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NSW Greenhouse gas emissions projections 2022

Methods paper

Department of Planning and Environment

Cover photo: Turbines at Hampton wind farm. Rosie Nicolai/DPE

Published by:

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ISBN 978-1-922975-98-0
EHG 2023/0092
February 2023

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Contents

List of tables

List of figures

Summary

The Department of Planning and Environment (the department) has projected future trends in greenhouse gas (GHG) emissions to inform the NSW Government's net zero policies and programs and support monitoring of progress towards achieving the state's net zero emissions objectives.

Emissions projections are prepared using the latest available activity data, peer reviewed methods and expert assumptions and indicate what NSW's future emissions could be if the assumptions underpinning the projections occur. Emissions are modelled for each year out to 2050 and by Intergovernmental Panel on Climate Change (IPCC) category, using sectors and subsectors consistent with the NSW Greenhouse Gas Inventory and national emissions projections. Emissions projections are developed for base case and current policy scenarios.

Base case emissions projections account for major factors impacting NSW emissions, including market trends and past state policies, but exclude the impact of the Net Zero Plan and related NSW Government policies targeting emissions reduction.

Current policy emissions projections are developed based on the base case scenario and accounting for emissions reductions projected to be achieved by the NSW Government's policies and programs. The current policy projections delivered in 2021 only accounted for funded programs implemented over 2020–2030 under Stage 1 of the Net Zero Plan for which abatement estimates were available by June 2021 (DPE 2022a). In this 2022 update, the scope of current policy projections has been expanded to include abatement forecasts for more stages of the Net Zero Plan and related government policies and programs, as follows:

- current actions under Stage 1 of the Net Zero Plan, including strategies, plans and programs announced in the latter half of 2021 and in 2022, which were not accounted for in the 2021 emissions projections
- related policies, including near-term anticipated policies and actions such as the NSW Environment Protection Authority (EPA) Climate Change Policy and Action Plan (EPA 2022a, 2022b) and upcoming reform of the Safeguard Mechanism by the Australian Government (DCCEEW 2022e)
- future initiatives related to reducing emissions and clean energy by the NSW Government supported by the NSW Climate Change Fund[1] (CCF) under Stages 2 and 3 of the Net Zero Plan over 2030–2050.

This methods paper outlines the assumptions and methods applied in preparing the 2022 base case and current policy emissions projections that informed the NSW Government's adoption of a 70% emissions reduction target by 2035, below 2005 levels. The first draft of the 2022 emissions projections were used to inform the 2035 target and reported in the Net Zero Plan Stage 1 Implementation Update 2022 (OECC 2022). The final 2022 emissions projections are presented in this methods paper.

Emissions projections and abatement projections are illustrated in this paper, with results also accessible via the interactive NSW Net Zero Emissions Dashboard (DPE 2022b) and as data downloads from the NSW Sharing and Enabling Environmental Data (SEED) portal (NSW Government 2022b).

Emissions projections will be updated annually to integrate the latest information and to account for progress being made to deliver abatement under the Net Zero Plan.

[1] The Climate Change Fund is established under Part 6A of the *Energy and Utilities Administration Act 1987*.

Introduction

NSW is committed to achieving net zero greenhouse gas (GHG) emissions by 2050 (OEH 2016). The Net Zero Plan Stage 1: 2020–2030, released in March 2020, is the NSW Government's plan to achieve emissions reduction over the next decade and prepare the state for further action in the decades to follow (DPIE 2020). The plan outlines how the Government will grow the economy, create jobs, and reduce the cost of living through strategic emissions reduction initiatives across the economy. The plan delivers on the objectives of the NSW Climate Change Policy Framework, which sets out long-term policy directions for action to mitigate and adapt to climate change.

The NSW Government monitors and reports on progress to net zero emissions and on the implementation of the Net Zero Plan with emissions reductions (actual and expected) and emissions forecasts included in NSW State of the Environment reports. Capabilities were established within the Department of Planning and Environment (the department) to:

- deliver state- and economy-wide emissions modelling and analysis to inform the NSW Government's net zero targets, policies and programs
- monitor and report on progress towards meeting NSW's net zero targets, including the impact of the NSW Government's net zero programs on NSW emissions.

NSW emissions are projected by year to 2050 for all sectors of the economy. Emissions projections are prepared using the latest available activity data, peer reviewed methods and expert assumptions and indicate what NSW's future emissions could be if the assumptions underpinning the projections occur. Projections are different from forecasts, with forecasts predicting actual future events and changes.

NSW GHG emissions projections include a range of key data inputs, assumptions and methods. The previous 2021 methods paper outlined the assumptions and methods applied in preparing the 2021 emissions projections that informed the adoption of the 2030 objective of achieving a 50% reduction in emissions below 2005 levels by 2030 (DPIE 2021d).

This methods paper outlines the assumptions and methods applied in preparing the 2022 emissions projections that informed the adoption of the 2035 objective of achieving a 70% reduction in emissions below 2005 levels by 2035 (OECC 2022).

Emissions projections will be updated annually to integrate the latest data and information and to account for progress being made to deliver abatement under the Net Zero Plan and related policies and programs.

Scenarios

Projections of direct (scope 1) emissions have been developed for base case (business-as-usual) and current policy scenarios to support assessments of progress towards achieving NSW's net zero emissions objectives.

Base case emissions projections exclude the impact of the Net Zero Plan and related NSW Government policies and actions but account for the impact of other external factors. Such factors include the COVID-19 pandemic, climate, global and local technology and energy shifts, land management changes, sectoral trends and changes in economic growth, and the broader policy context. Base case emission trajectories by year out to 2050 inform the level of effort required to progress towards achieving NSW's net zero objectives.

Current policy emissions projections are developed based on the base case scenario but account for emissions reductions projected to be achieved by the NSW Government's policies and programs. The current policy projections delivered in 2021 only accounted for funded programs implemented over 2020–2030 under Stage 1 of the Net Zero Plan for which abatement estimates were available by June 2021 (DPE 2022a).

In this 2022 update, the scope of current policy projections has been expanded to include abatement forecasts for more stages of the Net Zero Plan and related government policies and programs. The 2022 current policy emissions projections account for the impact of:

- current actions under Stage 1 of the Net Zero Plan, including strategies, plans and programs announced in the latter half of 2021 and in 2022, which were not accounted for in the 2021 emissions projections
- related policies, including near-term anticipated policies and actions such as the NSW Environment Protection Authority (EPA) Climate Change Policy and Action Plan (EPA 2022a, 2022b) and upcoming reform of the Safeguard Mechanism by the Australian Government (DCCEEW 2022e)
- future initiatives related to reducing emissions and clean energy by the Government supported by the NSW Climate Change Fund (CCF) under Stages 2 and 3 of the Net Zero Plan over 2030–2050.

Sectors

Projections are prepared at a sectoral level consistent with international guidelines adopted by the United Nations Framework Convention on Climate Change (UNFCCC), using the categories and naming conventions used by the Australian Department of Industry, Science, Energy and Resources (DISER) for national emissions projections (Table 1) (DISER 2020a, 2020b; DISER 2021a; DCCEEW 2022a). Emission factors used are generally consistent with the National Inventory Report 2020, published in 2022 (DISER 2022b, 2022c, 2022d). Reporting years are financial years, and so cover the 12 months ending 30 June of that year.

Table 1 Description of sector and subsector classifications

UNFCCC classification sector and subsector	Naming of sectors for projections
1 Energy (combustion + fugitive)	
Stationary energy	
Public electricity and heat production	Electricity generation
Stationary energy (all other excluding public electricity and heat production)	Stationary energy
Transport	Transport
Fugitive emissions from fuel	Fugitives
2. Industrial processes and product use	Industrial processes and product use (IPPU)
3. Agriculture	Agriculture
4. Land use, land-use change and forestry	Land use, land-use change and forestry (LULUCF)
5. Waste	Waste
Total net emissions	Total net emissions

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) (Myhre et al. 2013). Although the *Sixth Assessment Report* (AR6) released in August 2021 (IPCC 2021) has adjusted global warming potentials, NSW emissions projections use AR5 global warming potentials for consistency with the National Greenhouse Accounts. As GHGs vary in their radiative activity, and in their atmospheric resistance time, converting emissions into CO_2-e allows the integrated effect of emissions of the various gases to be compared.

Reporting boundaries

Reporting boundaries are consistent with the NSW Greenhouse Gas Inventory. Direct (scope 1) emissions are accounted for in the projections to support the assessment of progress towards achieving NSW's net zero objectives, and consistent with national emissions projections supporting Australia's reporting of progress towards commitments under the Paris Agreement (United Nations 2015). Emissions are projected from 2021–2050, with reference made to inventoried emission estimates for 1990–2020 (latest inventory year published at the time projections were prepared) (DCCEEW 2022d). Data inclusion cut-off was generally September 2022, with exceptions identified in the specific programs and sectors descriptions in subsequent sections.

Indirect emissions (scopes 2 and 3), lifecycle carbon and embodied carbon are not addressed in the base case and current policy projections documented in this methods paper.

The NSW projections for aviation and waterborne navigation reflect the reporting boundaries adopted by the Australian 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 Australian 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 Australian Government calculates emissions for domestic aviation and navigation for specific fuel types based on fuel consumption data from the Australian Energy Statistics (AES). Emissions are allocated to states and territories based on fuel consumption by jurisdiction, as reported within the AES and Australian Petroleum Statistics (APS).

Policies and programs supporting emissions reduction

Sectoral base case emissions projections informed the development of programs under the Net Zero Plan. Integrated emissions modelling for NSW Government actions ensures an optimal portfolio of net zero emissions policies and programs, accounting for cross-sector trade-offs and inter-dependencies. This includes the delivery of an integrated, ex-ante emissions abatement trajectory for the Net Zero Plan to support sectoral current policy projections and monitoring and reporting on the impact of the plan on total NSW emissions.

The 2022 current policy projections consider: announced policies under Stage 1 of the Net Zero Plan and related NSW Government actions (Table 2), relevant policies and actions anticipated in the near term, and future actions by the NSW Government under Stages 2 and 3 of the plan, based on currently committed funding.

Table 2 Recent policies and programs considered in the 2022 current policy projections

Policies and programs	Sectors
NSW Electric Vehicle Strategy (NSW Government 2021)	Transport
Zero Emission Bus Transition Strategy (TfNSW 2022a)	Transport
NSW Future Transport Strategy (TfNSW 2022b)	Transport
NSW Future Energy Strategy and Action Plan (TfNSW 2020a, 2020b)	Transport
Electricity Infrastructure Roadmap (NSW Government 2020a)	Electricity generation
Energy Security Safeguard (NSW Government 2020b)	Electricity generation
Peak Demand Reduction Scheme (NSW Government 2022c)	Electricity generation
Net Zero Industry and Innovation Program (NZIIP) (DPIE 2021c)	IPPU, Stationary energy, Fugitive emissions
NSW Hydrogen Strategy (DPIE 2021f)	IPPU, Stationary energy, Transport
Business Decarbonisation Support (DPIE 2021a)	IPPU, Stationary energy
Safeguard Acceleration Program (NSW Government 2020b)	Stationary energy
NSW Net Zero Buildings Initiative (DPIE 2021e)	Stationary energy
Sustainable Buildings State Environmental Planning Policy (NSW Government 2022d)	Stationary energy
NSW Waste and Sustainable Materials Strategy 2041 (DPIE 2022b)	Waste
Primary Industries Productivity and Abatement (DPIE 2022a)	Agriculture and LULUCF
NSW Sustainable Farming Program (DPE 2022e)	Agriculture and LULUCF
NSW Blue Carbon Strategy 2022–2027 (DPE 2022f)	LULUCF
NSW National Parks and Wildlife Service Carbon Positive by 2028 (NSW Government 2022e)	LULUCF

Other NSW Government policies that support progress towards net zero objectives include the NSW State Infrastructure Strategy 2022–2042 (INSW 2022) and the Net Zero Cities Action Plan (TfNSW 2022c).

Anticipated government policies assumed to support the uptake of available technologies in NSW, leveraging investments under Net Zero Plan programs, include:

- Draft NSW EPA Climate Change Policy (EPA 2022a) and Climate Change Action Plan 2022–25 (EPA 2022b)
- Safeguard Mechanism reform by the Australian Government (DCCEEW 2022e)
- 2022 Energy Savings Scheme (ESS) rule changes (NSW Government 2023a).

Recent and anticipated policies addressing land management with implications for land sector emissions and sequestration include the Local Land Services Act amendment, new Land Management (Native Vegetation) Code (DPE 2022g) and the NSW Natural Capital Statement of Intent (NSW Government 2022f).

Abatement was also forecast for future actions under Stages 2 and 3 of the Net Zero Plan under committed NSW CCF funding over 2030–2050. Such future actions were assumed to focus on sectors with significant remaining emissions and abatement opportunities such as industry, mining, transport, agriculture and stationary energy.

The Net Zero Plan includes a range of programs delivering indirect (scope 2) emissions reductions by reducing electricity consumption within government, residential, business and industry sectors, and programs that aim to reduce embodied carbon and address scope 3 emissions. Although not captured within the Net Zero Plan abatement trajectory or the current policy emissions projections, the emissions reductions supported by such programs are being tracked and will be reported on within NSW State of the Environment reports.

Peer review and future projections

The assumptions, inputs and results of the 2022 base case and current policy emissions projections were subject to peer review by independent expert reviewers external to government. The peer review concluded the projections to be appropriate for projecting potential carbon emissions and program impact out to 2035. Future emissions projections beyond 2035 have a higher degree of uncertainty, as discussed in the final section of this methods paper.

Improvements recommended by the peer reviewers will be addressed in the preparation of the 2023 projection update, with focus areas of improvement described in the concluding subsection of each sector chapter.

Emissions projection results

Base case and current policy emissions projections are presented and discussed in this section, with a more detailed account of the assumptions, methods and results for specific sectors given in subsequent sections.

The overall levels of confidence in emissions projections (Table 43 and Table 44) are considered to be 'medium' for projections to 2035 and 'low' for projections from 2035–2050. Despite detailed modelling and reasonable assumptions being applied within projections, lower levels of confidence are assigned to some sectors due to uncertainties in the pace of the global energy transition and the rate of uptake of clean technologies.

Although near-term projections primarily consider measures with medium to high levels of confidence, the sector focus and abatement effectiveness of actions under future stages of the Net Zero Plan are less certain. Further information on confidence levels and risk mitigation is provided in the final section.

Tracking to NSW 2030 and 2035 targets

NSW emissions were inventoried to be 132 million tonnes CO_2-e (Mt CO_2-e) for 2020, representing 27% of Australia's total emissions and an 18% (29 Mt CO_2-e) reduction on 2005 levels (Australian Government 2022).

The base case trajectory informs the level of effort needed towards achieving NSW's net zero objectives. Base case emissions projections account for external factors, including forecast population and economic growth, but exclude the impact of the Net Zero Plan and related NSW Government policies and actions. The 2022 base case projection update considers the ongoing impact of the COVID-19 pandemic on road transport and considers private sector commitments where timebound actions are published and subject to emissions monitoring and reporting provisions.

