IPCC 2000). By example, the decay rate, k, of food in NSW,

[15] The subsectors include emissions from water utilities, accommodation, communications, finance, insurance, property and business services, government and defence, education, health, and wholesale and retail trade.

assumed to be mostly dry temperate climate, is 0.06 yr^{-1} giving a half-life of 12 years (noting that $t_{½}$ = ln2/k).
- NSW WARRP data does not include the age of the landfill. Attempting to estimate the age and deposition history of landfills can lead to large errors in contemporary landfill GHG emissions.
- The landfill histories for the 27 specific landfills in the DISER dataset cannot be verified due to lack of historical record keeping and data availability.

Emission estimation method

Step 1 – estimation of NSW aggregate scope 1 territorial emissions

The landfills individually included in DISER's inventory are larger landfills that have triggered the NGER facility threshold for reporting (currently 25 kt CO_2-e per annum). DISER has gathered detailed waste disposal data for 27 landfills in NSW. Most of these landfills are still in operation. Some landfills have closed but continue to emit GHGs. Most of the landfill data post 2009 has been captured from NGERS, but pre-2009 data was collated from other undisclosed sources.

The NSW department's FOD modelling used input data from DISER for each of the 27 landfills. This included climate-specific parameters designated based on landfill location, and input data related to landfill gas captured for flaring, power generation or which has been transferred from the facility. DISER's landfill waste disposal history was retained for years prior to 2015–16, including some of the pre-2009 data that extends back several decades, for more accurate modelling. The DISER waste disposal data for each landfill was however replaced with NSW WARRP disposal data from 2015–16 onwards, using landfill-specific MSW, C&I and C&D tonnages.

Due to the differences in the NSW WARRP and DISER waste stream tonnages for individual landfills, there are step changes in the masses of MSW, C&I and C&D within the disposal time series. The use of the WARRP data for recent years also results in increases in annual NSW waste disposal totals given VENM is included in the data.

Residual disposal

DISER estimated residual disposal not captured under NGERS using the total disposal reported for NSW minus the sum of the NGERS disposal for the state (termed 'residual NSW').

The 'residual NSW' disposal figure aggregates disposal from smaller landfills (including council operated landfills). These smaller landfills do not produce sufficient emissions individually to trigger the NGER facility reporting threshold. Emissions from these smaller landfills are modelled as if the waste is being disposed at one facility.

In developing the NSW local-scale emissions, The NSW department estimated 'residual NSW' disposal data using the total WARRP waste disposal tonnages for NSW less the tonnages from the 27 individual landfills for which detailed data are available. FOD modelling was undertaken using DISER's annual estimates of historical total waste disposed of and landfill gas captured for 'residual NSW'. Given the limitations of the WARRP and DISER datasets, combining these datasets was found to be the best option to support the FOD modelling undertaken.

Step 2 – disaggregation of emissions by LGA

The emissions from the 27 landfills that were individually modelled were mapped to LGAs based on the location of landfills. Disaggregation of emissions associated with the 'residual

NSW' disposal was done based on the estimated percentage MSW + C&I mass contributions of these landfills given these waste streams contain the highest proportion of decomposable organic matter.

This spatially disaggregated set of emissions data was combined with the emissions data from the 27 landfills described above to give total NSW GHG emissions by LGA. Total emissions across all LGAs were checked against the NSW STGGI totals for solid waste.

Reasons for negative waste emissions for some LGAs in some years

Note that for some LGAs in certain years the emissions from solid waste can be negative. This is caused by the:

- actual volume of landfill gas captured exceeding the modelled CH_4 generation at a landfill facility
- transfer of landfill gas outside of the facility boundary to a third party combined with landfill gas capture at the waste facility exceeding modelled CH_4 generation.

Solid waste emissions are however generally positive for most LGAs and for most years and are always positive at the state level.

Data limitations and quality

Emissions are affected by uncertainties and inaccuracies within the waste data collected by the NSW EPA and DISER, and by assumptions made in the modelling applied to disaggregate 'residual NSW' emissions by MSW + C&I combined masses.

The lack of accurate historical waste disposal and gas capture data for medium to large landfills is an issue, but because solid waste to landfill emissions only make up about 2% of total NSW emissions, the impact is less severe than inaccuracies in the emissions for other sectors.

Wastewater treatment

The department engaged ARUP Australia Pty Ltd to develop and apply methods to derive spatial wastewater treatment emissions by LGA for NSW (ARUP 2022). The data inputs, method and results from this work are described in this section.

Emissions were inventoried at LGA resolution for the state for two wastewater treatment categories: domestic/commercial and industrial. When aggregated, the domestic and commercial wastewater treatment emissions approximate total NSW STGGI emissions.

The assessment follows the guidelines specified by NGER (Measurement) Determination 2008, which outlines the equations, formulae and values that must be used or considered for quantifying GHG emissions. This calculation approach is based only on GHG emissions from wastewater treated in:

- domestic and commercial wastewater facilities, such as those operated by utilities like Sydney Water, Hunter Water, and local water utilities
- unsewered domestic wastewater treatment, such as on-site residential septic tank systems
- industrial wastewater facilities across 8 sectors of commodity production in NSW.

As domestic and commercial facility catchments span multiple LGA boundaries, the calculation approach includes a spatial disaggregation analysis to allocate emissions to the LGAs that generate the wastewater.

The methodologies for estimating emissions are described later in this section.

Wastewater emission sources

The wastewater treatment process is carried out in carefully managed conditions to chemically decompose complex contaminants in the wastewater and produce an effluent that is environmentally suitable for discharge. The decomposition of contaminants generates GHG emissions such as CH_4, CO_2 and N_2O.

Additionally, solids in the wastewater are removed from the stream as sludge, and often undergo further treatment steps, such as anaerobic decomposition. This process stabilises the sludge into biosolids for disposal and generates additional volumes of CH_4 as biogas.

Emissions of CO_2 generated are considered to be biogenic and are not included in the inventory. CO_2 produced from the flaring of CH_4 from waste is also considered to be of biogenic origin (DISER 2021d).

Most of the Australian population's domestic and commercial sewage discharge is treated at municipal wastewater treatment plants. According to the NIR (DISER 2021d), 'approximately 5 per cent of the Australian population is not connected to the domestic sewer and instead utilise on-site treatment of wastewater such as septic tank systems'. These septic tank systems generate CH_4 emissions that are included in the inventory. Since most major treatment facilities span multiple LGAs, domestic and commercial wastewater is in many cases disposed and treated outside of the LGA boundary, generating area-induced scope 3 emissions for those LGAs.

Most industrial facilities perform some level of wastewater treatment from industrial activities before disposing the effluent into the domestic sewer system to be treated further in municipal facilities.

Some emission sources found in the wastewater treatment process are considered separately under other inventory sectors or considered negligible and not inventoried:

- CH_4 emissions from effluent discharge to receiving waters; N_2O emissions from any form of industrial wastewater discharge; N_2O emissions from the discharge of municipal wastewater to ocean and deep ocean receiving waters – consistent with IPCC good practice (IPCC 2006a), these emissions are considered negligible and are not reported in the inventory
- CH_4 emissions from the combustion or external transfer of sludge biogas – considered fuel combustion emissions and calculated under a different sector of the GHG inventory (refer to the Stationary energy section)
- CH_4 emissions from the external transfer of sludge – considered solid waste emissions and calculated under a different sector of the GHG inventory (refer to the Waste section)
- N_2O emissions from septic tank systems – considered negligible and not reported in the inventory.

The method for calculating emissions from wastewater treatment is based on a model of the pathways for emission generation in the facility and considering the facility's treatment technologies and process streams for wastewater and sludge. This is consistent with IPCC best practice guidelines (IPCC 2006a) and NGER guidelines (CER 2021). DISER has developed models to track the decomposition steps of wastewater in NSW wastewater treatment facilities. The model simulates pathways and estimates generated quantities for wastewater emissions based on the volumes of wastewater treated, the discharge environment for the facility, the strength of the contaminants in the wastewater, and the treatment methods utilised by the facility.

The model is driven by multiple data inputs as listed in Table 28 to estimate historical emissions from 2015–16 to 2019–20.

Approximately 74% of the NSW population is collectively serviced across 45 facilities operated by Sydney Water and Hunter Water. These facilities are estimated to constitute 336 kt or 54% of NSW domestic and commercial wastewater treatment emissions (total of 619 kt for 2019–20).