Under the base case scenario, NSW's emissions are projected to decrease to 110 Mt CO_2-e in 2030, which is 32% below 2005 levels, and to 102 Mt CO_2-e in 2035, which is 37% below 2005 levels (Figure 1, Table 3).[2] A range of factors have contributed to the downward revision of the base case emissions trajectory, including: more rapid growth in the share of renewables within the National Electricity Market (NEM), driven in part by the high uptake rate of rooftop solar; changes in agricultural production patterns; the ongoing impact of COVID-19 on road transport (avoided commuting due to higher rates of work-from-home); growing private sector commitments; and changes in the outlook of global energy markets.

The 2022 current policy projections account for actions under Stage 1 of the Net Zero Plan and related policies, and future action under Stages 2 and 3 of the Net Zero Plan over 2030–2050, based on committed funding from the NSW CCF.

Under the current policy scenario, NSW's emissions are projected to reduce to 72 Mt CO_2-e in 2030, which is 56% below 2005 levels, with the 2030 emissions reduction target of 50% forecast to be achievable. The state's emissions are projected to fall to 48 Mt CO_2-e in 2035, which is 70% below 2005 levels, supporting progress towards a 2035 emissions reduction target of 70%, and a further reduction of emissions to 27 Mt CO_2-e by 2050 (Figure 1, Figure 2, Table 3).

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[2] Note that the final emissions projections presented in this report differ slightly from what is presented in the 2022 Implementation Update, due to final revisions to the base case and current policy modelling.

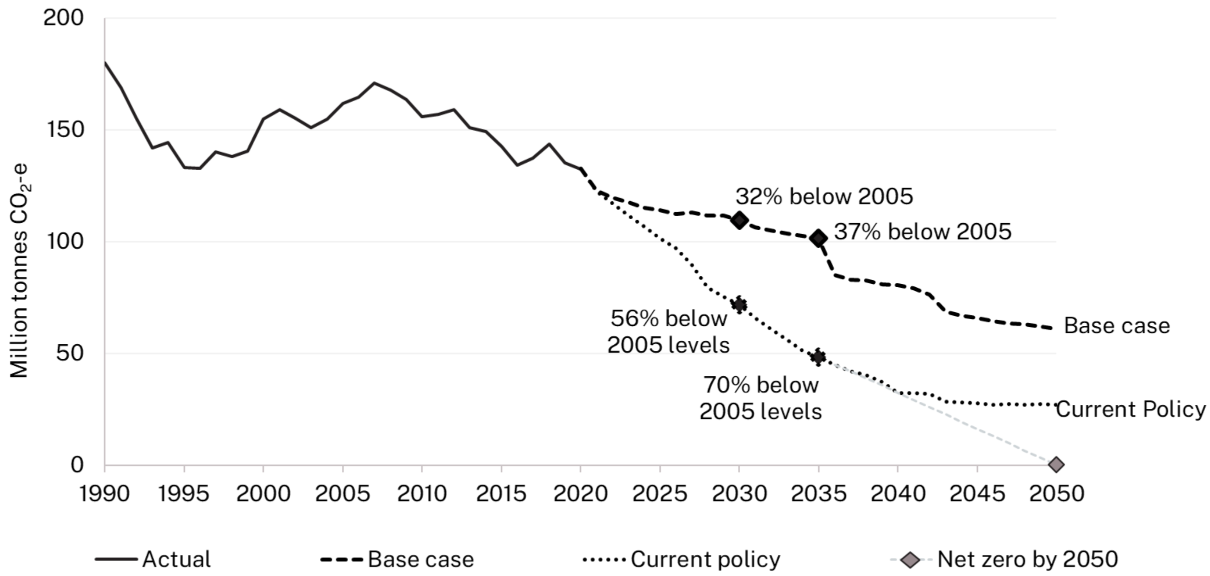

Figure 1 **NSW GHG emissions as inventoried (1990–2020) and projected under base case and current policy scenarios (2021–2050)[3]**

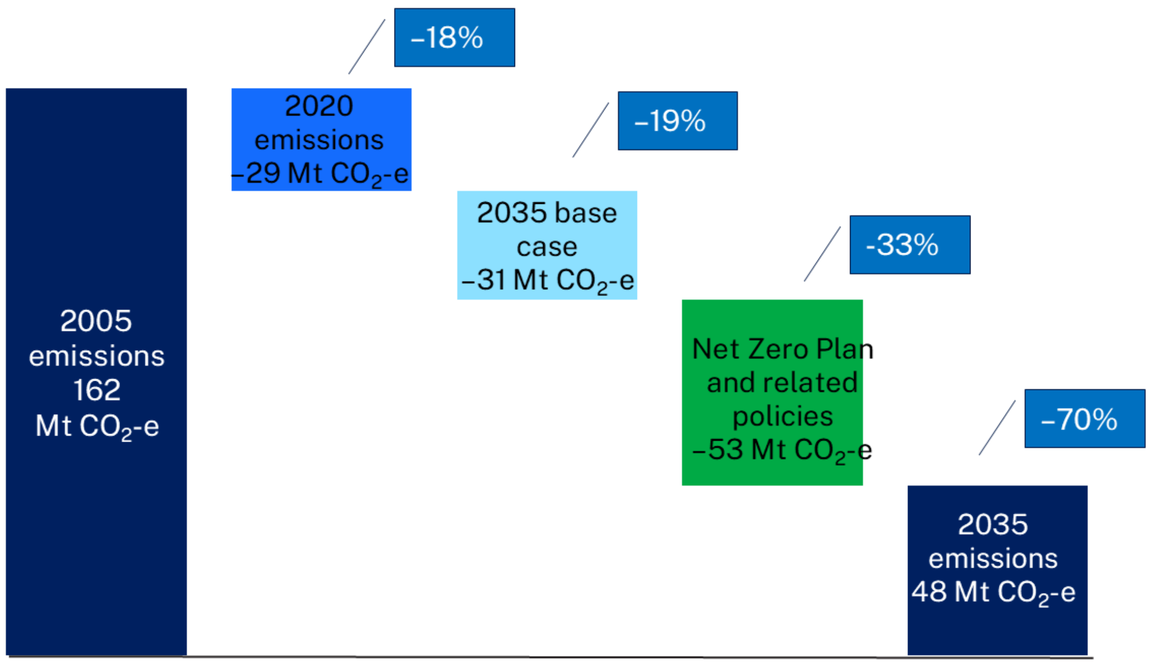

Figure 2 **Projected reductions in annual NSW emissions in 2035[3]**

[3] Note that the final emissions projections presented in this report differ slightly from what is presented in the 2022 Implementation Update, due to final revisions to the base case and current policy modelling.

Table 3 **NSW emissions as inventoried (2005, 2020) and projected (2030, 2035, 2050) compared to NSW emissions reduction targets[5]**

	NSW Greenhouse Gas Inventory		Projected NSW emissions		
	2005	2020	2030	2035	2050
Base case scenario (Mt CO_2-e)	162	132	110	102	62
Reduction below 2005 levels		–18%	–32%	–37%	–62%
Current policy scenario (Mt CO_2-e)	162	132	72	48	27
Reduction below 2005 levels		–18%	–56%	–70%	–83%
NSW emissions reduction targets			50% below 2005 levels	70% below 2005 levels	Net zero emissions

Current policy projections indicate further investment and breakthrough technologies and practices will be needed in latter decades to address residual emissions and achieve net zero emissions by 2050. This highlights the importance of policy review and performance tracking processes.

Projected reductions in NSW emissions by sector over 2020–2035, including reductions under the base case and the impact of current policies are shown in Figure 3. Much of the reduction in NSW emissions over 2020–2035 is projected to come from electricity generation as a result of the rapid uptake of renewable energy, with the renewable share of generation in NSW forecast to be over 90% by 2035 (Table 6). Renewables represent the lowest cost for new electricity generation and are supported by state and federal policies. Further discussion is provided in the electricity generation sector chapter.

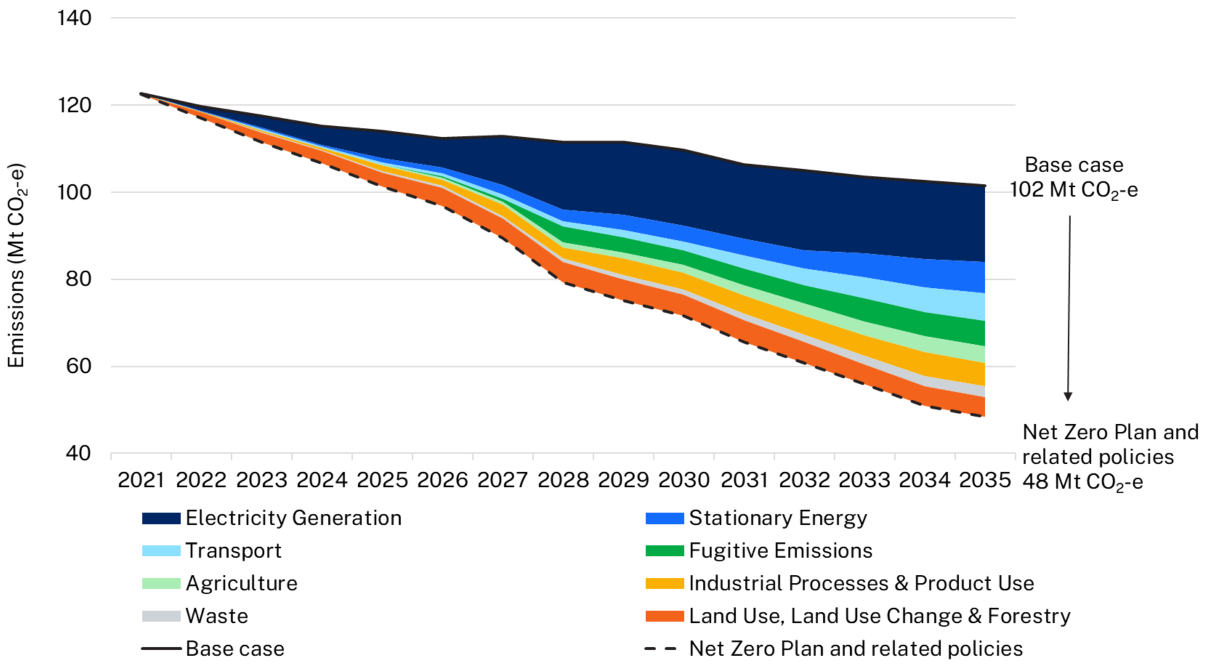

Figure 3 **Projected reduction in NSW emissions by sector over 2020–2035 under the current policy scenario**

Emissions reductions from other sectors are projected to grow under current policies and future action under committed funding as:

- technologies for abating industrial, mining and agricultural emissions mature and are increasingly adopted
- the share of electric and hydrogen-fuelled vehicles on the road increases
- carbon and biodiversity markets expand
- more organic waste is diverted from landfill
- a growing number of households, businesses and institutions reduce their electricity and gas usage.

Emission trends under the base case scenario

Inventoried NSW emissions (1990–2020) and base case emissions projections (2021–2050) by sector are shown in Figure 4 and Table 4.

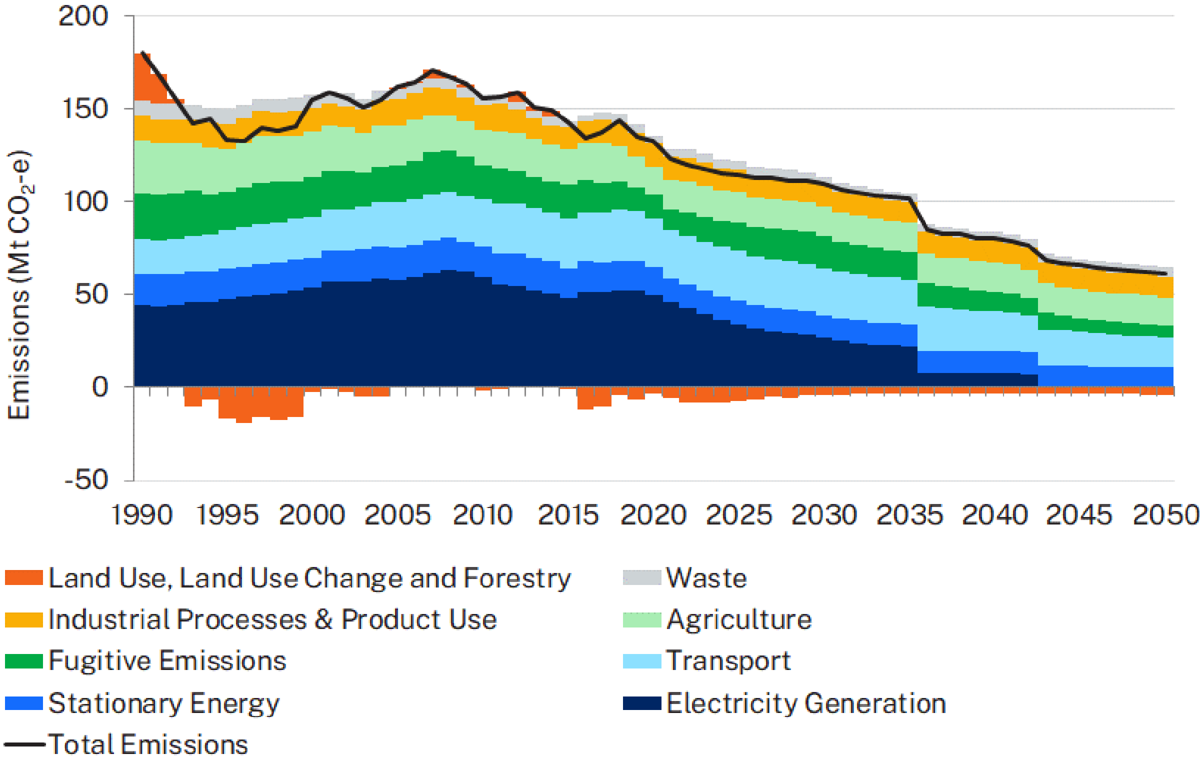

Figure 4 **NSW emissions by sector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**[4]

Whereas NSW electricity generation emissions are projected to reduce as the share of renewables in the NEM increases, emissions from transport, agriculture and mining are projected to persist or increase in the period to 2030 before slowly decreasing in latter decades.

Annual fugitive emissions from coal mining and gas production and supply are projected to grow by 37% over 2020–2030, primarily as a result of coal mine extensions and mining of more methane-rich coal seams. Transport emissions are projected to persist

[4] The large step changes evident in the chart are due to the closure of coal fired power stations, resulting in a step change decrease in emissions corresponding to the year of closure.

over the next decade with emissions reductions due to electric vehicle uptake and higher work-from-home rates offset by increased vehicle activity, growth in the share of sport utility vehicles (SUVs) and light commercial vehicles (LCVs), and increasing emissions from trucks and aviation. Agriculture emissions are projected to grow as a result of anticipated restocking of livestock post the drought conditions of 2019 and 2020.

Table 4 NSW sectoral emissions as inventoried and projected for the base case scenario

Sector	NSW Greenhouse Inventory (Mt CO_2-e)		Base Case Projections (Mt CO_2-e)			
	2005	2020	2030	2035	2040	2050
Electricity generation	58.1	49.6	26.8	22.1	7.8	0.2
Stationary energy	17.4	15.6	12.1	12.1	11.9	10.4
Transport	23.9	25.9	25.6	23.9	21.0	16.4
Fugitive emissions	19.8	12.5	17.1	14.6	11.0	5.9
Agriculture	21.9	15.3	15.7	15.7	15.7	15.5
IPPU	13.9	12.8	11.6	11.4	11.3	11.1
Waste	5.6	3.8	4.5	4.6	4.7	5.2
LULUCF	1.0	–3.1	–3.7	–2.9	–3.2	–3.7
Total emissions	**161.6**	**132.4**	**109.6**	**101.5**	**80.3**	**61.0**

The net sink in the LULUCF sector is projected to remain at recent levels, with emissions from plantation harvesting and the conversion of forests to agricultural and other land uses offset by sequestration by forests.

The difference in inventoried emissions for 2020 and projected emissions in 2030 for the waste, stationary energy and industrial processes sectors is in part due to method differences. Waste emissions projections are higher than inventoried due to bottom-up modelling of landfill and wastewater treatment emissions in the NSW projections. The more detailed projection of stationary energy and IPPU sector emissions however results in lower emissions being projected when compared with inventory estimates for some subsectors.

Some of the decline in the IPPU sector is due to the phase-down of hydrofluorocarbon (HFC) imports under federal policies, with corporate commitments also contributing to the emissions reductions projected within the IPPU and stationary energy sectors.

Further discussion on sector-specific methods and results is in subsequent sections.

Emission trends under the current policy scenario

Inventoried emissions (1990–2020) and current policy emissions projections (2021–2050) by sector are shown in Figure 5 and Table 5.

Nearer-term sector emissions projections have higher confidence levels given they are based on known policies and programs and bottom-up modelling of abatement. Longer-term sector emissions projections are less certain due to being based on assumptions regarding the sector and abatement pathways to be targeted by future actions under Stages 2 and 3 of the Net Zero Plan and top-down modelling of the abatement likely to be achieved.

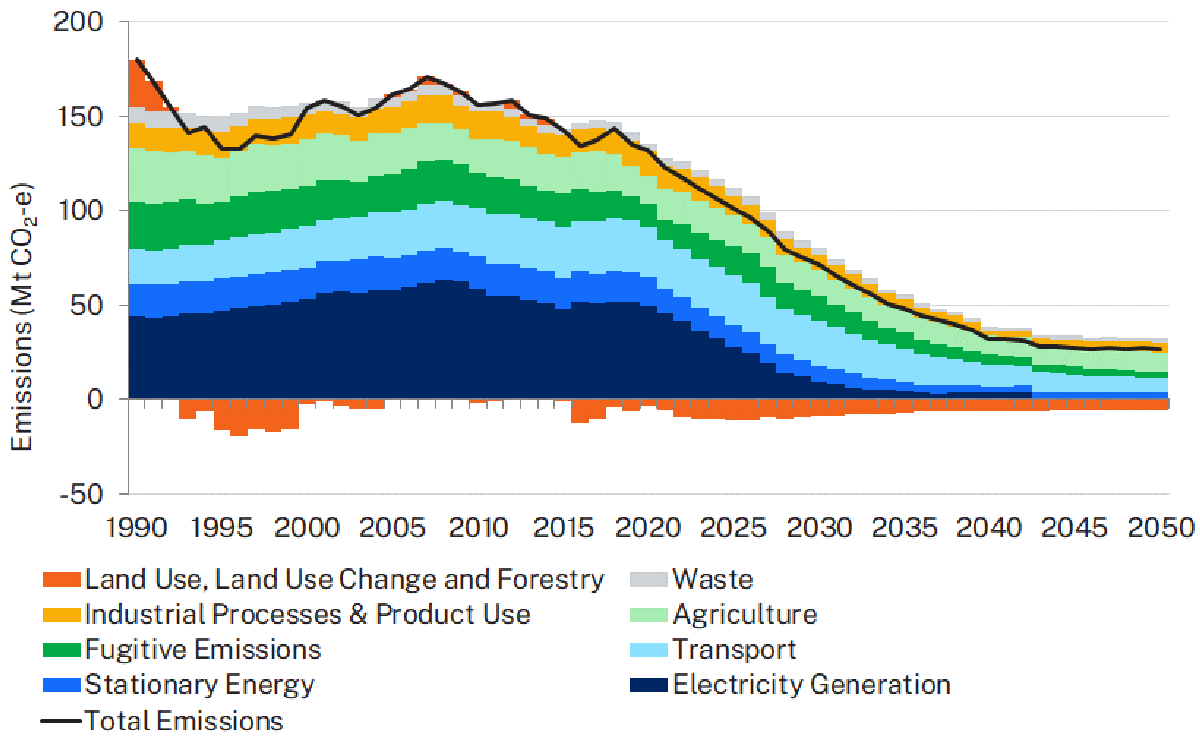

Figure 5 **NSW emissions by sector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)**

Table 5 **NSW sectoral emissions with current policy scenario projections**

Sector	NSW Greenhouse Inventory (Mt CO_2-e)		Current policy projections (Mt CO_2-e)			
	2005	2020	2030	2035	2040	2050
Electricity generation	58.1	49.6	9.5	4.5	3.4	0.2
Stationary energy	17.4	15.6	8.4	5.0	3.6	3.7
Transport	23.9	25.9	23.6	17.5	11.5	7.3
Fugitive emissions	19.8	12.5	13.7	8.7	5.5	3.2
Agriculture	21.9	15.3	14.0	11.8	9.9	10.4
IPPU	13.9	12.8	7.7	6.2	2.8	5.5
Waste	5.6	3.8	3.4	2.0	1.6	1.9
LULUCF	1.0	–3.1	–8.7	–7.5	–6.1	–5.4
Total emissions	**161.6**	**132.4**	**71.5**	**48.3**	**32.2**	**27.0**

Emissions projections to 2035

Current policies, including the NSW Electricity Infrastructure Roadmap (NSW Government 2020a) and the Energy Security Safeguard (NSW Government 2020b), are projected to support the acceleration of the state's electricity sector transition. Annual NSW electricity generation emissions are projected to reduce by 81% over 2020–2030 and by 92% by 2035 compared to 2020 levels.

Recent NSW Government policies addressing transport sector emissions include the NSW Electric Vehicle Strategy (NSW Government 2021), the NSW Hydrogen Strategy (DPIE 2021f), the Zero Emission Bus Transition Strategy (TfNSW 2022a) and the NSW Future Transport Strategy (TfNSW 2022b), with road transport prioritised (Table 2). Leveraging market trends, NSW Government policies are projected to support transport sector emissions reductions of 9% over 2020–2030 and 32% over 2020–2035, driven substantially by reductions in light vehicle emissions.

Emissions from the stationary energy sector are projected to decrease due largely to increased electrification of mining and manufacturing processes supported by several NSW Government policies and programs (Table 2), and including the expanded scope of funding opportunities under the 2022 ESS rule changes (NSW Government 2023a).

Stationary energy and industrial process emissions at high emitting facilities are a focus for the Net Zero Industry and Innovation Program (NZIIP), with the intention of supporting such facilities to decarbonise their operations and targeting significant emissions reductions by 2030. Under this $1 billion program, $305 million of grant funding is currently available to support such reductions (NSW Government 2023b).

Options have been identified to abate methane (CH_4) emissions at NSW coal mines, and the NZIIP and Coal Innovation NSW (CINSW) funded South32 Ventilation abatement demonstration facility project address the abatement of fugitive emissions. It is anticipated the NSW EPA Climate Change Policy and Action Plan and the reform of the Safeguard Mechanism by the Australian Government will support the adoption of available technologies leveraging investments under the Net Zero Plan. Under the current policy scenario, annual fugitive emissions increase by 9% over 2020–2030 (compared to 37% for the base case scenario) and reduce after 2030 to be about 30% below 2020 levels by 2035.

NSW Government policies and programs addressing agriculture and LULUCF sector emissions include the Primary Industries Productivity and Abatement Program (DPIE 2022a), the NSW Sustainable Farming Program (also referred to as Nature Positive Farm Program) (DPE 2022e), the NSW Blue Carbon Strategy 2022–2027 (DPE 2022f) and the NSW National Parks and Wildlife Service Carbon Positive by 2028 plan (NSW Government 2022e). Other recent policies addressing land management with implications for land sector emissions and sequestration include the Local Land Services Act amendment, new Land Management (Native Vegetation) Code (DPE 2022g) and the NSW Natural Capital Statement of Intent (NSW Government 2022f).

Enteric CH_4, primarily from cows and sheep, represents the largest source of emissions within the IPCC agriculture sector (11.5 Mt CO_2-e, 75% of agriculture emissions in 2020). There is significant, feasible potential to abate enteric CH_4 emissions in NSW from feedlot and dairy cattle through dietary modification, with lower levels of abatement for other cattle and sheep (Almeida and Hegarty 2021). NSW is a major agricultural producer with large livestock herds and has the market scale necessary to accelerate commercialisation and adoption of low emissions technologies and practices (OCSE 2020).

Leveraging available and emerging abatement technologies and growing environmental markets and corporate commitments (e.g. Meat and Livestock Australia and the National Farmers Federation aim to see Australian agriculture trending towards being carbon neutral by 2030), NSW Government policies and investment are projected to support agriculture sector emissions reductions of about 9% over 2020–2030 and 23% over 2020–2035. NSW Government net zero programs and land management policies are projected to increase the net sink in the LULUCF sector by enhancing carbon sequestration and reducing land clearing across land tenures.

Emissions reductions are projected for actions under the Waste and Sustainable Materials Strategy 2041: Stage 1 2021–2027, which target a 10% reduction in waste generation and a 50% reduction in organics disposed to landfill by 2030. This strategy also has provision for increased landfill gas capture with associated funding support. Under the current policy scenario, annual waste sector emissions reduce by 32% by 2035 compared to 2020 levels.

Emissions projections 2035–2050

Emissions projections for post-2030 reflect ongoing emissions reductions due to the impact of Net Zero Plan Stage 1 programs and related policies, and further abatement forecasts for future actions under Stages 2 and 3 of the plan.

Emissions reductions were forecast for future actions under Stages 2 and 3 of the Net Zero Plan based on committed NSW CCF funding of around $150 million per year over 2030–2050. Such future actions were assumed to focus on sectors with significant remaining emissions and abatement opportunities such as the industry, mining, transport, agriculture and stationary energy sectors. Abatement was forecast through top-down modelling based on NSW Government funding models and average abatement costs over the period to 2050 for hard to abate sectors from the literature (McKinsey 2021).

Emissions projected to be abated by sector under Stages 1 to 3 of the Net Zero Plan and related policies under already committed funding are illustrated in Figure 6, with the extent of emissions projected to be unabated shown. Emissions reductions from electricity generation reduce after the latter half of the 2030s given the closure of 4 of 5 remaining coal fired powered stations by that time was accounted for within the base case projections.

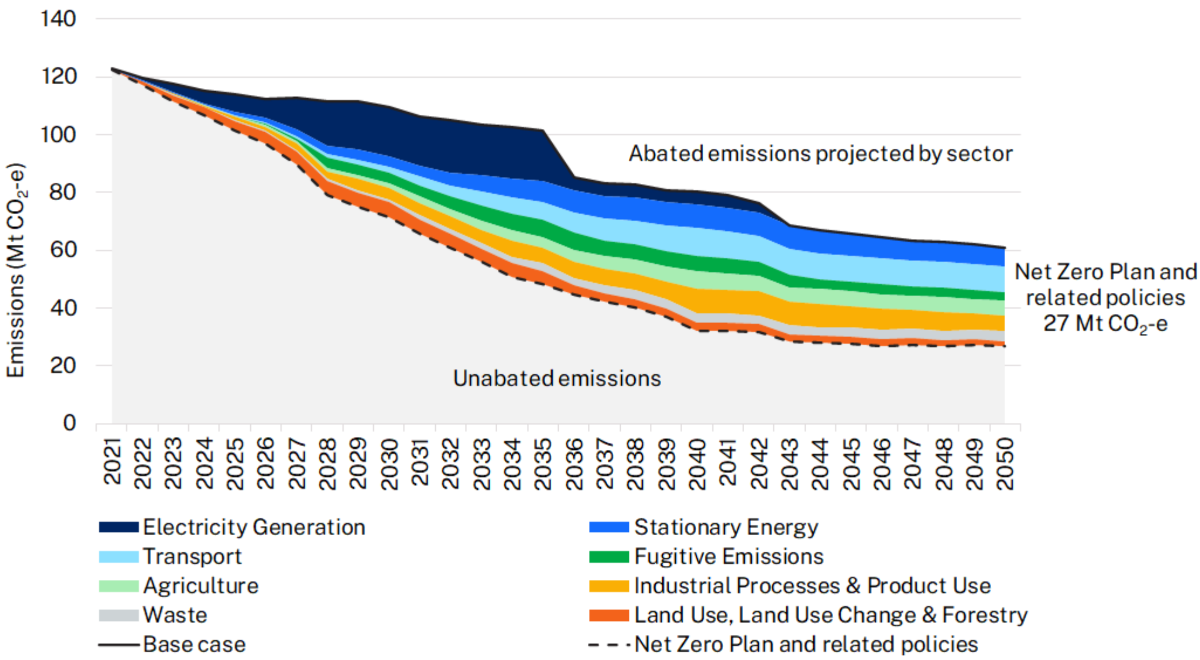

Figure 6 **Projected reduction in NSW emissions by sector over 2020–2050 under the current policy scenario**

Remaining (residual) emissions by sector for the current policy scenario are shown for selected years in Figure 7. Such emissions include hard to abate sources within agriculture, transport, mining, manufacturing and buildings, and legacy waste emissions. Further information is provided in subsequent sections on sector-specific residual emissions.

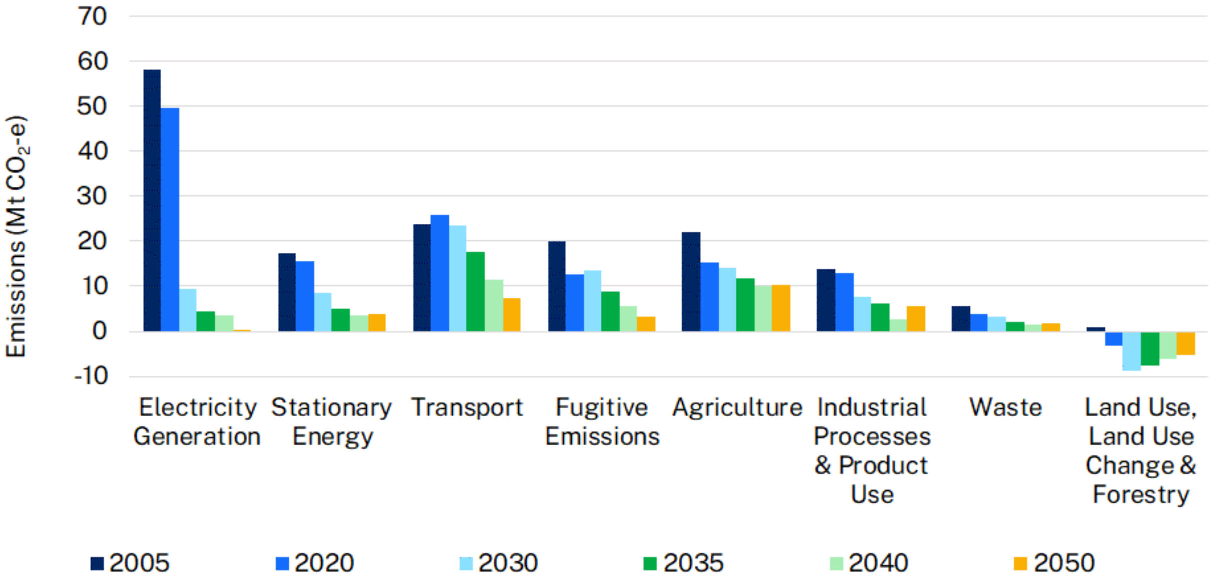

Figure 7 **NSW emissions by sector for selected years based on inventory estimates (2005, 2020) and current policy emissions projections for future years**

Emissions and abatement projections are accessible via the interactive NSW Net Zero Emissions Dashboard (DPE 2022b) and as data downloads from the NSW Sharing and Enabling Environmental Data (SEED) portal (NSW Government 2022b).