The domestic and commercial wastewater facilities include those operated by the key utilities in NSW, with influent volume data (in equivalent population) applied: Sydney Water, Hunter Water, Central Coast Council, Thredbo and Essential Energy. These are referred to as key catchments. Utilities servicing the remainder of NSW are referred to as local water utilities.

The spatial study area and the key catchments assessed are shown in Figure 13.

Additionally, industrial wastewater treatment emissions were estimated across 116 industrial facilities and 8 sectors that meet NPI reporting criteria. The industrial emissions were estimated at 416 kt for 2019–20.

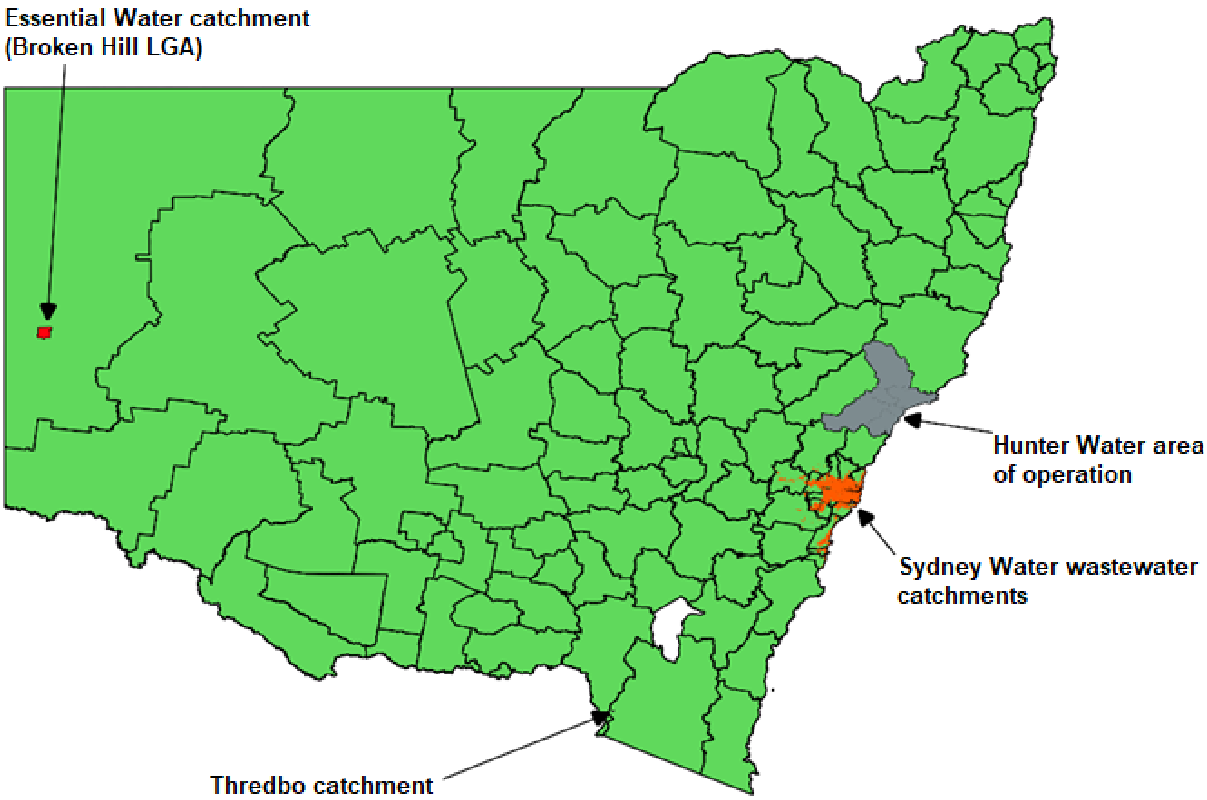

Figure 13 NSW LGAs and domestic and commercial key catchments

Data sources

Foundational datasets used in the estimation and disaggregation of wastewater treatment emissions are listed in Table 28.

Table 28 Data used in the estimation of wastewater treatment emissions

Data reference	Description	Resolution	Source
ASGS 2019	Population projections	Annual NSW population projections by LGA to 2041 extended to 2050	NSW Department of Planning, Industry and Environment (DPIE) population projections 2015–16 to 2049–50
NSW LGA boundaries	NSW LGA spatial data	Administrative boundaries for LGAs	Data.gov.au NSW LGA Geoscape Administrative Boundaries
NSW STGGI 2018–19	NSW wastewater treatment emissions	Total NSW emissions disaggregated by IPCC category and subcategory	STGGI data for category 5D (domestic and commercial, industrial) (NSW GHG 2016–19 dataset as received November 2021)
DISER industrial facility data	Industrial facility identification	Identification (name, location) of facilities by sector in NSW	DISER collated data from facility reporting
NPI data 2016–2019	Industrial facility name, location, employment figures and emissions figures (in addition to facilities identified by DISER)	Reporting results for all industrial facilities identified in the NPI database	NPI database of industrial facilities meeting NPI reporting thresholds
DISER municipal facility data	Municipal facility influent (equivalent population) Municipal facility effluent nitrogen content (tonnes) Municipal facility discharge environment classification	Facility-specific influent and effluent contaminant analytical data up to 2019 for key utilities in NSW Facility-specific discharge environment definition for key utilities in NSW	DISER collated data from utility reporting
DISER commodity production data	Historical national commodity production rates by industry sector	Annual commodity production (in litres or tonnes)	DISER collated data from facility reporting

The following was noted when compiling the data to support emission estimation:

- The municipal facility influent, effluent and nitrogen dataset was not complete, and estimates were calculated for certain facilities or reporting years. This is not expected to contribute to large errors in the inventory.
- Commodity production is reported on a national sector level; thus, the NSW sector allocations were estimated. This may contribute to errors in estimating the wastewater generated within each sector.
- An economic analysis was applied to forecast the facility-level commodity production rates to estimate industrial wastewater generation. The NPI database only captures facilities meeting a reporting threshold and therefore is not a full representation of all industrial activity in NSW.
- Data for certain industrial sectors are confidential and not available for inventory reporting.
- The spatial distribution of LGAs over municipal sewerage catchments was estimated, which may affect emissions distribution by LGA. Furthermore, fluctuations in population density distribution may lead to inaccuracy in spatial disaggregation.
- The emissions pathways in wastewater treatment are dependent on a knowledge of process streams and treatment technologies in place at the facility. There is a significant degree of variation in treatment process combinations used between each industrial facility. Thus, the emissions pathways were formed at a sector level, as there is a higher likelihood of consistency between facilities within each sector.
- There are noted inconsistencies within the STGGI data for the industrial wastewater emissions that indicate a high level of variability in the inventory estimation process.
- Emissions are affected by uncertainties and inaccuracies within the municipal facility data collected by DISER, and by assumptions made in the modelling applied to represent the wastewater treatment pathways. There is also an impact from population density distribution assumptions for the disaggregation step of the NSW population by municipal catchment.
- The lack of data for a number of municipal facilities is an issue. This was mitigated using estimates of the missing data points derived from trends in the remainder of the input data.

Emission estimation method – domestic and commercial wastewater

Chemical oxygen demand (COD) is a common analyte in wastewater treatment. It is a measure of the oxygen equivalent of organic material in wastewater that can be oxidised chemically. In essence, it is used to indicate the quantum of organic material in the wastewater that must be treated. The treatment of this organic material is the source of scope 1 CH_4 emissions in wastewater treatment.

The process flow diagram (PFD) for CH_4 emissions developed for this assessment is a simplification of a typical wastewater treatment process (Figure 14). It was developed primarily to provide a simple COD balance to quantify COD flows, and in turn, quantify emissions. For this assessment, all COD flows are referred to in terms of mass rates (tonnes per annum).