Comparison with 2021 base case emissions projections

In 2019, base case emissions were projected to be about 129 Mt CO_2-e in 2035, with base case emissions updated in 2021 to be about 111 Mt CO_2-e in 2035. In comparison, in the 2022 update base case NSW's emissions are revised to be 102 Mt CO_2-e in 2035 (Figure 8). Major factors contributing to the downward revision of the NSW base case emissions trajectory compared to the 2021 projections include:

- the department's downgraded population projections for NSW released in March 2022 (DPE 2022c) due to the loss of several years of inbound migration during COVID-19 and the follow-on impacts from lower future fertility rates
- road transport emissions projections were revised to account for ongoing COVID-19 impacts of avoided commuting due to higher rates of working from home by people within certain professions (refer to relevant transport sector chapter)
- quantification of anticipated emissions reductions from high emitting industries under corporate commitments, where timebound actions are published and subject to emissions monitoring and reporting provisions (refer to relevant sector chapters)
- more refined modelling of road transport emissions based on light vehicle travel and freight movement forecasts from Transport for NSW (TfNSW), and further scrutiny of emissions from stationary energy and industrial processes.

Base case projections are based on the latest commodity forecasts and account for potential new manufacturing with domestic production at base case emission intensities assumed for commodity growth. The projections also include potential emissions from gas projects, coal mining extensions and plausible new coal mining within strategic releases. Despite overall emissions for NSW being lower than projected in 2021, higher emissions are projected for certain sectors such as fugitive emissions from coal mining due to coal mine extensions and mining of more CH_4-rich coal seams.

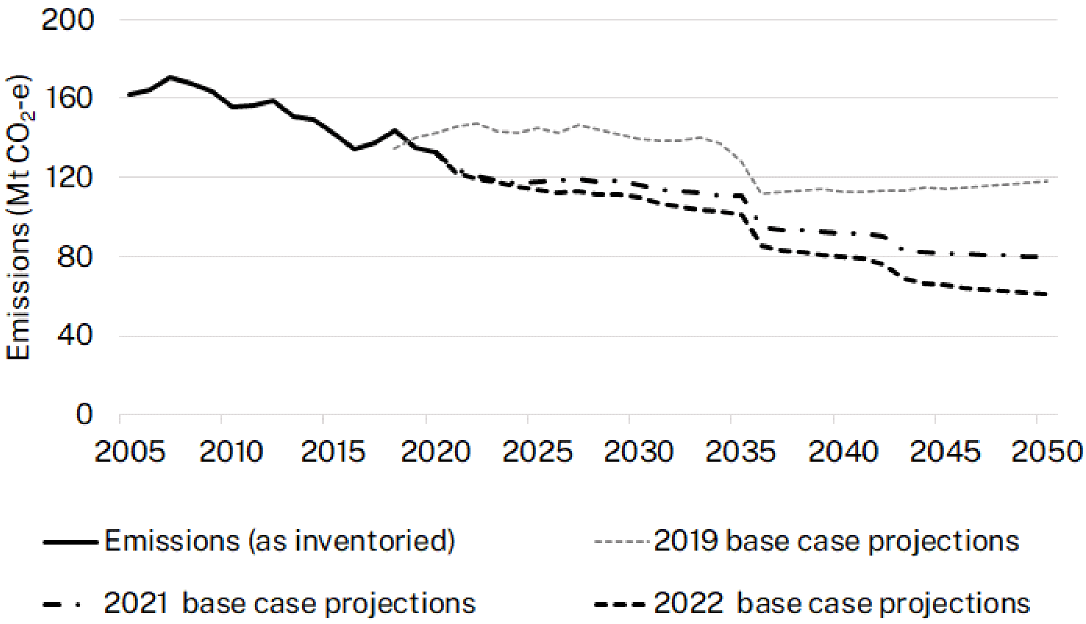

Figure 8 **Comparison of 2019, 2021 and 2022 base case projections for NSW emissions (projected emissions excluding the Net Zero Plan and related policies)**

The 2021 current policy emissions projections provided a lower bound (conservative) estimate of emissions reductions. These projections did not account for all actions under Stage 1 of the Net Zero Plan nor related NSW Government actions. The NSW Hydrogen Strategy (DPIE 2021f), NSW Waste and Sustainable Materials Strategy 2041 (DPIE 2022b) and the National Parks and Wildlife Service Carbon Positive by 2028 Plan (NSW Government 2022e), for example, were announced after the completion of the 2021 projections and abatement was not captured for all actions under these strategies.

The 2022 current policy projections account for an expanded number of programs under Stage 1 of the Net Zero Plan and consider the broader impacts of such programs under related NSW Government policies (Figure 9). These emissions projections also address abatement to be achieved under recently confirmed funding for actions under Stages 2 and 3 of the Net Zero Plan.

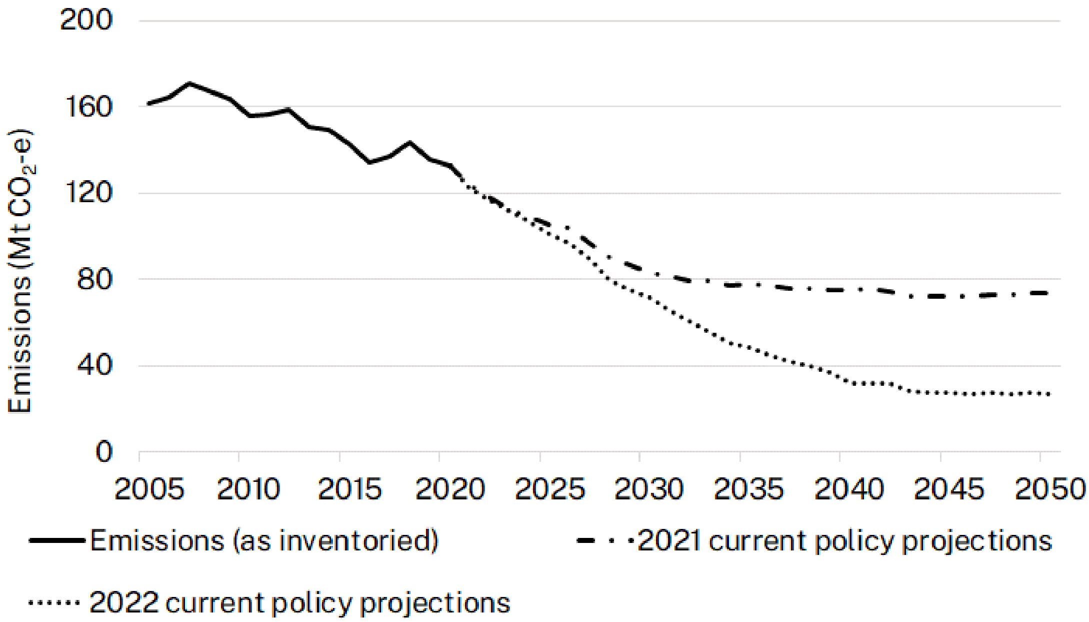

Figure 9 **Comparison of 2021 and 2022 current policy projections for NSW emissions**

Electricity generation

This subsector of energy industries covers 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.

The base case projections referenced in the 2021 methods paper (DPE 2022a) remain the best available data for the 2022 projections. Data, methods and assumptions applied are therefore consistent with the previous methods paper. Comparisons are however made to the recently published results from the Australian Energy Market Operator (AEMO) 2022 Integrated System Plan (ISP) (AEMO 2022a) and from the 2022 update of the national emissions projections (DCCEEW 2022b).

Base case emissions projections

Base case emissions projections exclude the impact of the NSW Electricity Infrastructure Roadmap (NSW Government 2020a) and the Energy Security Safeguard (NSW Government 2020b). Reference is made to modelling and analysis for the AEMO 2020 ISP released in July 2020 and the national emissions projections published by DISER in December 2020, which do not account for the NSW Electricity Infrastructure Roadmap and Energy Security Safeguard.

Base case NSW electricity sector emissions projections to 2030 were based on the outputs from modelling commissioned by DISER and undertaken by ACIL Allen for the NEM. This modelling underpinned the national emissions projections released in December 2020 (DISER 2020a). ACIL Allen's proprietary market simulation model – PowerMark – was used to project emissions in the NEM to 2030. Demand, included in the model as an exogenous assumption, was taken from the AEMO Electricity Statement of Opportunities (ESOO) 2020 central scenario (AEMO 2020a). New large interconnector projections in the NEM are also exogenous inputs into the model and were set in line with the central development pathway under AEMO's 2020 ISP (AEMO 2020b). The ACIL Allen modelling adopted the Clean Energy Regulator's (CER's) pipeline of large-scale renewable projects (as at August 2020) (CER 2020a), after which new renewable capacity was induced by their model. The CER's modelling of rooftop solar to 2025 was adopted in the ACIL Allen projections (CER 2020c), after which the projections adopted growth rates from AEMO's high distributed energy resources (DER) rooftop solar projections under the ESOO 2020.

For post-2030, reference was made to model outputs for the central and high DER scenarios from the AEMO 2020 ISP (AEMO 2020b), ensuring consistency with the technology mix from the ACIL Allen modelling to 2030.

The modelling from the AEMO 2020 ISP accounts for announced and end-of-technical-life retirements of power stations (as captured in the AEMO 2019 Input and Assumptions Workbook for the 2020 ISP modelling). End-of-life retirements are determined by AEMO according to the equipment age. Units may be retired earlier by the model if this is determined to be the least cost to the power system. Power station retirements were projected in the AEMO 2020 ISP modelling to be primarily addressed through variable renewable energy (VRE) generation supported by flexible, utility-scale dispatchable resources for firming. Existing gas-powered generation was forecast to continue playing an important role in the NEM, with new flexible gas generators potentially having a role depending on gas prices.

The base case projections indicate the NEM is undergoing a significant transformation from a system of centralised large coal and gas generation towards an array of smaller-scale, widely dispersed wind and solar generators, grid-scale storage and demand response (AER 2021). NSW electricity generation emissions projections for the base case are shown in Figure 10. Emissions are projected to decrease from 51.9 Mt CO_2-e in 2019 (11% below 2005 levels) to 26.8 Mt CO_2-e in 2030 (54% below 2005 levels) mainly due to the growing share of renewable generation in the NEM.

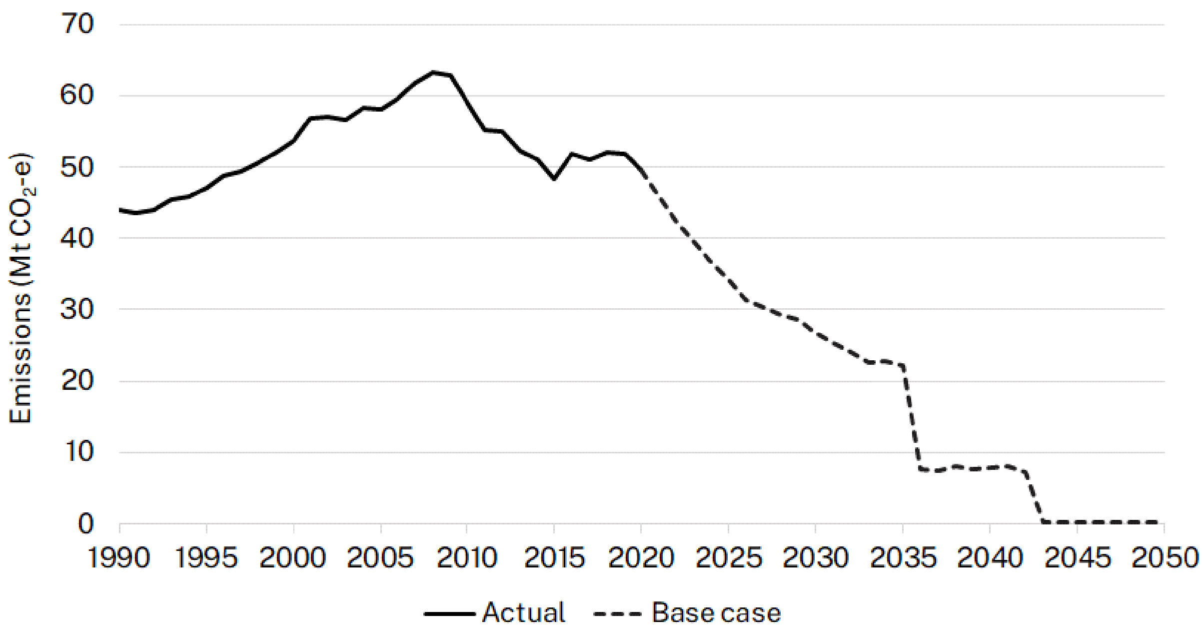

Figure 10 **NSW public electricity generation emissions as inventoried (1990–2020), with base case emissions projections (2021–2050)**

As a result of the COVID-19 pandemic energy demand reduced due to a drop in commercial load associated with businesses closing during lockdowns, but this was reported to be partly offset by a rise in household consumption (AER 2021). The impact of COVID-19 on electricity demand was however projected to be transient with future NEM emissions dominated by the shift to renewables and scheduled retirements of coal fired generators.

Based on the electricity demand forecasts underpinning the projections, the NEM was projected to experience little growth in electricity demand as energy efficiency offsets increases in demand associated with population growth. Increasing electricity consumption from electric vehicles (EVs) was expected to drive additional consumption by 2030, with rooftop solar projected to meet a growing share of the demand, reducing the demand to be met through the grid (DISER 2020a).

Base case EV uptake rates modelled by the department (refer to the Transport section) are consistent with the moderate–high EV stock forecasts underpinning the 2020 ISP high DER scenario.

Current policy emissions projections

Current policy emissions projections include the impact of the NSW Electricity Infrastructure Roadmap (NSW Government 2020a) and the Energy Security Safeguard (NSW Government 2020b). The GHG emission intensity of electricity supply in NSW is expected to reduce significantly in coming decades under the NSW Government's

Electricity Infrastructure Roadmap. Building on the 2019 NSW Electricity Strategy and the 2018 NSW Transmission Infrastructure Strategy, the enabling legislation for the Roadmap, the *Electricity Infrastructure Investment Act 2020* (NSW), was enacted into law in December 2020.

The Energy Security Safeguard includes expanding and extending the existing ESS to 2050 and introducing a new Peak Demand Reduction Scheme.

Emissions reductions to be achieved through the implementation of the Electricity Infrastructure Roadmap are dependent on the development pathway. Two independent modelling studies were commissioned by the NSW Government to assess preferred development pathways, including assessments of the impact of potential development pathways on electricity generation emissions. Neither modelling study is considered more accurate than the other, with forecasts taken to represent an appropriate range for our abatement estimates. The abatement trajectory for current policy emissions from the NSW electricity generation sector is therefore expressed as a central estimate and range (Figure 11). The abatement projected to be achieved in 2030 is in the range of 12.9–21.5 Mt CO_2-e (central estimate of 17.2 Mt CO_2-e).