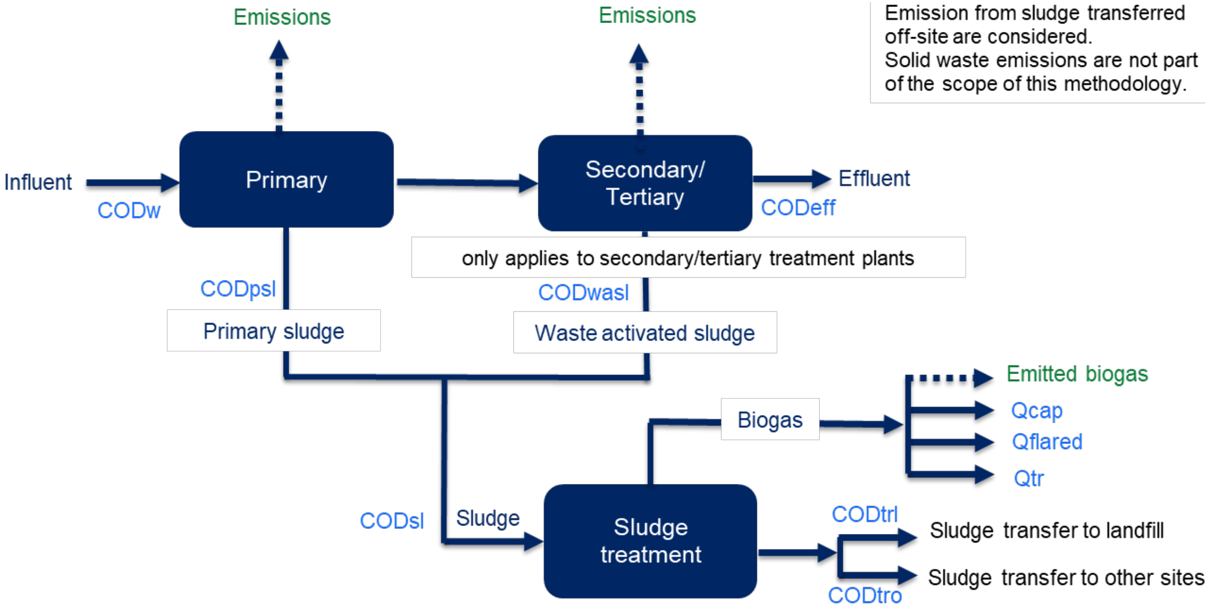

Figure 14 Pathways for CH_4 emissions from domestic and commercial wastewater handling

Emissions from sludge transferred off-site are considered solid waste emissions and not part of the scope of this methodology. CODw = COD for wastewater; CODpsl = COD for primary sludge; CODwasl = COD for waste activated sludge; CODtrl = COD for sludge removed to landfill; CODtro = COD for sludge removed to another site; CODsl = COD for combined primary and waste activated sludge; CODeff = COD for effluent stream; Qcap = sludge biogas captured for combustion; Qflared = sludge biogas flared; Qtr = sludge biogas transferred off-site.

The PFD for N_2O emissions developed for this assessment is a simplification of a typical wastewater treatment process (Figure 15). It was developed primarily to provide a simple nitrogen balance to quantify the flows of nitrogen, and in turn, quantify the N_2O emissions. For this assessment, all nitrogen flows are referred to in terms of mass rates (tonnes per annum).

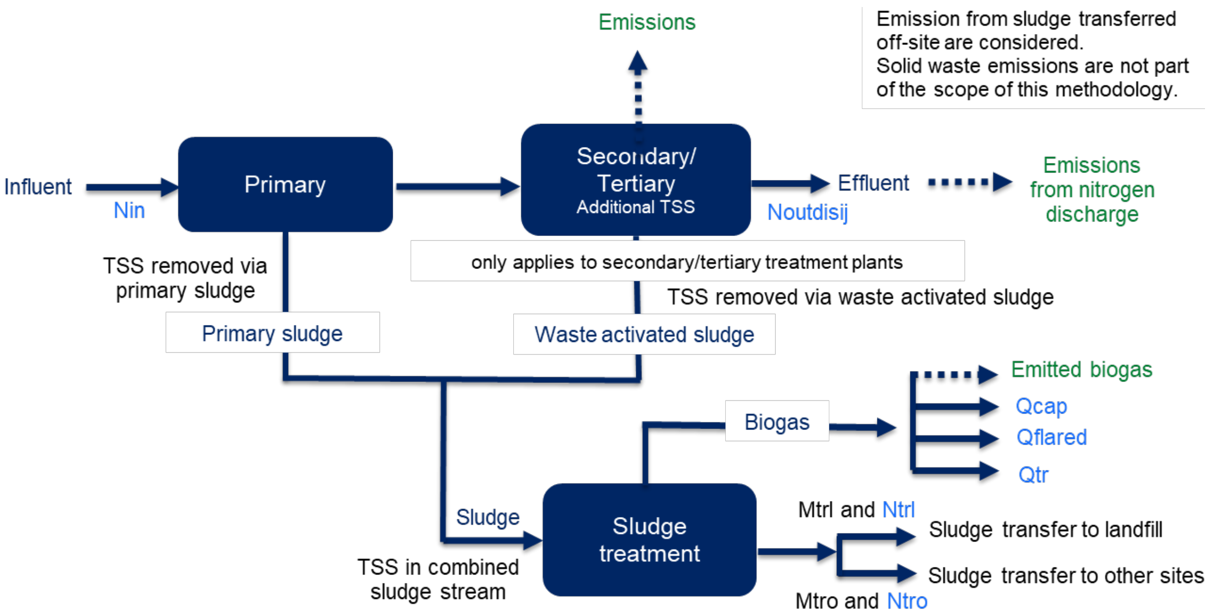

Figure 15 Pathways for N_2O emissions from domestic and commercial wastewater handling

Emissions from sludge transferred off-site are considered solid waste emissions and not part of the scope of this methodology. TSS = Total suspended solids; Nin = nitrogen quantity in influent; Noutdisij = quantity of nitrogen discharged; Mtrl = dry mass sludge transferred out of plant to landfill; Mtro = dry mass sludge transferred out of plant to a site other than landfill; Ntrl = quantity of nitrogen in sludge transferred out of plant to landfill; Ntro = quantity of nitrogen in sludge transferred out of plant to a site other than landfill.

Step 1 – aggregation of population into municipal catchments

The total population serviced by each municipal facility is a critical factor when estimating the volume of wastewater treated and GHG emissions generated from treatment.

Municipal sewerage catchments often span multiple LGAs, especially for large utilities like Sydney Water and Hunter Water; thus, geospatial analysis was employed to calculate and understand the allocation of LGA populations into municipal catchments.

The remaining population not captured by these catchments was estimated using the ASGS 2019 population projections, allowing for an uplift to capture commercial wastewater generation. This population was modelled as one whole catchment for a treatment process that is representative of the facilities found in these areas. This facility is modelled to service ‘residual NSW’. Additionally, the unsewered population of NSW was spatially estimated and considered for emissions calculations separately.

This step aggregates the NSW population into municipal facilities for emissions estimation.

Step 2 – estimation of emissions by facility

DISER has gathered influent equivalent population, effluent nitrogen content, and discharge environment classification for municipal facilities in NSW, capturing a subset of the facilities in the state. The DISER data was collected for each municipal facility modelled for each year, with any missing data points estimated using the rest of the dataset.

For each municipal facility, the emissions pathway was represented in the model to calculate the flows and contaminant decomposition process. Pathways were modelled using process flow parameters to quantify the flows of wastewater being treated, the masses of sludge generated, and the volumes of biogas generated.

The DISER municipal facility data were used as inputs for each facility's process flows. The influent and effluent inputs for the 'residual NSW' facility were estimated using their population aggregates.

The quantities of COD and nitrogen in each flow were used to calculate a balance of COD and nitrogen treated during the process. These losses represent the emissions of CH_4 and N_2O (respectively) released to the atmosphere from each facility.

The process flow parameters for sludge removal modelled the masses of sludge that are externally transferred and removed from the inventory. The model also considered the generation and separation of sludge biogas. Biogas externally transferred or combusted was removed from the calculation to isolate the volume of sludge biogas flared at the facility. Emissions of CH_4 from biogas flaring was estimated for the wastewater treatment sector's GHG inventory.

Additionally, the nitrogen content in the facility effluent was coupled with a classification of the effluent discharge's receiving waters. This allows for an estimate of N_2O emissions released from waste in the receiving waters. Effluent released into ocean and deep ocean waters is not considered to generate a significant amount of N_2O emissions.

The unsewered population of NSW was estimated separately using a model of CH_4 generation per capita. N_2O emissions from septic tank systems are considered negligible and are not included in the inventory.

Step 3 – disaggregation of emissions by LGA

The aggregation method from Step 1 was reversed to reallocate facility emissions to emissions by LGA. This includes unsewered emissions and emissions from the 'residual NSW' facility. For domestic and commercial catchments, GIS intersection analysis was done to calculate and spatially divide the allocations between catchments and LGA population. These results allow for a reversible aggregation step to collect population into catchment distribution, estimate facility-level emissions, and re-distribute the resulting emissions to population by LGA. A summary of the method is given in Table 29.

For population without identified catchment spatial data, these were collected into a single representative facility and assessed together. The unsewered population was removed from these projections and assessed separately.

There are multiple utility wastewater facilities in NSW that service multiple LGAs. Examples of this are the Burwood Beach WWTW catchment and Sydney Water's Malabar and North Head systems. Because of this overlap, to enable the emissions calculations per facility, the LGA populations must first be aggregated into each catchment.

Catchment extents were geospatially overlaid with LGA polygons, with catchment area percentage used as each LGA's portion of the catchment loads. This is considered a suitable method as the most common overlaps occur in residential areas of comparable population densities.

The intersection of catchment and LGA boundaries produces spatial fragments. For each fragment, 2 surface area percentages were calculated as: 1) percentage of LGA, and 2) percentage of catchment. These calculations link the LGA population to the catchment serviced population. A snapshot of the geospatial aggregation process is shown in Figure 16 and Figure 17.

Table 29 Methodology summary – spatial aggregation of LGA population

Spatial aggregation method	
Inputs	LGA shapefile Catchment shapefiles Population table
Calculations	GIS (intersection) analysis GIS (area calculation) analysis
Assumptions	Comparable population density across catchment All population spatially within a key catchment is considered sewered Sydney Water's Duffys Forest catchment has been merged with the Warriewood catchment as they are operationally linked Catchment percentages were assumed for fragments within Hunter Water, Thredbo, and Essential Water catchments Thredbo catchment is approximately 1,000,000 m^2 and services 25% of the sewered population in the Snowy Monaro Regional LGA Essential Water catchment consists of 100% of the Broken Hill LGA 3% of the NSW population is considered unsewered
Outputs	Results of area percentages by catchment and by LGA for each fragment to enable aggregation/disaggregation calculations