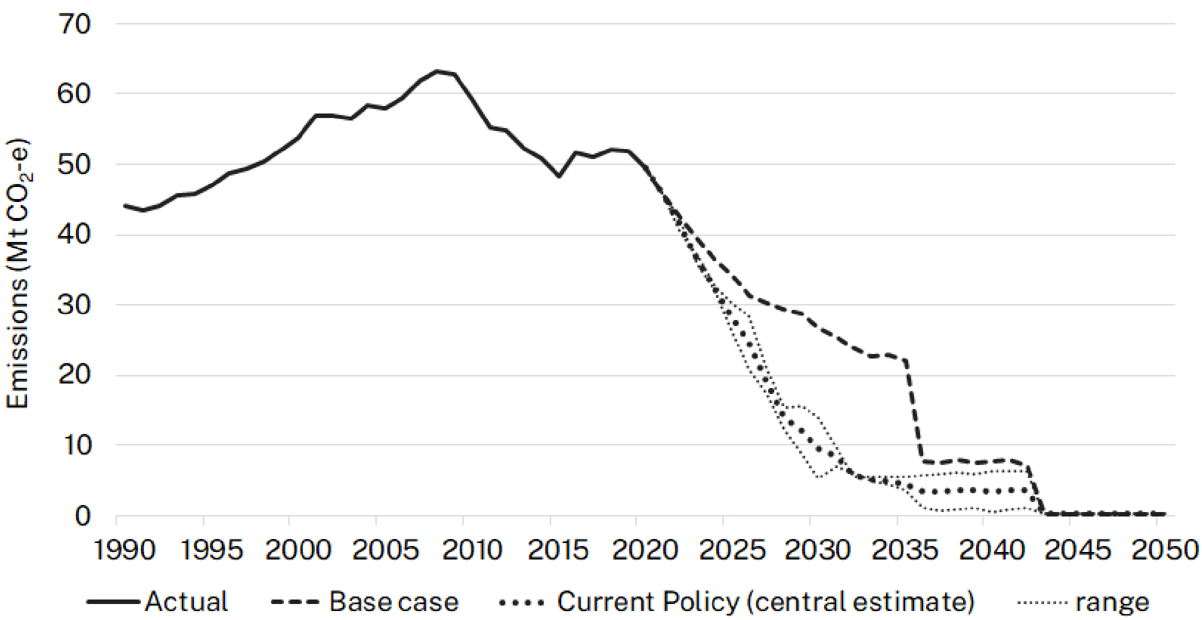

Figure 11 **NSW electricity generation emissions as inventoried (1990–2020), with base case and current policy (central estimate, range) emissions projections (2021–2050)**

Comparison with AEMO 2022 and DCCEEW 2022 forecasts

Current policy electricity generation emissions are compared to emission estimates based on the AEMO 2022 ISP (AEMO 2022a) and the 2022 update of the national emissions projections (DCCEEW 2022b) (Table 6).

The Step Change scenario is published by AEMO as the most likely scenario within the 2022 ISP. The national emissions projections include a baseline scenario, which accounts for the NSW Electricity Infrastructure Roadmap together with a range of other federal and state existing measures, and a 'with additional measures' scenario that also takes further measures to be implemented under the Australian Government's Powering Australia Plan into account (DCCEEW 2022b).

Current policy electricity generation emissions for NSW (this study) are lower than those projected for the AEMO Step Change scenario and comparable or higher than emissions projected by the Australian Government for 2030 and 2035.

The renewable share of electricity generation in NSW is forecast to be above 80% by 2030 and greater than 90% by 2035 by all forecasts and 97% by 2035 according to DCCEEW baseline projections (Table 6).

Table 6 NSW electricity generation emissions and renewable share of generation

	Electricity generation emissions in NSW (Mt $CO_{2\text{-}e}$)					Renewable share of generation in NSW		
	2005	2020	2025	2030	2035	2025	2030	2035
NSW Electricity Infrastructure Roadmap Central Estimate (basis for 2021 and 2022 current policy projections)	58	50	28	10	5	49%	84%	93%
DCCEEW (2022b) Baseline scenario	58	50	31	8	2	47%	87%	97%
DCCEEW (2022b) With Additional Measures scenario	58	50	31	6	1	–	–	–
AEMO (2022a) 2022 ISP Step Change scenario	58	50	38	14	8	41%	82%	91%

Considerations for projection updates

NSW Electricity Infrastructure Roadmap counterfactual modelling is underway, with updated modelling for the Roadmap also in progress. Model results are expected to be available in 2023 and will be used to inform the 2023 emissions projections.

Stationary energy (excluding electricity)

Stationary energy related emissions arise from the burning of fuels for energy production, in the form of heat, steam or pressure (and exclude electricity generation and transport).

Base case emissions projections for this sector were undertaken for energy industries (coal, gas), manufacturing industry and construction, and ‘other sectors’, which include primary industries (agriculture, forestry, fishing) and commercial/institutional and residential sectors (buildings).

Current policy emissions projections account for abatement projected to be achieved due to Net Zero Plan programs and related policies (Table 2).

Base case emissions projections

Energy industries (coal, gas)

Coal mining

Detailed GHG emissions data was obtained from the CER for each coal mine in NSW based on facility reporting under the National Greenhouse and Energy Reporting Scheme (NGERS). This included emissions from onsite consumption of liquid and gaseous fuels and oils and greases.

For all new greenfield projects and brownfield extensions, data was based on information from published Environmental Impact Statements (EIS). All reported liquid fuel consumption emissions for stationary (which includes non-road fuel consumption) and mobile activities were lumped together. The liquid fuel emissions were split between stationary and mobile sources based on previous NGERS facility data if the mine was an extension project, or based on comparable existing mines for new projects, distinguishing between underground and open-cut mining operations.

An emission intensity was developed for each mine based on the 2020–21 NGERS emissions data for stationary and mobile combustion and mine-specific run-of-mine (ROM) coal volumes data from Coal Services Pty Ltd (Coal Services 2022). Emissions were projected forward using these mine-specific emission intensities as a constant multiplied by the changing ROM coal tonnages out to 2050 as forecast for each mine by the Mining, Exploration and Geoscience group (MEG) within the Department of Regional NSW.

The 2022 projections include updated ROM coal forecasts provided by MEG (dated June 2022). In line with company announcements, the Dendrobium extension project was removed and operations at Mount Arthur were forecast to ramp-down for an expected 2030 closure. Other changes included scaling back the number of strategic release areas from 5 to one and including the Hunter Valley Operations extension project.

Gas production, processing and distribution

Detailed GHG emissions data was obtained from the CER for each gas facility in NSW based on facility reporting under NGERS. This included stationary combustion emissions from gas production and processing plants, gas transmission and gas supply networks.

For large gas pipelines such the Moomba to Sydney (MSP) and the Eastern Gas Pipeline (EGP) where there is inline compression, an emission intensity was calculated based on the latest NGERS emissions data for stationary gaseous and liquid combustion and pipeline gas throughput (petajoules per annum, PJ p.a.). The projected emissions were calculated based on the future throughput of the pipeline.

The key change compared to the 2021 projections is the inclusion of emissions from 2 inline compressor stations on the MSP adding approximately 65 kt CO_2-e p.a. The projections included the 2 developments: 1) Port Kembla Gas Terminal (PKGT) and 2) Narrabri Gas Project (NGP), which were assumed to commence operations in 2023 and 2025, respectively. Data for these 2 projects were obtained from EIS available in the public domain (DPE 2022d). The EIS stationary energy emissions data were based on maximum gas production.

The main gas production forecasts (in PJ p.a.) for the NGP and PKGT were based on the AEMO Gas Statement of Opportunities (GSOO) 2021 Central Case (scenario 1) (AEMO 2021). The GSOO 2022 (AEMO 2022b) did not include a central estimate, but a comparison of 2021 vs 2022 residential/commercial low gas price consumption forecasts showed that the 2022 forecasts were on average 3% lower. As it was unclear how this change would affect the stationary energy emissions from the gas projects, the production forecasts were held at 2021 levels.

To estimate future stationary energy emissions for the NGP, the base case assumed that onsite power demand would be met by importing grid electricity. The NSW electricity grid will become increasingly decarbonised in accordance with the NSW Electricity Infrastructure Roadmap, providing further abatement for the project. This assumption is however yet to be confirmed by the project proponent.

The forecast emissions were scaled according to the fraction of production in a given year compared to maximum production. The same approach was taken for stationary energy emissions for the PKGT.

Manufacturing industries and construction

These base case emissions projections have been substantially refined as follows:

- integrated the latest NGERS data, EIS information for new projects and commodity forecasts
- incorporated sectoral efficiency and productivity improvements (in place of assuming the emission intensity of future production will remain constant)
- considered corporate carbon reduction commitments.

A detailed overview of the revised approach applied is therefore provided below.

In this section 'BAU' refers to business-as-usual projections, with no abatement applied. The base case projections integrate abatement estimated to occur as a result of firm corporate commitments and federally funded emissions reduction projects.

Projections approach

Bottom-up model

Facility-specific projections are used for industries in NSW with facility-level production data. This model aggregates facility-level emissions data to sector level. In addition to NGERS data, data was obtained from the AES (DCCEEW 2022c) to check agreement with the data reported within the NSW Greenhouse Gas Inventory for specific sectors.

The emissions are calculated according to the formula:

$$E_t = E_{t-1}\ \Delta production$$

where:

E_t = emissions in year t (tonnes CO_2-e)

E_{t-1} = emissions in the previous year

$\Delta production$ = percentage change in production between year t and year t–1.

Top-down model

Application of the top-down model depends on the emission source and the availability of data. It is assumed that changes in sector emissions are proportional to changes in production, which are in turn proportional to changes in sector revenue. As the forecasts apply to Australia as a whole, it is assumed that each facility in a specific industrial sector in NSW will be affected equally.

The approach uses revenue forecasts to 2026 for each commodity or sector from market analyst reports from IBISWorld (IBISWorld 2022). The annual sector-level emissions are then projected forward in accordance with changes in sector revenue forecasts to 2026. For future emissions to 2050, a linear trend was assumed starting with the 2026 emissions.

Iron and steel

This subsection covers stationary energy emissions from fuel consumed by the production process, and coke oven gas (COG) related emissions. The steel production from 3 facilities (BlueScope Port Kembla, InfraBuild Steel Mill Sydney and Commonwealth Steel Waratah) is summed to model the iron and steel stationary energy emissions.

Emissions from the consumption of COG are not captured under NGERS but the energy consumption is. COG emissions are derived using facility energy consumption data for COG and an emission factor of 37.08 kg CO_2-e/GJ (NGA 2021). Only BlueScope Port Kembla uses COG; therefore, BlueScope Port Kembla is selected as the representative facility for modelling the main scenario.

The Office of the Chief Economist (OCE) projection scenario (for FYs 2022–2027) and domestic growth scenario (using the OCE Compound Annual Growth Rate (CAGR)) (for FYs 2028–2050) are selected as the BAU main scenario. The main scenario for steel production is identical to that assumed for IPPU related iron and steel emissions. The current GHG emission intensity for FY 2021 is assumed as a constant until FY 2050.

For FYs 2022–2027, data from the OCE June 2022 Resources and Energy Quarterly (REQ) forecast (DISER 2022f) and March 2022 REQ forecast (DISER 2022e) (covering 2025–2027) are used to predict iron and steel production in NSW as shown in Table 7.

Table 7 OCE forecasts for iron and steel percentage change in production

2022	2023	2024	2025	2026	2027
–7.3%	–1.0%	–0.4%	0.003%	0.0007%	0.0001%

From FYs 2028–2050, a domestic growth scenario is assumed with new production expansion continuing. The steel production growth rate is assumed to be equal to the OCE CAGR of 0.9%, as stated in the OCE REQ March 2022 forecast (DISER 2022e).

The base case projection is developed based on the BAU projections but accounts for corporate abatement commitments as outlined in the Greenhouse Gas Report (Appendix J) of BlueScope Steel's Blast Furnace No. 6 Reline Project EIS (BlueScope 2022a) (Table 8).

Table 8 **Abatement assumed based on BlueScope Steel's published emissions reduction commitments (BlueScope 2022a)**

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Dual lance tuyeres	2027–2050	Offsetting external metallurgical coal purchases. COG injection has the potential to reduce emissions by approximately 150,000 t CO_2-e p.a.	Company commitment
Hot blast gas waste heat recovery	2027–2050	Potential reduction of approximately 11,000 t CO_2-e p.a.; enables injection of COG into the blast furnace	Company commitment
Alternative fuel (use of charcoal produced from forestry waste)	2035–2050	Total emissions reduction 5% p.a. (estimation)	Company commitment

Production of solid fuels

This subsection covers production of coke, coal tar, and coal by-products such as liquefied aromatic hydrocarbons. In NSW this is largely coke production related to iron and steel.

NGERS does not capture emissions from the production of solid fuels; therefore, emissions projections were based on historical data from the State and Territory Greenhouse Gas Inventory (STGGI) and projected forward using iron and steel production projections above.

Non-ferrous metals

The major emission source in this subsector is from aluminium production. The emissions projections are based on the percentage change in output from the Tomago aluminium facility.

For FYs 2022–2027, a combination of data from the OCE were used (OCE REQ (June 2022) and OCE REQ (March 2022) forecasts) covering 2025–2027 for forecasting iron and steel production in NSW as shown in Table 9.

Table 9 **OCE forecasts for aluminium percentage change in production**

2022	2023	2024	2025	2026	2027
–0.87%	2.87%	–0.44%	1.32%	1.30%	0.00%

For FYs 2028–2050, the domestic growth scenario (OCE CAGR) assumes that new production expansion will continue. The aluminium production growth rate is assumed to be equal to the OCE CAGR of 0.6% for FYs 2022–2027, as stated in the OCE REQ (March 2022) forecast (DISER 2022e).

As per the IPPU aluminium production emissions projections, the main BAU scenario takes the OCE projections (FYs 2022–2027) and the domestic growth scenario projections (FYs 2028–2050). The FY 2021 GHG emission intensity is assumed to be constant out to FY 2050.

As noted in the NSW Regional and Local Greenhouse Gas Emissions Methods paper (NSW Government 2022g), there is a significant gap between the NGERS emissions for the non-ferrous metals subsector and the STGGI (DCCEEW 2022f) emissions. The NGERS data accounts for 50–60% of the STGGI emissions. As discussed in the local emissions method paper, the source of the discrepancy was investigated, and the conclusion was that the STGGI emissions for non-ferrous metals may be overestimated.

Therefore, the NGERS data are used as the basis for the projections from 2021–2050, thus showing a drop from 187 kt CO_2-e in 2020 to 97 kt CO_2-e in 2021. The source of the discrepancy is still being investigated with the DCCEEW.

Note that no abatement commitments have been identified for the non-ferrous metals subsector.

Chemicals

This subsection is disaggregated to facility level and includes emissions due to ammonia and nitric acid production, polymer production, with the remaining facilities grouped as other chemical manufacturing.

Historical emissions were collected from NGERS facility data. A cross-check against the STGGI for chemicals revealed a large gap in emissions when compared to the aggregated facility emissions data from NGERS. The gap could not be explained by comparison with the AES data for the sector. One plausible explanation is discussed in the polymer production subsection below.