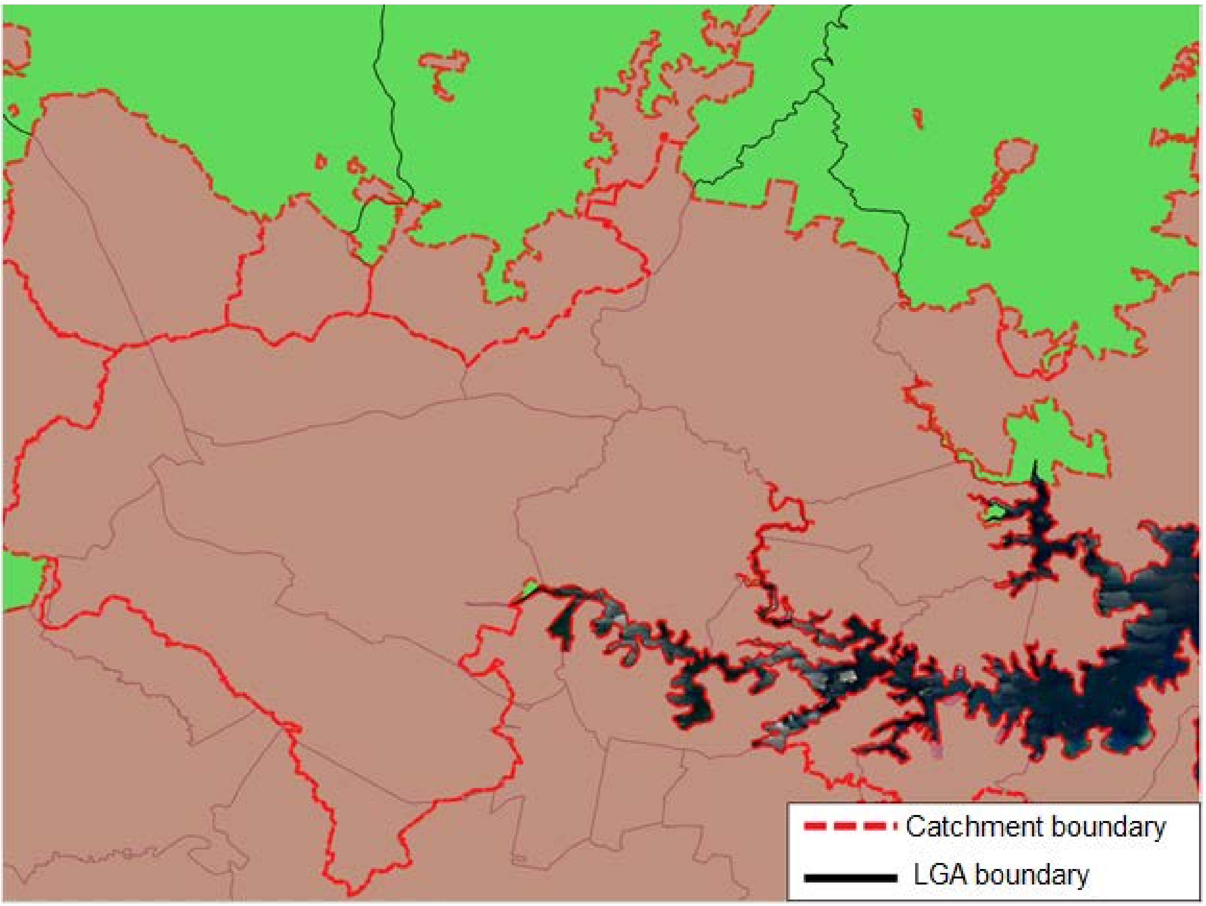

Figure 16 GIS overlay of catchment and LGA boundaries

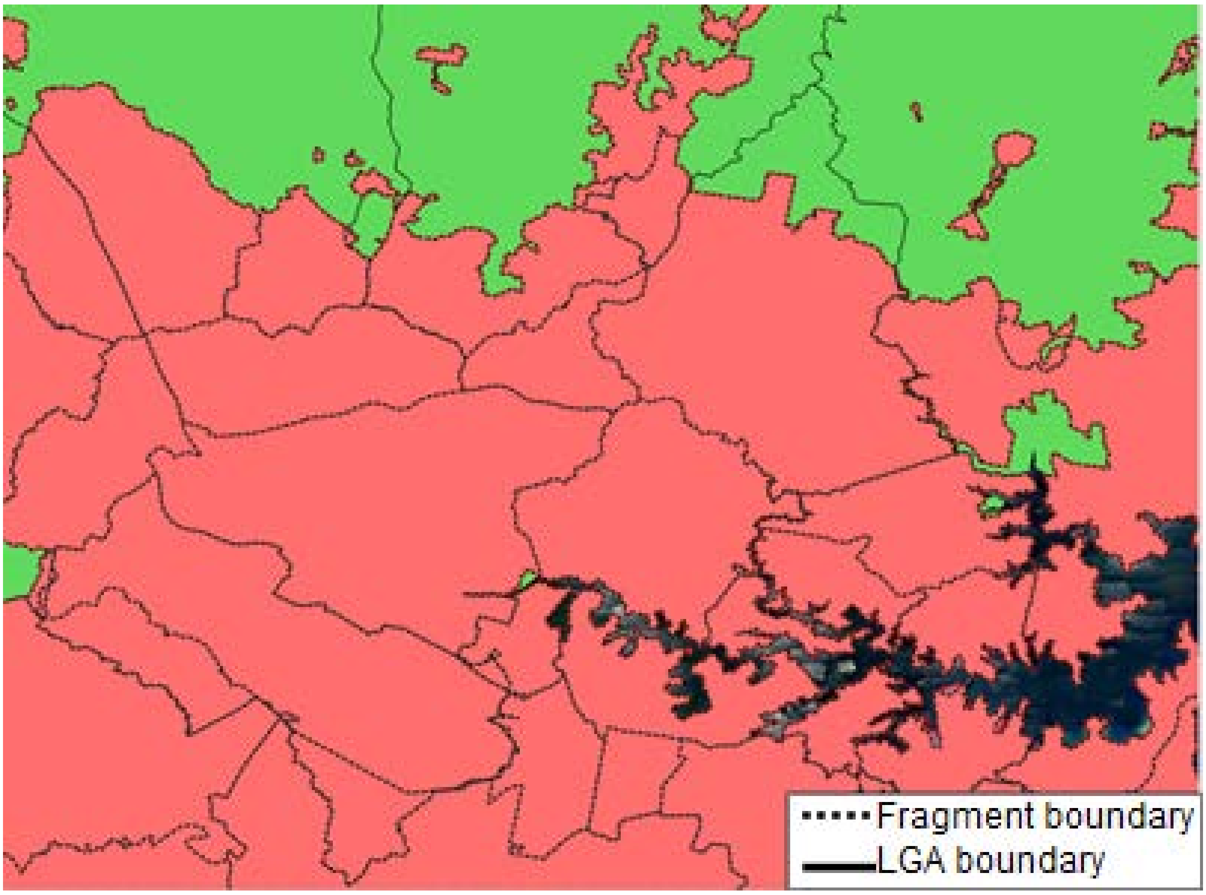

Figure 17 Spatial results of fragment boundaries

Sample result: A particular fragment was found to be 9.7% of the Bombo catchment and 7.1% of the Kiama LGA; thus, 9.7% of Bombo Wastewater Treatment Plant's influent domestic hydraulic loads can be attributed to 7.1% of Kiama LGA's population.

Emission estimation method – industrial wastewater

The industrial sectors assessed are listed in Table 30. These sectors are consistent with sectors outlined in the National Greenhouse and Energy Reporting (Measurement) Determination 2008. Sectors with 2- or 3-digit ANZSIC codes comprise subsectors that are considered for the assessment.

Table 30 Industrial sectors for assessment

Sector	ANZSIC code
Dairy	113
Paper	1510
Meat	1111 and 1112
Organic chemicals	18 and 19
Sugar	1181
Beer	1212
Wine	1214
Fruit and vegetable	1140

Step 1 – estimation of wastewater volumes generated at each facility

The industrial facilities assessed were identified from industrial facility data collected by DISER and from facilities obtained from the NPI database.

Unlike municipal catchments, industrial wastewater treatment facilities are located on-site at the facility as a point source; therefore, no spatial aggregation step is required aside from identifying the LGA that each facility is located in.

The wastewater volumes in the facility influent are estimated using projections of the facility's commodity production. This data was not available. An economic analysis was employed to estimate the commodity production for each facility based on the employment numbers, which are available from the NPI database. Any missing employment data points were estimated using trends in the remainder of the dataset.

Step 2 – estimation of emissions by facility

Estimation of industrial wastewater emissions is similar to the method used for the domestic and commercial municipal facilities. Instead of equivalent population influents, the wastewater influent volumes are based on the commodity production estimates derived in the previous step.

Since there are a large number of facilities covered in the model, the facilities were considered together based on their sectors (beer, meat, dairy, etc.). It was assumed that the wastewater treatment process within each sector is consistent between each facility. The process parameters for the industrial treatment pathways (sludge removal, biogas production, etc.) were modelled on a sector level.

Consistent with IPCC good practice, N_2O emissions are considered negligible and are not reported in the inventory (IPCC 2006b). CH_4 emissions from the combustion or external transfer of sludge biogas and from the external transfer of sludge are removed from the inventory in the same manner as with municipal facilities.

Step 3 – disaggregation of emissions by LGA

The sector-wide emissions were allocated to each facility using their fraction of commodity production within the sector. Subsequently, emissions were disaggregated by LGA using the industrial facility's location.

Since the industrial facilities are point sources of emissions, with wastewater treated on-site, all emissions from industrial wastewater treatment are considered scope 1 within each LGA.

Data limitations and quality

Emissions are affected by uncertainties and inaccuracies within the industrial facility data collected by DISER, and by assumptions made in the modelling applied to represent the wastewater treatment pathways. There are also further potential impacts from the commodity production estimation step, as it did not consider future efficiencies in industrial production. While employment numbers are not the ideal method for projecting commodity production, the method was necessary due to the lack of granular production data by facility and so that the results can be disaggregated by facility (and hence by LGA).

The DISER and NPI data only capture industrial facilities of note, and in the NPI database's case, industrial facilities meeting certain emissions threshold criteria. As a consequence, there are likely numerous industrial facilities not captured in the inventory, with no data available to robustly account for emissions estimation. These facilities are likely small in scale and do not contribute significantly to the industrial wastewater treatment sector emissions.

Wastewater handling (overall) is estimated to make up approximately 25% of the waste sector's overall emissions, which itself makes up approximately 2% of total NSW emissions; thus, the overall impact of the limitations in data is mitigated by the smaller scale of the state's wastewater treatment emissions.

Electricity consumption (scope 2)

Householders, businesses and other energy end-users draw electric power predominantly from the grid despite the fast penetration of rooftop solar voltaic panel installation and increasing access to off-grid renewable energy.

Grid power is generated by a pool of power stations connected by a transmission network operated in the National Energy Market (NEM). In NSW the majority of grid power is still fossil fuel-based but the share of renewable energy sources is steadily increasing due to market trends, and this will accelerate with implementation of the NSW Electricity Infrastructure Roadmap (NSW Government 2020).

The consumption of electricity by end-users across the state collectively causes emissions at fossil fuel-based power generators, including power stations located in NSW and in jurisdictions such as Victoria that supply electricity to NSW within the NEM.

Scope 2 emissions account for GHG emissions from the generation of purchased electricity. Purchased electricity is defined as electricity that is purchased or otherwise brought into the operational boundary of an entity (National Greenhouse Account Factors 2021). Scope 2 emissions from electricity generation consumed within the electricity, gas, water and waste services industry sector includes own use of electricity by generators and is not necessarily purchased electricity. These emissions do not therefore meet this definition.

Scope 2 emissions are allocated based on the location where the purchased electricity is used and are categorised based on electricity use by residential and non-residential sectors.

Method overview

Electricity consumption data was sourced from Distribution Network Service Providers (DNSPs) at a range of spatial resolutions (LGA; postcode level; SA1), and distinguishing between residential and low voltage and high voltage business consumption. Spatially allocated high voltage business use was not available for one network, with reference made to NGERS data to allocate such usage to LGAs.

Scope 2 emissions were estimated by applying EFs for electricity consumption in NSW from the National Greenhouse Account Factors for the relevant year.

Aggregation was done using ABS SA1 (postcode) to LGA grid correspondences with consumption allocated to LGAs by population ratio where SA1 (postcode) boundaries crossed LGA boundaries.

Residential electricity consumption and scope 2 emissions by LGA were retained. Low and high voltage electricity consumption from DNSPs and wholesale consumption from the NEM were consolidated to protect NGER facility data and are published as business electricity consumption and emissions.

Aggregated total consumption by the DNSP network was compared to the figures reported by DNSPs to the Australian Energy Regulator (AER).

Data sources and issues

DNSP electricity consumption data

Electricity consumption data was sourced from the 3 DNSPs operating in NSW: Ausgrid, Essential Energy and Endeavour Energy, for financial years 2015–16 to 2018–19. Due to varying data storage methods and confidentiality constraints, the DNSPs provided consumption data at differing resolutions. The DNSPs made available the following data:

- Ausgrid (publicly available) – residential and low voltage business consumption at LGA resolution, and number of meters
- Ausgrid (publicly available) – aggregated total of high voltage business consumption, and number of meters (no spatially resolved data available due to confidentiality)
- Essential Energy (custom provided) – residential, and low and high voltage business consumption at SA1 resolution, and number of meters
- Endeavour Energy (custom provided) – residential, and low and high voltage business consumption at postcode resolution.

Electricity consumption data from Essential and Endeavour were aggregated to LGA level, consistent with Ausgrid data. Aggregation was done using ABS SA1 (postcode) to LGA grid correspondences with consumption allocated to LGAs by population ratio where SA1 (postcode) boundaries crossed LGA boundaries.

Aggregated totals were largely consistent (within 1%) of the consumption reported by DNSPs to the AER, indicating consistency between the meter-based consumption data and reported network-wide totals.