Chemicals – ammonia and nitric acid production

The NGERS stationary energy emissions for Orica Kooragang Island are given for ammonia and nitric acid production. The emissions associated with the production of both commodities are summed to derive a total emission intensity. The BAU emission scenario is based on the percentage change in output from the Orica Kooragang Island facility. The current GHG emission intensity for FY 2021 is assumed constant to FY 2050.

For ammonia, the BAU scenario is identical to that used for the IPPU – chemicals industry – ammonia production. A domestic growth scenario is selected as the main BAU scenario.

Domestic growth scenario – ammonia

Published information from Orica is used, assuming that ammonia production will grow linearly from ~0.310 Mt p.a. (NGERS) in FY 2021 to 0.385 Mt p.a. in FY 2030. Production is capped at 0.385 Mt p.a. from FY 2030. This projection is based on information that Orica provided for its ammonia plant expansion project to increase production capacity to 0.385 Mt p.a. (Orica AEMR 2021).

For nitric acid, the BAU scenario is identical to that used for the IPPU – chemicals industry – nitric acid production. A domestic growth scenario is selected as the main BAU scenario.

Domestic growth scenario – nitric acid

From FYs 2022–2031, Australia's 2020 chemical industry emissions projections (DISER 2020a) are used instead of the 2021 projections (DCCEEW 2022a). This is because the 2021 projections included the Emissions Reduction Fund project for Orica (the EnviNOx process to remove nitrous oxide (N_2O) – considered abatement under IPPU emissions), and therefore these projections are used for consistency with the IPPU nitric acid related emissions projections (Table 10).

From FYs 2032–2050, published information from Orica describes an additional HNO_3 plant that will be operating in FY 2031. The production of HNO_3 will grow linearly to reach 0.605 Mt p.a. in FY 2051. The maximum capacity is 0.605 Mt p.a. following the expansion (Orica AEMR 2021).

Table 10 DCCEEW forecasts for chemical industry, percentage change in production

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
2.4%	2.4%	1.0%	0.4%	0.5%	0.9%	0.9%	0.9%	0.4%	0.5%

Orica's nitric acid projection is scaled up against the total nitric acid production, due to Thales group reporting minor emissions for nitric acid production. The base case projections are developed based on the BAU projections, but accounting for abatement commitments described in Orica's Climate Action Report 2021 (Orica CAR 2021) (Table 11).

Table 11 Abatement assumed based on Orica's published emissions reduction commitments (Orica CAR 2021)

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Energy efficiency, electrification of energy consumption and heat recovery	2035–2050	Assumed to reduce 5% p.a. from 2035–2050	Company commitment
Medium to long-term sourcing of advanced biofuels, other low carbon fuels	2030–2050	Assumed to reduce 50,000 t CO_2-e p.a. (20% of 250,000 t CO_2-e p.a. of natural gas combustion)	Company commitment

Chemicals – polymer production

A BAU emissions scenario has been considered, based on the percentage change in output from the Qenos Botany Bay facility. This plant processes ethane feedstock sourced from the Cooper Basin in South Australia into approximately 250 kt of ethylene p.a. for 2 downstream polyethylene plants producing low density polyethylene (LDPE) and linear low density polyethylene (LLDPE) (Qenos 2022a).

Qenos's production data is not reported in NGERS, therefore assumptions are made based on public information. The historical production estimate is based on information from the official website (Qenos 2022a) stating that annual production consists of 70 kt LDPE and 100 kt LLDPE. It is assumed that the maximum capacity is 210 kt of polyethylene p.a. (Qenos 2022b).

There is no public information regarding future production expansions. It is assumed that forecast production has no growth from 2016–2025 and from 2026, the production grows to reach 210 kt in 2046 based on the growth rates for ethane steam cracking (BNEF NEO 2021; BNEF 2021a). Production remains at 210 kt from 2046–2050.

The base case projection is developed based on the BAU projection, but accounting for abatement commitments (Table 12).

Table 12 Abatement assumed based on published commitments (Qenos 2022c)

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Alternative fuel (e.g. hydrogen)	2030–2050	Assumed to reduce 85,000 t CO_2-e p.a. Assumed 50% of the coal consumption is replaced by renewable fuel	Company commitment (Qenos 2022c)

As noted in the NSW Regional and Local Greenhouse Gas Emissions Methods paper (NSW Government 2022g), there is a significant gap between the NGERS emissions for the chemicals subsector and the STGGI (DCCEEW 2022f) emissions. The NGERS data accounts for 40% of the STGGI emissions. As discussed in the local emissions method paper, the source of the discrepancy was investigated, and the conclusion was that the STGGI emissions for chemicals may be overestimated.

Another possible reason for the discrepancy is that for some activities (e.g. carbon black manufacture) significant quantities of fossil fuel feedstock is used as a source of carbon; however, relatively little is combusted (DISER 2022b, p. 77). In NGERS, it is speculated that a proportion of fossil fuels (especially ethane) have been counted as fossil fuel feedstocks. The accounting of fossil fuels as a feedstock instead of a fuel that is combusted may lead to the gap between reported NGERS and STGGI emissions for chemicals.

At this stage, the reason for the discrepancy is not clear. Therefore, the NGERS data are used as the basis for the projections from 2021–2050. This accounts for the drop in emissions from 2,405 kt CO_2-e in 2020 to 833 kt CO_2-e in 2021. The source of the discrepancy is still being investigated with the DCCEEW.

Chemicals – other chemical manufacturing

Other chemical manufacturing occupied a small portion of emissions. The emissions projection is forecast based on the DCCEEW 2020 Australian emissions projections.

For FYs 2022–2030, the 2020 emissions projections for the chemical industry are used (DCCEEW 2022a). For FYs 2031–2050, a CAGR of 0.5% is assumed.

Non-metal minerals

This sector covers glass and glass products, ceramics, cement, lime, plaster and concrete product, and other non-metallic minerals.

The emissions for glass and glass products, ceramics were forecast using IBISWorld revenue forecast data averaged over the above subsectors (IBISWorld 2022). After FY 2026, a linear regression was applied to extend the projection to FY 2050. The changes in production in these subsectors to FY 2026 are shown in Table 13.

Table 13 IBISWorld revenue forecast data for non-metal minerals, percentage change

	2022	2023	2024	2025	2026
Glass production	–0.8%	1.5%	2.9%	2.5%	2.2%
Ceramics	8.0%	5.7%	1.5%	0.2%	2.5%

The emissions for cement, lime plaster and concrete product were forecast using Bloomberg New Energy Futures (BNEF) cement production forecasts for Australia (BNEF NEO 2021; BNEF 2021a). It is assumed that changes in sector emissions are proportional to changes in production.

For other non-metallic minerals production, emissions are a fixed value over time as only one relatively small facility in NSW produces other non-metallic minerals (based on data provided by NGERS).

The base case projection is developed based on the BAU projection, but accounting for Boral's abatement commitments (Table 14).

Table 14 Abatement assumed based on published commitments (Boral 2022a, 2022b)

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Alternative fuel – Berrima kiln chloride bypass	2023–2050	Assumed to reduce 50,003 t CO_2-e p.a. Chloride bypass to increase use of alternative fuels from current 15% to 30% by the end of FY 2023	NSW Major Resource Recovery Infrastructure grant $4.6 million (DPE 2022h)

Pulp, paper and print

This sector covers pulp, paper and paperboard manufacturing and printing services. The emissions for the industry were forecast using IBISWorld revenue forecast data (IBISWorld 2022).

Table 15 IBISWorld revenue forecast data for pulp, paper and print, percentage change

	2022	2023	2024	2025	2026
Pulp, paper and print	3.6%	–2.2%	0.9%	1.0%	–2.5%

Emissions projections were calculated as per chemical industry emissions.

Food processing, beverages and tobacco

The emissions for the industry were forecast using the IBISWorld revenue growth rates taking the average of beer, wine, fruit and vegetable and meat processing as a proxy for the sector (IBISWorld 2022).

Table 16 IBISWorld revenue forecast data for food processing, beverages and tobacco

	2022	2023	2024	2025	2026
Food processing, beverages and tobacco	1.07%	1.58%	0.41%	0.9%	1.22%

Emissions projections were calculated as per chemical industry emissions.

Other sectors

For other manufacturing, IBISWorld revenue growth rates (average of steel pipe/tube manufacturing and structural steel fabricating) were applied (IBISWorld 2022).

Table 17 **IBISWorld revenue forecast data for other manufacturing, percentage change**

	2022	2023	2024	2025	2026
Other manufacturing	0.43%	0.92%	1.50%	0.57%	1.54%

For construction, growth forecasts were based on the Low Emissions Building Materials (LEBM) Program's forecast from FYs 2022–2050 (all materials for building and infrastructure construction). The LEBM forecast particularly models impacts to this trajectory resulting from interventions undertaken in the LEBM Program, grouped by the streams of work within the program in June 2021.

Table 18 **IBISWorld revenue forecast data for construction, percentage change**

	2022	2023	2024	2025	2026
Construction	–2.50%	–0.06%	2.87%	5.04%	–0.13%

For other metal mining such as silver, lead and zinc, IBISWorld revenue growth rates for silver, lead and zinc ore mining were used as a proxy (IBISWorld 2022).

Table 19 **IBISWorld revenue forecast data for other metal mining, percentage change**

	2022	2023	2024	2025	2026
Other metal mining	1.52%	1.35%	2.51%	1.22%	1.03%

For textiles, the IBISWorld revenue growth rates for synthetic and natural textile manufacturing were used (IBISWorld 2022).

Table 20 **IBISWorld revenue forecast data for textiles, percentage change**

	2022	2023	2024	2025	2026
Textiles	0.88%	–0.13%	–0.29%	–0.51%	–0.32%

As noted in the NSW Regional and Local Greenhouse Gas Emissions Methods paper (NSW Government 2022g), there are gaps between the NGERS emissions for the construction, textiles and other manufacturing subsectors and the STGGI (DCCEEW 2022f) emissions. The NGERS data accounts for 40% or less of the STGGI emissions.

As discussed in the local emissions method paper, the source of the discrepancy was investigated, and the conclusion was that the STGGI emissions for these sectors may be overestimated.

For projections modelling purposes, the construction, textiles and other manufacturing subsector emissions were lumped as 'Other' under Manufacturing industries and construction. The NGERS data for Other was used as the basis for the projections from 2021–2050, thus showing a drop of from 1,276 kt CO_2-e in 2020 to 509 kt CO_2-e in 2021. The source of the discrepancy is still being investigated with the DCCEEW.

Other sectors

Other sectors contributing to stationary energy emissions include primary industries (agriculture, forestry, fishing) and commercial/institutional and residential sectors. These sectors accounted for total emissions of about 5 Mt CO_2-e in 2020, making up about 30% of total NSW stationary energy (excluding electricity generation) emissions with emissions in the residential, commercial and institutional sectors accounting for about 70% of these 'other sector' emissions. Emissions from buildings are primarily driven by gas use in residential and commercial buildings.

Commercial/institutional

Base case projections for this sector were updated based on projections for the NSW commercial/institutional building sector included in the Commercial Buildings Energy Consumption Baseline Study 2022 commissioned by DISER and delivered by Strategy. Policy. Research. (SPR 2022). This building baseline study includes annual gas use data and BAU projections for the NSW commercial building sector for 2012–2050.

National Greenhouse Account 2021 factors were applied to estimate associated emissions on an annual basis out to 2050. Projected emissions for historical years are typically within about 5% of the emissions for this subsector reported for NSW within the STGGI for 2020 (DCCEEW 2022f).

Diesel consumption is not addressed in the National Commercial Buildings Energy Consumption Baseline Study. Projections were based on recent trends in the ratio of diesel/gas use emissions for this subsector from STGGI data and the BAU projections for gas use in NSW from the national building baseline study.

Residential

Fuel-specific emissions for the NSW residential sector were obtained from the DCCEEW inventory team for 1990–2020. Natural gas use emissions were projected based on 2022 NSW Common Planning Assumption population projections and regression analysis of residential natural gas consumption and population data for 2001–2020 (R2=0.97).

No temporal trends were evident in historical emissions from the use of petroleum products, with average emissions for 2010–2020 assumed for the period out to 2050. Wood and wood waste emissions have trended down over 1990–2020, and this trend was linearly forecast for future years (DCCEEW 2022d).

Agriculture, forestry and fishing

Base case projections for energy use (primarily diesel) within primary industry (agriculture, forestry, fishing) were based on the NSW contribution to national emissions for this subsector (DCCEEW 2022f) and national emissions projections to 2030, with linear forecasts for post-2030 emissions.

Stationary energy base case emissions projections

Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the stationary energy sector are shown in Figure 12. Emissions from this sector have fallen moderately in recent years due to increases in power generation efficiency and renewable energy, more energy-efficient equipment and appliances and fuel switching. Emissions from this sector are projected to persist with modest growth over the medium term without NSW Government policies.

Manufacturing accounts for over 40% of emissions in this sector in recent years and its contribution is projected to grow to 55% by 2050. In 2030, contributions to stationary energy emissions are projected to be: manufacturing (43%), energy industries (30%), buildings (commercial, institutional and residential) (22%) and primary industries (agriculture, forestry and fishing) (6%).

In 2030, over 80% of the stationary energy emissions within the energy industries category are projected to be from diesel consumption at primarily open-cut coal mines. Diesel is used to power mobile plant and equipment such as haul trucks, dozers and loaders, with a more minor share being used for stationary power.

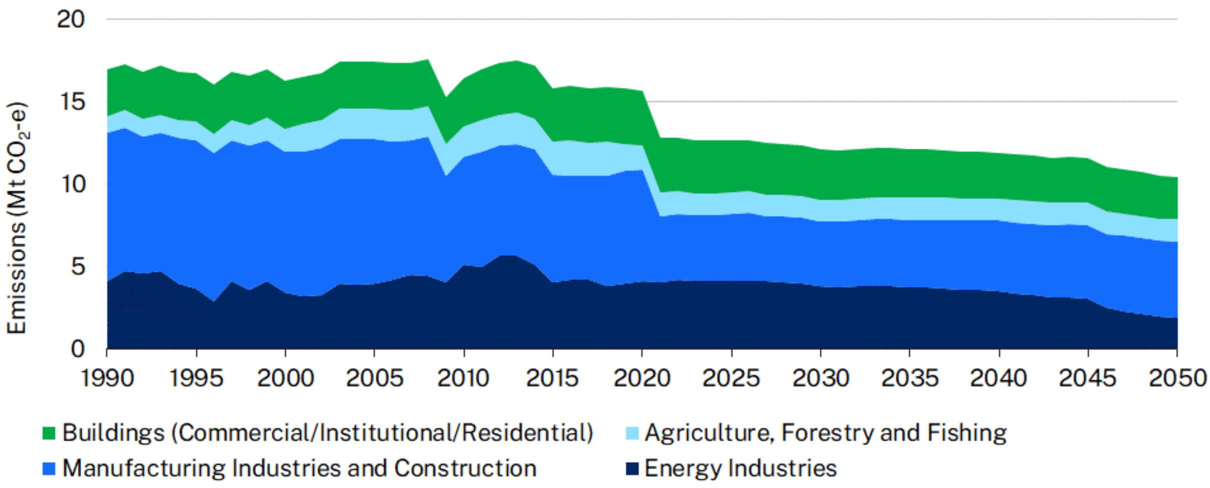

Figure 12 **Stationary energy emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**

Current policy emissions projections

A number of programs under Stage 1 of the Net Zero Plan address stationary energy related emissions across economic sectors (Table 2).