There are 2 major limitations in using the data from the DNSPs:

- high voltage business consumption in Ausgrid's network is only reported as an aggregate total due to confidentiality concerns
- DNSP data does not capture consumption by businesses sourcing electricity directly from the NEM.

Reference was made to electricity consumption by facilities within the NGERS data to address DNSP data limitations.

NGERs facility data

Electricity consumption and scope 2 emissions data were extracted for facilities purchasing electricity from the grid. Data was excluded for facility aggregates reporting under NGERS since these generally comprise multiple smaller facilities that are assumed likely to be accounted for within the SA1 electricity consumption data. Facility geocoordinates were used to allocate the facilities to LGAs.

To address data limitations and ensure confidential data from NGERS facilities are protected, additional post-processing of facility data was undertaken:

- Some facility entries did not contain valid geocoordinates. Upon inspection, the majority of these referred to transport facilities, pipeline transport or telecommunications services. Since these are also likely to be distributed usage, they were assumed to be included in Ausgrid's low voltage consumption and were omitted to avoid double counting.
- Some facility entries for the electricity transmission and distribution networks referred to energy losses. These were treated separately for purposes of comparison with reported electricity consumption totals from other sources (e.g. AES).
- Two entries related to energy usage by the NSW rail network, with the facility location given as the head office or not specified. Since electric trains source energy from high voltage overhead lines, the electricity consumption was assumed to be distributed across Ausgrid and Endeavour's networks, weighted by the residential energy consumption in each LGA as a proxy for number of potential passengers. Calculated consumption in Endeavour's network was omitted since it will already be included in the postcode level data.
- Some facilities participate directly in the NEM and were therefore considered separately. A list of market customers published by the Australian Energy Market Operator (AEMO)

was used to identify facilities in NGERS that participate in the market directly. Power stations using grid electricity for auxiliary purposes were assumed to source electricity directly rather than through a distribution network.

After excluding the facility entries noted above, remaining facilities were arranged in order of highest electricity consumption, with top facilities equal in number to the number of high voltage meters in the Ausgrid network extracted for inclusion.

Ausgrid publishes electricity consumption by LGA shortly after the end of the financial year. To account for subsequent LGA amalgamations and boundary changes, ABS correspondences were used to allocate Ausgrid reported consumption to the updated LGAs based on population ratio.

Wholesale electricity consumers participating directly in the NEM (NEMC) were identified and their consumption allocated to LGAs based on the lists of wholesale consumers published by AEMO and facility data from NGERS.

Electricity and emission estimates

A summary of the electricity supplied to customers by DNSPs and wholesale electricity purchased directly from the NEM is given in Table 31 (excludes distribution and transmission losses). Total scope 2 emissions calculated based on EFs for NSW from the 2021 National Greenhouse Accounts Factors across LGAs are included in the table.

Table 31 Electricity use in NSW based on data from DNSPs and from wholesale purchases and estimated scope 2 emissions (accounting only for electricity purchased as per the definition in the National Greenhouse Accounts 2021)

Network	Electricity supplied / purchased (GWh)			
	2015–16	2016–17	2017–18	2018–19
Ausgrid	25,361	25,382	25,171	25,234
Essential	11,997	12,157	12,306	12,489
Endeavour	16,518	16,273	16,726	16,793
NEMC	8,802	8,999	8,935	9,029
Total	**62,678**	**62,811**	**63,138**	**63,545**
	% of electricity use			
	2015–16	**2016–17**	**2017–18**	**2018–19**
% Residential	30.1%	30.1%	29.9%	30.0%
% Non-residential, classed as 'business'	69.9%	69.9%	70.1%	70.0%
	Scope 2 emissions (kt CO_2-e)			
	2015–16	**2016–17**	**2017–18**	**2018–19**
Residential	15,648	15,491	15,306	15,065
Non-residential, classed as 'business'	36,374	36,014	35,836	35,136
Total	**52,022**	**51,505**	**51,142**	**50,201**

Verification

The derived LGA-level electricity consumption from this method is compared to the DNSP-based totals reported to the AER as part of the Economic Benchmarking Regulatory Information Notice (RIN). The comparisons are shown in Table 32. There was close agreement between the derived LGA-level consumption and the total energy delivered according to the DNSP RIN responses.

Table 32 Comparisons of estimates derived with DNSP-based totals reported to the AER

Source (units)	2015–16	2016–17	2017–18	2018–19
Ausgrid – LGA data (this study) – GWh	25,361	25,382	25,171	25,234
Ausgrid – RIN response – GWh	25,618	25,669	25,387	25,424
Coverage by this study (%)	**99.0**	**98.9**	**99.1**	**99.3**
Essential – LGA data (this study) – GWh	11,997	12,157	12,306	12,489
Essential – RIN response – GWh	12,313	12,388	12,532	12,730
Coverage by this study (%)	**97.4**	**98.1**	**98.2**	**98.1**
Endeavour – LGA data (this study) – GWh	16,518	16,273	16,726	16,793
Endeavour – RIN response – GWh	16,645	16,716	16,639	16,759
Coverage by this study (%)	**99.2**	**97.3**	**100.5**	**100.2**
All DNSPs – LGA data (this study) – GWh	53,876	53,812	54,203	54,517
All DNSPs – RIN responses – GWh	54,576	54,773	54,559	54,913
Coverage by this study (%)	**98.7**	**98.2**	**99.3**	**99.3**

As electricity flows through the transmission and distribution networks, energy is lost due to electrical resistance and the heating of conductors. Losses are equivalent to about 10% of the total electricity transported between power stations and market customers. AEMO determines Marginal Loss Factors for each financial year with detailed analysis required to apply such factors to calculate total losses. For the purpose of comparing electricity consumption estimates in this study to electricity flows reported by TransGrid for their AER RIN response, transmission and distribution losses were assumed to be about 10% (Table 33). Total electricity consumption (including assumed losses) is generally in good agreement with TransGrid reported figures (within 1–5%).

Table 33 Comparisons with electricity consumption reported by TransGrid

Source (units)	2015–16	2016–17	2017–18	2018–19
Total energy from LGA data (delivered to meters, excluding losses) – GWh	62,678	62,811	63,138	63,545
As above but including assumption of 10% transmission and distribution losses – GWh	68,945	69,092	69,452	69,900
TransGrid – energy delivered (minus ACT (Evoenergy) – GWh	69,324	72,086	72,848	71,514
% coverage by LGA data (including losses) – compared to energy delivered by TransGrid	99%	96%	95%	98%

Total scope 2 emissions estimates were compared to emissions for NSW published in the National Inventory by Economic Sector (NIBES) (Table 34). To support direct comparisons scope 2 emissions from the electricity generation consumed within the electricity, gas, water and waste services industry sector is excluded since it primarily includes the own use of electricity by generators and is not necessarily purchased electricity.[16]

Scope 2 emissions from electricity consumption by the residential sector was estimated to be lower than reported for NSW within the NIBES across all years, ranging from 14% lower in 2016–17 to 5% lower in 2018–19. Emission estimates from other sectors were however 3–6% higher than reported NIBES emissions for NSW. Overall, study estimates for scope 2 emissions across all sectors were within 1% of NIBES emissions for NSW.

Table 34 Comparisons with scope 2 estimates in the NIBES

Network	Electricity supplied / purchased (GWh)			
	Scope 2 emissions (kt CO_2-e)			
Scope 2 emissions estimate (this study)	**2015–16**	**2016–17**	**2017–18**	**2018–19**
Residential	15,647	15,490	15,305	15,064
Non-residential, classed as ‘business’	36,373	36,014	35,836	35,135
Total	**52,021**	**51,504**	**51,141**	**50,199**
	Scope 2 emissions (kt CO_2-e)			
Scope 2 emissions (NIBES)	**2015–16**	**2016–17**	**2017–18**	**2018–19**
Residential	17,144	18,056	16,581	15,880
Other (excluding DIV D electricity, gas, water and waste services)	35,003	34,118	34,426	33,992
Total (excluding DIV D electricity, gas, water and waste services)	**52,147**	**52,173**	**51,007**	**49,872**
	Agreement (study estimate as % of NIBES emissions)			
Scope 2 emissions (NIBES)	**2015–16**	**2016–17**	**2017–18**	**2018–19**
Residential	91%	86%	92%	95%
Other (non-residential, business)	104%	106%	104%	103%
Total	**100%**	**99%**	**100%**	**101%**

Data limitations and quality

Uncertainties are introduced due to differences in the spatial resolution of electricity consumption data from DNSPs, unavailability of resolved data for certain market segments, and from the aggregation of SA1 and postcode data to LGAs.

Ausgrid-published LGA-level data does not include high voltage power users but provides a network-wide lumpsum of electricity consumption by all the high voltage users. The lump sum accounts for 30% of the total business consumption in Ausgrid’s area. NGERs data was used in this study to address this gap with subsequent aggregation with other non-residential users to retain confidentiality.

[16] Australian Government, National Inventory by Economic Sector 2018.

In 2021, the department collaborated with AEMO to determine whether electricity consumption data could be more efficiently and consistently extracted for NSW from records held by AEMO. This project was however not successful in delivering improved data, resulting in the department continuing to use data sourced from DNSPs, supplemented by NGERs data.

Overall confidence in the electricity consumption and scope 2 emission estimates developed is considered medium to high given it is based primarily on spatially resolved consumption data, with total consumption and emissions verified based on third party sources. Publication of more granular consumption data by market segment would be useful but is constrained by data confidentiality.

References

ABS (Australian Bureau of Statistics) (2016) Employment data 2016, Australian Bureau of Statistics, www.abs.gov.au/statistics/microdata-tablebuilder/tablebuilder

ABS (2018) Agricultural Commodities by SA2 2015-2016, Australian Bureau of Statistics, accessed 11 June 2020.

ABS (2019) Water use on Australian farms, Australian Statistical Geography Standard (ASGS) regions 2015-16, Australian Bureau of Statistics, accessed 25 September 2020.

ABS (2020) *Survey of Motor Vehicle Use*, Australian Bureau of Statistics, annual publication, www.abs.gov.au/ausstats/abs@.nsf/PrimaryMainFeatures/9208.0?OpenDocument

ACRIS (Australian Collaborative Rangelands Information System) (2013) Australian Collaborative Rangelands Information System (ACRIS), accessed 29 September 2020.

AECOM (2014) *Wood Smoke Control Measures Cost Benefit Analysis Report*, AECOM Australia Pty Ltd, Sydney, 19 December 2014, www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/woodsmoke/wood-smoke-control-measures.ashx

AMSA (Australian Maritime Safety Authority) (2022) List of registered ships, Australian Maritime Safety Authority.

ARUP (2022) 'Spatial and Future Projections of Industrial and Domestic Wastewater Treatment Emissions in NSW, Methods Paper', unpublished report prepared for the NSW Department of Planning and Environment, 16 March 2022.

BITRE (Bureau of Infrastructure and Transport Research Economics) (2021a) 'Projections for on-road VKT by state and territory', unpublished update provided to he NSW department in November 2021. Related published report (earlier projections): BITRE (2019) *Australian aggregate freight forecasts – 2019 update*, Research report 152, Australian Government Department of Infrastructure, Transport, Cities and Regional Development, Bureau of Infrastructure, Transport and Regional Economics.

BITRE (2021b) *Trainline*, volumes 1–8, Bureau of Infrastructure and Transport Research Economics, www.bitre.gov.au/publications/2021.

BITRE (2022a) Australian Domestic Airline Activity – time series, Bureau of Infrastructure and Transport Research Economics.

BITRE (2022b) Australian Domestic Aviation Activity Annual Publications, Bureau of Infrastructure and Transport Research Economics.

BITRE (2022c) Maritime Statistics, Bureau of Infrastructure and Transport Research Economics.

CASA (Civil Aviation Safety Authority) (2022) Data files for registered aircraft, Civil Aviation Safety Authority.

CER (Clean Energy Regulator) (2020) NGER Solid Waste Calculator 2019–20, Australian Government Clean Energy Regulator.

CER (2021) *Estimating emissions and energy from wastewater handling (domestic and commercial) and (industrial) guideline*, Australian Government Clean Energy Regulator, July 2021, http://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/Estimating%20emissions%20and%20energy%20from%20wastewater%20handling%20guideline.pdf

CER (2022a) Electricity sector emissions and generation data, Australian Government Clean Energy Regulator.

CER (2022b) Safeguard facility reported emissions, Australian Government Clean Energy Regulator.

Climate Active (2022a) Public Disclosure Statements – Qantas, Climate Active.

Climate Active (2022b) Public Disclosure Statements – Virgin Australia, Climate Active.

DEE (Department of the Environment and Energy) (2018) *National forest and sparse woody vegetation data version 3.0*, Australian Government Department of the Environment and Energy, accessed 29 September 2020.

DCCEEW (Department of Climate Change, Energy, the Environment and Water) (2022a) Australian Energy Statistics, Australian Government Department of Climate Change, Energy, the Environment and Water.

DCCEEW (Department of Climate Change, Energy, the Environment and Water) (2022b) National Greenhouse Gas Inventory – Kyoto Protocol classifications, Australian Government Department of Climate Change, Energy, the Environment and Water.

DCCEEW (Department of Climate Change, Energy, the Environment and Water) (2022c) National Greenhouse Gas Inventory – Paris Agreement Inventory, Australian Government Department of Climate Change, Energy, the Environment and Water.

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2009), *Second National In-Service Emissions Study (NISE2), Light duty petrol vehicle emissions testing: RTA.07.2828.0309-final report*, Department of the Environment, Water, Heritage and the Arts, March 2009, www.environment.gov.au/archive/transport/publications/nise2.html

DISER (Department of Industry, Science, Energy and Resources) (2020) *Australian Energy Update 2020*, Australian Department of Industry, Science, Energy and Resources, www.energy.gov.au/publications/australian-energy-update-2020

DISER (Department of Industry, Science, Energy and Resources) (2021a) *Australian Energy Update 2021*, Australian Department of Industry, Science, Energy and Resources, www.energy.gov.au/publications/australian-energy-update-2021

DISER (2021b), *Australian Petroleum Statistics 2021*, Australian Government Department of Industry, Science, Energy and Resources, www.energy.gov.au/publications/australian-petroleum-statistics-2021

DISER (2021c) *National Inventory Report 2019, Volume 1*, Australian Department of Industry, Science, Energy and Resources, April 2021, www.industry.gov.au/data-and-publications/national-greenhouse-accounts-2019/national-inventory-report-2019

DISER (2021d) *National Inventory Report 2019: Volume 2*, Australian Department of Industry, Science, Energy and Resources, www.industry.gov.au/sites/default/files/April%202021/document/national-inventory-report-2019-volume-2.pdf [PDF 15.6MB]

DISER (2021e) *State and Territory Emissions Report 2019*, April 2021, Australian Department of Industry, Science, Energy and Resources.

DISER (2022), *National Inventory Report 2020: The Australian Government Submission to the United Nations Framework Convention on Climate Change, Volume 1*, www.industry.gov.au/sites/default/files/May%202022/document/national-inventory-report-2020-volume-1.pdf [PDF 8.9MB]

DPIE (Department of Planning, Industry and Environment) (2020a) *Net Zero Plan Stage 1: 2020–2030*, NSW Department of Planning, Industry and Environment, Parramatta, www.environment.nsw.gov.au/topics/climate-change/net-zero-plan

DPIE (2020b) NSW Landuse 2017 v1.2, SEED – The Central Resource for Sharing and Enabling Environmental Data in NSW, NSW Department of Planning, Industry and Environment, accessed 17 September 2020.

DPIE (2021) *Net Zero Plan Stage 1: 2020–2030 Implementation Update*, NSW Department of Planning, Industry and Environment, Parramatta, www.environment.nsw.gov.au/research-and-publications/publications-search/net-zero-plan-stage-1-2020-30-implementation-update

EEA (European Environment Agency) (2019) *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019, 1.A.3.b.i Passenger Cars, 1.A.3.b.ii Light commercial trucks, 1.A.b.iii Heavy-duty vehicles including buses, 1.A.3.b.iv Motorcycles*, European Environment Agency, October 2019.

EPA (Environment Protection Authority) (2012), *Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2008 Calendar Year: On-Road Mobile Emissions*, NSW Environment Protection Authority, August 2012.

EPA (2019) *Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2013 Calendar Year: On-Road Mobile Emissions*, NSW Environment Protection Authority, October 2019.