Manufacturing and energy industry emissions are addressed by NZIIP, including the High Emitting Industry, New Low Carbon Industry Foundations and Clean Technology focus areas.

The Business Decarbonisation Support program supports emissions reductions within primarily medium to large energy users in industrial and commercial sectors. The Safeguard Acceleration Program supports the expansion of the Energy Security Safeguard, including helping industry get ready for the new Peak Demand Reduction Scheme and broadening activities service providers offer under the existing ESS.

Policies and programs contributing to emissions reduction forecasts for the commercial and institutional building sectors through projected gas savings include the Accelerating Net Zero Buildings initiative and the Sustainable Buildings State Environmental Planning Policy (SEPP) announced in August 2022 and set to commence on 1 October 2023 (NSW Government 2022d). The Sustainable Building SEPP sets sustainability standards for residential and non-residential development, aims to reduce GHG emissions from energy use, establishes processes to monitoring embodied emissions of building materials, and requires new buildings to be net zero ready by 2035. The emissions projections include an assumption that post-2035 new commercial and institutional buildings will no longer rely on gas or diesel to meet their energy requirements. Minor gas savings within the residential sector are also estimated to be achieved through the NSW Government's BASIX program and the SEPP.

Detailed abatement modelling was undertaken for each of the abovementioned programs, accounting for program funding allocations and annual expenditure profiles, specific actions under each program, abatement costs ($/t CO_2-e abated), and forecasts of likely private investment to be leveraged.

Actions under the NSW Hydrogen Strategy and supply chain benefits arising from the NSW Electric Vehicle Strategy are likely to indirectly support pathways for hydrogen-fuelled vehicles and battery electric vehicles (BEVs) and equipment replacing diesel-powered mobile plant and equipment at mine and manufacturing sites. Whereas electrification is a dominant pathway to replace fuel combustion for stationary applications in the near term (supported by Stage 1 programs), hydrogen-fuelled vehicles and BEVs and mobile equipment are anticipated to be viable for deployment by the early 2030s.

Projections assume the NSW EPA Climate Change Policy and Action Plan and the reform of the Safeguard Mechanism by the Australian Government will support the adoption of available technologies leveraging expanding energy and carbon markets, investments under Stage 1 programs and funding under future stages of the Net Zero Plan.

Open-cut mines operating post-2042 are assumed to replace non-road diesel equipment with clean technology starting in 2032. The abatement to be achieved post-2030 by replacing diesel-powered mobile plant and equipment was modelled on a mine-by-mine basis accounting for the extent of emissions projected for the mine and the forecast remaining mine life.

Fuel switching and energy measures within NSW industry were identified, with opportunities to support a 25% reduction in energy use from gas and diesel by 2030 and assumed to reach about 60% by 2050. Activities are likely to include: implementation of solar thermal and biogas process heating; upgrading and electrification of process heating; production process improvements; boiler replacements; and waste heat recovery.

A recent study identified available and cost-effective measures to reduce diesel consumption from agriculture in NSW in the near term by about 10% for mobile applications and by about 25% for stationary energy (Gjerek et al. 2021). Opportunities are likely to include replacing diesel pumps with solar photovoltaic powered electric pumps or electrification (grid), and energy efficiency improvements through optimal speed control.

Fuel switching and energy saving opportunities within the commercial, institutional, small business and residential sectors were also considered with increased uptake anticipated to leverage the expanded ESS, representing a broader market impact beyond direct emissions reductions under the Business Decarbonisation and Safeguard Acceleration programs.

The integrated abatement in the stationary energy sector modelled to be achieved as a result of these programs is shown in Figure 13, with resultant current policy projections for this sector compared to base case projections in Figure 14.

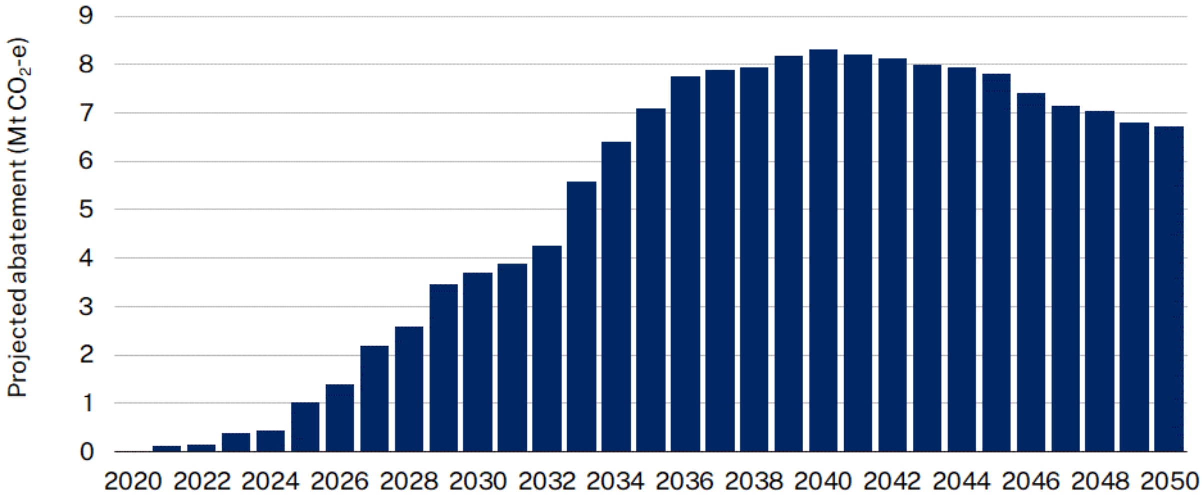

Figure 13 **Abatement of stationary energy (excluding electricity generation) emissions projected to be achieved by Net Zero Plan Stage 1 programs**

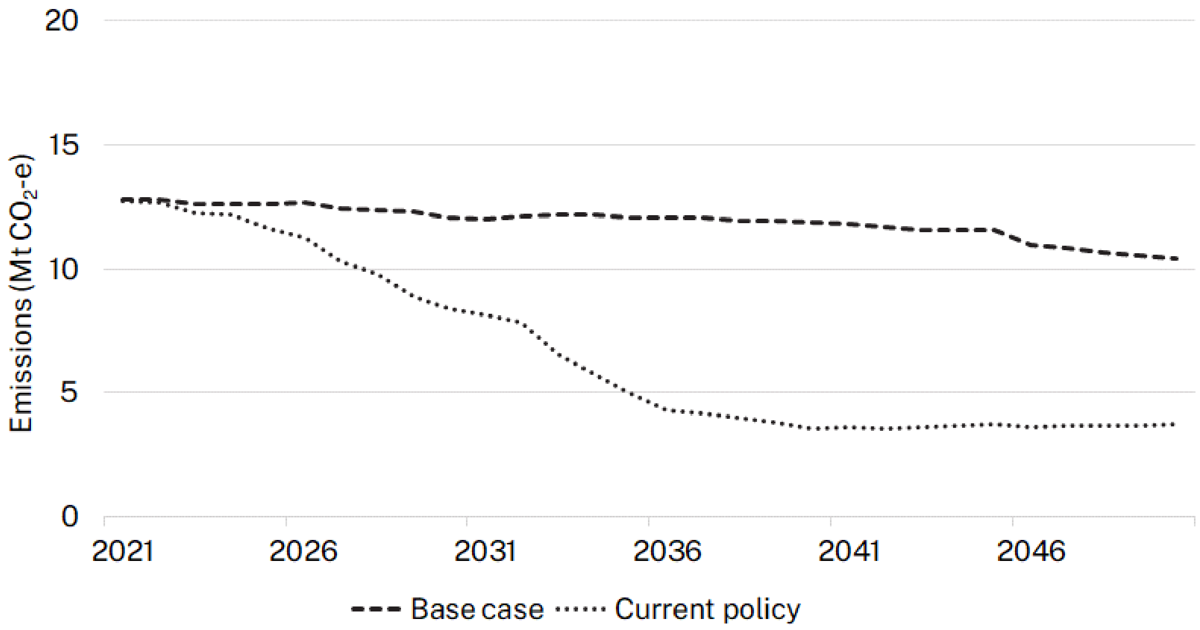

Figure 14 **Comparison of NSW stationary energy (excluding electricity generation) emissions projected under the base case and under current policy (2021–2050)**

Considerations for projection updates

Future projection updates will consider:

- the latest NGERS data, EIS information for new projects and commodity forecasts
- potential market impacts of the European Union Carbon Border Adjustment Mechanism and the implications of growing corporate carbon reduction commitments
- more resolved modelling of building related emissions.

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). Emissions from the generation of electricity used by EVs and rail are accounted for in the electricity sector.

More detailed emissions projections were undertaken for road transport and domestic aviation due to the more significant contribution of these sectors. Road transport accounted for 88% and domestic aviation for 7% of NSW transport emissions in 2019, with railways (3%), waterborne navigation (2%) and other transport sources (0.3%) being more minor sources.

Current policy emissions projections accounted for the abatement projected to be achieved due to programs under the Net Zero Plan addressing primarily road transport (Table 2).

Base case emissions projections

Road transport

Light duty vehicles (LDVs), including passenger cars, LCVs and motorbikes, contributed 73% of road transport emissions in 2020, with the remaining 27% due to heavy duty vehicles (mainly trucks).

Base case projections approach

The department's NSW fleet and emissions models were applied to project emissions from light and heavy duty vehicles using a state-aggregated modelling approach (Figure 15). NSW fleet-aggregate emission factors were forecast by vehicle type for recent and future years, and applied together with vehicle kilometre travel (VKT) projections from transport modelling by TfNSW to project future emissions.

An overview of the overall approach applied is as follows, with further detail on the department's fleet and emissions modelling provided below:

- Fleet modelling was used to projects the future profile of the NSW light and heavy duty vehicle fleets by estimating fleet growth, vehicle sales and vehicle attrition from a base year of NSW registration data.
- TfNSW provided VKT projections for light and heavy duty vehicles, with transport model outputs spanning regional and metropolitan areas of the state.[5] This included annual VKT by speed band and vehicle type (cars, LCVs, articulated and rigid trucks) and annual VKT for buses and coaches.
- Fuel consumption figures from the fleet model and VKT estimates were compared with benchmark sources for model validation. VKT estimates for recent years were compared to Australian Bureau of Statistics (ABS) Survey of Motor Vehicle Use (SMVU) data (ABS 2020b), with VKT projections compared to the Australian Government Bureau of Infrastructure and Transport Research Economics (BITRE) VKT projections for NSW (BITRE 2019). Calculated fuel consumption was compared to state-aggregate fuel use from the APS.

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[5] Strategic Transport Model (STM) and Freight Movement Model (FMM) for the Greater Metropolitan Area, and the Regional Transport Model and Regional Freight Model for regional NSW.

- Fleet-aggregate emission factors were derived using the department's vehicle emissions model and stock projections from the fleet model. Emission factors were derived by vehicle type and speed class, with GHG emissions expressed as grams of CO_2-e per km travelled. Derivation of fleet-aggregate emission factors accounted for the impact of seasonal effects, cold start correction factors and VKT splits by fuel/motive power for each of the base vehicle types.
- Annual emissions were projected based on fleet-aggregate emission factors (g/km) applied with annual VKT projections. This was done by vehicle category and speed bin for each scenario and year, to estimate total emissions for modelled years.
- GHG estimates for a pre-COVID-19 base year (2019) were compared with road transport emissions published for the NSW Greenhouse Gas Inventory, and scaling factors derived and applied to approximate the inventory estimates.

The modelling accounted for:

- travel behaviour in future scenarios, including proposed transport infrastructure projects from the Greater Sydney Integrated Network Plan (GSINP)
- ongoing impacts of COVID-19 on land-use forecasts and work-from-home and peak spreading travel behaviour. This scenario incorporated the latest research (as at May 2022) about changes likely to occur post-COVID-19 with a lower rate of population growth (particularly in Sydney), aligned with the department's 2022 population update. Reduced commuter travel due to higher rates of work-from-home and lower travel demand during morning and afternoon peaks are accounted for.

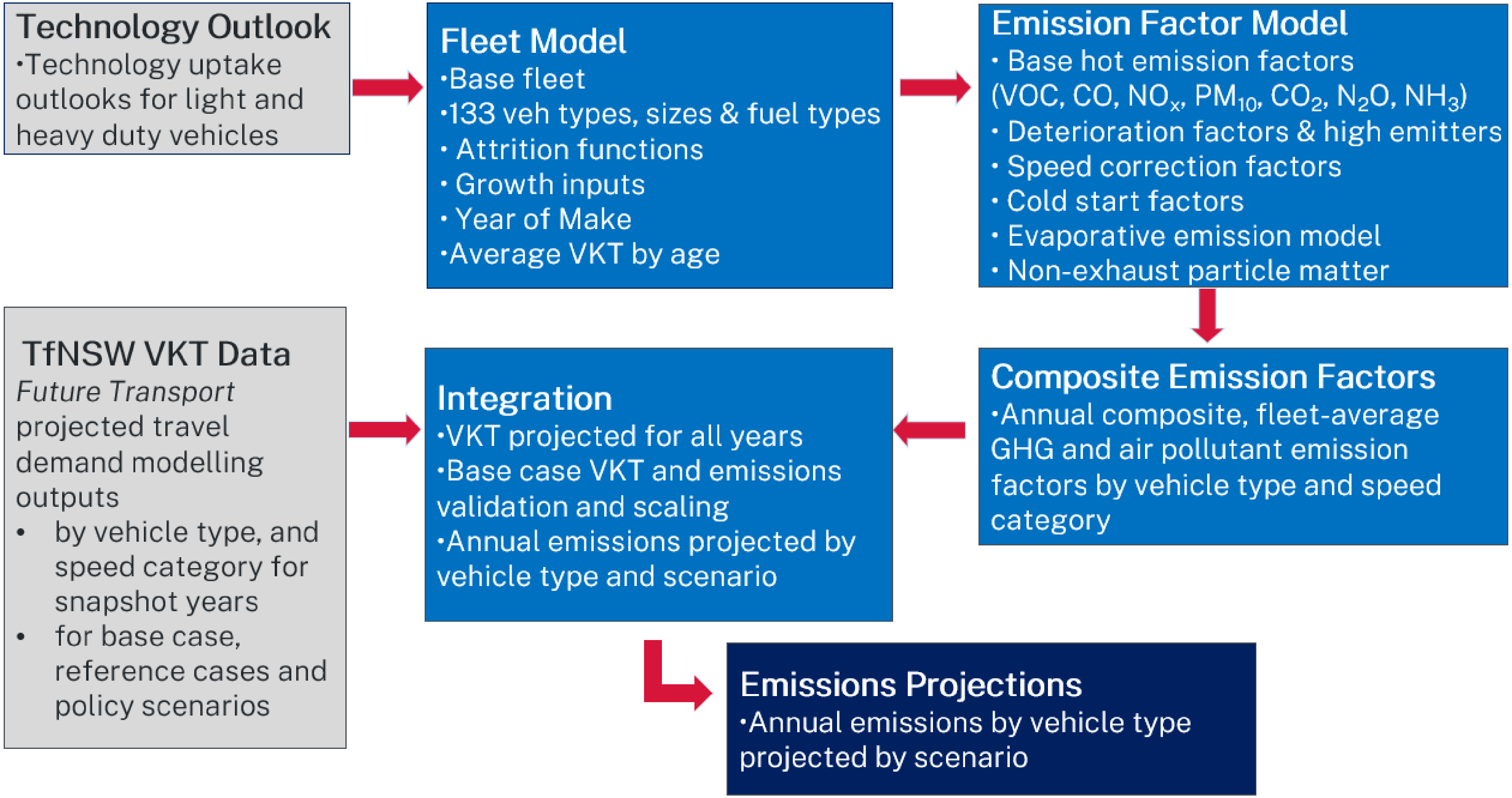

Figure 15 Fleet and emissions modelling applied for base case road transport projections

Fleet and emissions modelling

The NSW fleet and emissions models applied to project road transport emissions are based on models developed for the NSW EPA Air Emissions Inventory (EPA 2012, 2019). These models were extended for NSW application and updated to incorporate the latest emission factors and vehicle sales trends.