EPA (2022) *NSW State of the Environment 2021*, NSW Environment Protection Authority, www.soe.epa.nsw.gov.au

Geoscience Australia (2017) Oil and Gas Pipelines of Australia, Geoscience Australia.

OEH (Office of Environment and Heritage) (2016) NSW Climate Change Policy Framework, published 2016, NSW Office of Environment and Heritage, Sydney.

IPCC (Intergovernmental Panel on Climate Change) (2000) *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 5, 5.7, Intergovernmental Panel on Climate Change, www.ipcc-nggip.iges.or.jp/public/gp/english

IPCC (2006a) *IPCC Guidelines for National Greenhouse Gas Inventories, Overview*, Intergovernmental Panel on Climate Change, www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories

IPCC (2006b) *Guidelines for National Greenhouse Gas Inventories, Volume 5 Waste*, Intergovernmental Panel on Climate Change.

IPCC (2014) *Fifth Assessment Report, Working Group 1*, Chapter 8, pp.73–79, www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf [PDF 18.5MB]

IPCC (2019) *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Calvo Buendia E. Tanabe K, Kranjc A, Baasansuren J, Fukuda M, Ngarize S, Osako A, Pyrozhenko Y, Shermanau P and Federici A (eds), Cambridge University Press, Cambridge, www.ipcc.ch/report/ar5/wg1

Motorsport Australia NSW Supersprints (2022) NSW Supersprints Tracks, Motorsport Australia NSW Supersprints.

Ndevr Environmental (2022) 'NSW Aviation, Rail and Marine Transport Emissions 2021', unpublished paper prepared for the NSW Department of Planning and Environment, March 2022.

NPI (National Pollutant Inventory) (2020) National Pollutant Inventory (2019–20), www.npi.gov.au/npi-data/latest-data

NSW Government (2020) Electricity Infrastructure Roadmap, NSW Government.

NSW Government (2022) SEED: The Central Resource for Sharing and Enabling Environmental Data in NSW, NSW Government, www.seed.nsw.gov.au/net-zero-emissions-dashboard

Port Authority of NSW (2022) Port Botany, Port Authority of NSW, Walsh Bay NSW.

TfNSW (Transport for NSW) (2022a) NSW Boat Registrations and Licences, Transport for NSW.

TfNSW (2022b) Opal Trips – Ferry, Transport for NSW.

TfNSW (2022c) Train Patronage – Monthly Figures, Transport for NSW.

TfNSW (2022d) Travel Insights, Transport for NSW.

Trackfinder (2022) Trackfinder, Trackfinder.

World Resources Institute (2014) *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An accounting and reporting standard for cities* (GPC), C40 Cities Climate Leadership Group and ICLEI – Local Governments for Sustainability (ICLEI), December 2014, https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities.

Appendix A: Protecting NGERS data confidentiality

In the preparation of local-scale emissions for NSW, emissions and data reported by facilities under the NGER Act 2007 are used together with emissions and other data from sources such as the STGGI, ABARES and the ABS. The CER has strict rules regarding the disclosure of data reported under the NGERS, in accordance with the non-disclosure requirements under the NGER Act. Measures implemented to ensure the confidentiality of facility data reported under the NGERS are detailed below.

The CER recommends testing the aggregation of NGER data by applying frequency and dominance rules with thresholds; for example, each cell must have at least 10 contributing units, with the top 2 units not contributing more than 75% of the total.

To ensure compliance with non-disclosure rules, alternative sources of public emissions data were identified for some facilities (e.g. data published by the CER for facilities reporting under the Safeguard Mechanism) or proxies used to estimate emissions in some cases.

Emissions were also aggregated to LGA resolution and by sector for certain IPCC sectors when preparing the local-emissions dataset for publication to ensure requirements are met as shown in Table 1. Some sectors are broken down by subsector where possible to do so within confidentiality requirements (e.g. waste subsectors include solid waste and domestic/commercial and industrial wastewater treatment emissions). No facility name or other identifying data is included in the published dataset.

Steps to ensure confidentiality of NGER data

GHG emissions data are published and viewable by LGA and by sector via the public NSW Net Zero Emissions Dashboard. Each major sector or subsector was treated as a ‘cell’ to check compliance with the CER’s cell dominance and frequency rules.

Electricity generating facilities

Several stationary energy cells contain emissions from public electricity generating facilities. This data is already publicly available at the facility level (CER 2022a) and therefore is considered to be non-confidential for the purposes of publication.

Large emitters

With electricity generating facilities removed, a number of LGAs contained large GHG emitting facilities that were breaching the cell dominance rule. This was noted for the following LGAs:

- Wollongong
- Wingecarribee
- Bayside
- Port Stephens
- Shoalhaven
- Wollondilly
- Newcastle.

The breaches were caused by large emitters such as iron and steel and aluminium production facilities, coal mines, chemical manufacturing plants and cement works accounting for 60–80% of the LGA’s stationary energy or IPPU emissions. This could potentially disclose NGER data.

The problem was alleviated by considering the publicly released facility emissions data reported under the Commonwealth's Safeguard Mechanism (CER 2022b). The Safeguard Mechanism emissions data is published annually with data available for all years addressed by the local-scale emissions.

Reporting under the Safeguard Mechanism applies when a facility's direct scope 1 emissions exceed 100 kt CO_2-e in a given year. Some facilities will be included and excluded in various years depending on whether the 100 kt CO_2-e cap is exceeded. If a facility is excluded in a given year, a person could infer an upper limit to the facility's emissions from previous years' reports, assuming it continues to operate.

The inclusion of the NGER data for large facilities does not breach NGER confidentiality when such data are reported under the Safeguard Mechanism and so are in the public domain.

Residual issues

Having considered facility emissions from public electricity generators and facilities with disclosed data under the Safeguard Mechanism, attention shifted to LGAs with facilities that are dominant emitters when compared to other facilities within a sector/subsector despite their having small to moderate emissions. This could potentially result in the unintended disclosure of confidential NGER facility data if not addressed. Each sector with this issue is identified below and the measures implemented to ensure confidentiality described.

Pipeline fugitive emissions

One of the issues concerns fugitive emissions from natural gas pipelines in an LGA. Fugitive emissions are reported by LGA with pipeline emissions dominant except where coal mines operate. Pipeline fugitive emissions are therefore estimated by LGA based on the length of the pipeline in each LGA as a fraction of the total pipeline length. This fraction is used to apportion the total pipeline 'facility' fugitive emissions to each LGA.

When published, the fugitive emissions will appear as a single line item for LGAs where such emissions occur. It will not be possible to deduce which pipeline facility is represented in cases where multiple pipelines run through an LGA, nor total facility emissions, based on the data presented. This will ensure the confidentiality of pipeline fugitive emissions.

The only exception to this is where a pipeline facility is restricted to one LGA. In this case, a proxy was used to estimate emissions rather than relying on NGER data; average fugitive emissions intensity as a function of pipeline gas throughput is applied. This method supports the generation of a new set of approximate GHG emissions that replaces NGER data.

Coal mine fugitive emissions

In several cases, there are underground and open cut mines that emitted below the Safeguard Mechanism cap yet still have emissions that dominate the fugitives from fuels cell. In these cases, proxy data were used to avoid disclosing the NGER facility data.

The proxy was based on the average fugitive emissions intensity of each coal mine as a function of the ROM coal produced per annum. Coal production was sourced from third party sources. The average covers all financial years of interest. Using the average emission intensity and annual ROM production, a new set of approximate GHG emissions were generated for inclusion in the NSW local-scale emission account.

Solid waste and wastewater treatment emissions

The emissions from solid waste are generated using a combination of WARRP waste data, DISER data and FOD modelling. No WARRP, DISER or NGER data is disclosed.

Wastewater treatment data is based on plant data (influent hydraulic loads, COD, and many other estimated parameters) and although the emissions are calculated using NGER methods, NGERS data are not disclosed.

Other facilities

The remaining facilities causing potential issues in relation to disclosure appeared to be small facilities in regional areas. In many cases, there is a sufficient number of other facilities in a cell where the facilities in question will only contribute 30–50% of the emissions. No proxy emissions were used in these cases. Where a facility's emissions dominated a cell (i.e. 70–100% of a cell) proxy emissions were generated. This solution was applied for 19 facilities.