The fleet model projects the future fleet profile by estimating fleet growth, vehicle sales and vehicle attrition from a base year of NSW registration data. Vehicle numbers for NSW for the base year of 2012 were taken from the ABS Motor Vehicle Census (MVC) (ABS 2019). Within each light vehicle type (e.g. passenger cars, SUVs, LCVs), the MVC data was apportioned into vehicle sizes based on a detailed analysis of the entire TfNSW registration database. The age profile was calculated to match the TfNSW registration data.

The LDV fleet model 2012 base year was projected forward to December 2020 using year-on-year fleet growth from the ABS MVC for passenger vehicles (including cars and SUVs) and LCVs. This achieved close to identical total LDV stock numbers in 2020. The growth in passenger vehicle and LCV numbers was apportioned into fuel types and the fleet model size categories based on detailed VFACTS sales data (FCAI 2019)[6] supplemented by TfNSW data on new registrations.

Projected growth in the LDV fleet was estimated by fitting saturating curves to the trend of passenger vehicles and LCVs per capita and applying these relationships to the department's population projections (DPE 2022c). For each projection year, the number of vehicles leaving the fleet was estimated using attrition functions, and the annual sales estimated by adding the attrition numbers to the estimated growth in vehicle numbers for the year.

Annual vehicle sales by vehicle type were divided into fuel types (motive power) by applying a percentage of the sales figure. The base case uptakes of BEVs and plugin hybrid vehicles (PHEVs) were adopted from modelling by Veitch Lister Consulting as referenced in the NSW Electric Vehicle Strategy (NSW Government 2021). The sales share of hybrid vehicles was adopted from previous modelling done by the CSIRO for the Australian Government to inform the national GHG emissions projections (Graham et al. 2019). The balance of the projected annual sales was taken to be petrol and diesel in relative proportions fixed at the average observed in the VFACTS sales data for 2019–20 (FCAI 2019).

Rigid and articulated fleet growth is estimated from historical growth in fleet numbers from the TfNSW registration database supplemented by the ABS MVC. Detailed analysis by 30 heavy vehicle configurations (GVM/GCM and truck–trailer combination types by axle configuration) performed by the National Transport Commission (2022) is used to establish historical trends of the total fleet disaggregated by fleet model size category.

The heavy duty vehicle fleet is projected to 2020 from the base year of 2012 by applying the actual growth from the registration records, resulting in 2020 model fleet numbers matching the registration data. New truck sales are estimated from the difference between the growth of the fleet minus the annual attrition; although for heavy vehicles this is complicated by interstate transfer of vehicles and other unidentified factors contributing to erratic year-on-year trends in vehicle numbers by year of manufacture

[6] The Federal Chamber of Automotive Industries (FCAI) publishes monthly and annual vehicle sales data in the VFACTS reports. The department purchases detailed VFACTS reports periodically to support fleet modelling.

(YOM). To estimate future fleet growth a linear regression of historical growth against gross state product (GSP) was performed, as logically the freight task would be expected to increase as economic activity increases.

The uptake rates of zero or low emission heavy vehicles, as a percentage of new vehicle sales, are estimated by consideration of projections from a range of sources (Graham and Havas 2021; Reedman et al. 2021; BNEF 2021b) and including uptake rates for hydrogen-fuelled trucks modelled for the NSW Hydrogen Strategy. Near-term NSW/Australian trends were also informed by current announced policy and original equipment manufacturer announcements regarding supply of low/zero emission trucks to Australia.

Zero emission vehicle uptake is allocated between the fleet model truck sizes considering the duty cycles (loads, trip distances and annual VKT) in relation to technology capability and information on the total cost of ownership of different technologies. It is assumed on this basis that hydrogen-fuel cell vehicles (HFCVs) will be used in the near and medium term where BEVs are not suitable in terms of range and charging times for the heavier long haul operations. Where published technology uptakes are projected as a percentage of the total fleet stock, sales shares were estimated iteratively to match the fleet percentages. For both rigid and articulated trucks, the small uptake of PHEVs was adopted from Graham and Havas (2021), the HFCV uptake modelled next and the BEV uptake modelled last and capped to balance the total fleet technology sales shares to 100%.

The fleet model estimates VKT per vehicle as a function of age based on an analysis of 10 years of pooled data from the ABS SMVU (ABS 2020b). Total fleet VKT was estimated for each vehicle and fuel type category by multiplying the number of vehicles of each YOM by the corresponding annual VKT and summing over the YOMs.

The emissions model estimates the fleet-aggregate emission factors (g/km), allowing total emissions to be calculated by multiplying the VKT by vehicle type and fuel type by the emission factor. Emission factors derive from:

- the Australian National In-Service Emissions (DEWHA 2009) study 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 estimated by reference to the European EMEP Guidebook (EEA 2019), which is the basis of the COPERT model and consideration of the historical Australian data
- diesel vehicle emission factors and fuel consumption based on limited Australian test data and the guidebook/COPERT data (TER 2021)
- the Australian Diesel National Environment Protection Measure (DNEPM) study, which tested pre-ADR70 and ADR70 rigid and articulated trucks
- the South Australian Test and Repair program, which tested pre-ADR70, ADR70 (~Euro I- II) and ADR80/00 (Euro II) trucks
- ADR80/02 (Euro IV) to ADR 80/04 (Euro VI) emissions and fuel consumption are estimated by reference to the European EMEP Guidebook, which is the basis of the COPERT model and consideration of the historical Australian data.

CO_2 emission and fuel consumption factors were extensively reviewed and revised by the department in 2021 to support road transport modelling.

New petrol and diesel vehicles entering the NSW fleet were assumed to be certified to Euro 5 (ADR79/04) and Euro 6 was assumed to be adopted from 2027. Hybrid vehicles and PHEVs were assumed to consume 22–31% and 53–58% less fuel than equivalent internal combustion engine (ICE) light vehicles respectively, based on Green Vehicle Guide data for matching ICE and hybrid/PHEV models and consideration of international studies on the difference between official test results and real-world fuel consumption (ICCT 2017, 2019; TNO 2018). Exhaust emissions are assumed to scale with fuel consumption.

Motorcycle emissions

Motorcycle emissions were projected to 2030 based on national emissions projections for these sectors multiplied by the ratio of NSW emissions to national emissions for each sector for the latest GHG inventory year (2019), with the 2021–2030 trend continued to 2050 (DISER 2020b, 2021a).

Domestic aviation

Domestic aviation refers to civil domestic passenger and freight traffic that departs and arrives in NSW, including take-offs and landings for these flight stages. The subsector includes all aircraft purchasing aviation fuel in NSW for domestic use, including:

- commercial domestic (passenger and freight) flights
- private and charter flights.

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

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

Activity data

Data used in the projection of NSW domestic aviation emissions are listed in Table 21.

Table 21 Data referenced for projection of aviation emissions

Dataset	Description	Source
NSW population	NSW population projections based on Common Planning Assumptions to 2060–61	DPE 2022c
BITRE airport traffic data	Domestic revenue passenger numbers by airport (1985–2022)	BITRE 2022a
APS	Sale of domestic and international aviation fuel in NSW (2010–11 to 2021–22)	DISER 2022a
NSW Greenhouse Gas Inventory	NSW domestic aviation emissions (1990–2020)	DCCEEW 2022d
NGERS facility-level reporting data	kL of fuel combusted in NSW and emissions for commercial aviation	Confidential data provided by the CER

Base case projections approach

Fuel used in aviation is disaggregated into commercial flights, charter flights and other private aircraft use. NGERS data includes fuel (and emissions) for commercial and charter flights. The AES provide fuel consumption for all aviation (total jet fuel and aviation gasoline used in the sector). The AES also include fuel used for military use and this is therefore removed based on an assumption that 8.2% of jet fuel and 0.1% of avgas is assigned for military use (DISER 2022b).[7]

[7] Military reported in a separate category

When military fuel is excluded, the AES fuel consumption is very similar to fuel consumption derived (back calculated) from the total aviation emissions reported under the STGGI. Therefore, to normalise the sum of the total disaggregated emissions to STGGI emissions, the difference between the NGERS reported fuel consumption and the total estimated STGGI fuel consumption is assigned to other private aircraft use.

Disaggregation of emissions into the categories above allows emissions projections to be derived separately, using different growth assumptions where appropriate.

Domestic commercial aviation emissions were projected based on NSW population projections to 2050 and accounting for trends in domestic and regional revenue passenger movements relative to state population numbers over 1990–2022.

Domestic/regional passenger movements have increased at a faster rate than population due to people travelling more (movement/population of 1.1 in 1990 increasing to 3.8 in 2019).

The COVID-19 pandemic has had a significant impact on domestic aviation in NSW, with an approximate 70% decrease in domestic passenger numbers in NSW from FY 2019 to FY 2021. The industry is still in recovery, with FY 2022 domestic passenger numbers in NSW still significantly down on pre-COVID-19 levels (~60%).[8]

The impact of COVID-19 has also halted the trend of increasing passenger movements, with movements in FY 2021 reverting back to 1990 levels of 1.1 movements per population.

In projecting future passenger numbers, there are 2 questions to address:

- What is the expected date for a return to pre-COVID-19 passenger numbers?
- Is the growth in passenger numbers expected to recover to pre-COVID-19 growth rates (i.e. movements/population continue to increase at pre-COVID-19 rates)?

The central traffic forecast used for Waypoint 2050 analysis (ATAG 2021) is based on lower growth rates than experienced in the last decade, with a slow recovery to 2019 levels by 2024 and then a re-baselining of growth. Similarly, the International Air Transport Association (IATA) predicts an industry-wide return to 2019 passenger numbers by 2024, although domestic travel may recover sooner (by 2023) (IATA 2022).

Similar assumptions to these are adopted for our projections with a COVID-19 recovery year of 2024 (for a return to 2019 passenger numbers). However, to account for the ongoing impacts of hybrid work practices and video conferencing, a reduction in business air travel is adopted. Consistent with TfNSW modelling, we have applied a 25% reduction in business air travel from 2024, based on the assumption that corporate travellers comprise 12% of total passenger numbers (PwC n.d.).

In summary, future passenger numbers for NSW are projected out to 2050, as follows:

- for 2023, the linear trend from 2021–2022 is continued
- for 2024, passenger numbers recover to pre-COVID-19 (FY 2019) levels; however, an ongoing reduction of 25% in business travel is assumed
- for 2025–2050, the historical linear trend in growth (1990–2019) is continued.

The resultant trend is shown in Figure 16.

[8] Calculated based on outbound domestic passenger movements in NSW airports (BITRE 2022a).

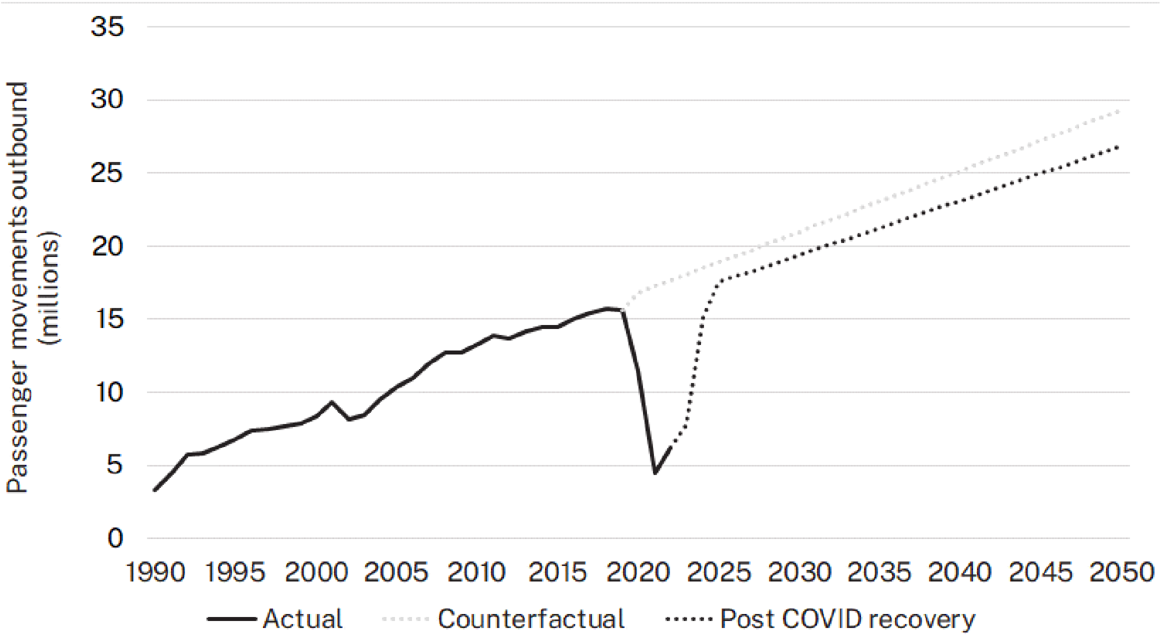

Figure 16 **Projected revenue passenger numbers (outbound) for NSW, 2023–2050**

On the basis of population projections and forecasts for passenger movements per capita, total domestic and regional passenger movements were projected to increase from about 31 million in 2019 to about 53 million in 2050 (down from the previously projected 58 million in our 2021 projections). Passenger movements projected were lower than unconstrained domestic/regional passenger movements projected in the 2010 Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport 2010), but comparable to projections within the Sydney Airport Master Plan (Sydney Airport 2019) for 2039, accounting for Western Sydney Airport Stage 1 passenger projections (Deloitte 2017).

The IATA Fly Net Zero commitment requires member airlines to achieve net zero carbon by 2050, achieved through emissions reductions from efficiency improvements, sustainable aviation fuel (SAF), emerging technology (hydrogen, electric) and offsets (IATA 2021). Passed in October 2021, the commitment is not directly referenced by major airlines operating in NSW (as of October 2022).

In March 2022, the Qantas Group released its Climate Action Plan (Qantas 2022), which commits to average fuel efficiency improvements of 1.5% per year from 2023–2030 (baselined to 2019) and investment in SAF to ensure 10% in the fuel mix by 2030 and 60% by 2050. Qantas fuel efficiency improvements are included in the base case projections; however, it is anticipated that commitments for investment in SAF locally in NSW would require some government support for local production. Qantas's current purchasing agreements for SAF are for international flights out of London and California. For this reason, potential emissions reductions for SAF are not included in base case projections for NSW.

Similarly, IATA commitments for efficiency improvements and SAF have not been adopted into firm commitments by other commercial airlines in NSW; however, it is assumed that the IATA fuel efficiency improvements of 3% below BAU by 2035 will be adopted by commercial airlines in NSW (noting that the Qantas commitment goes beyond this commitment).

Base case projections also do not account for technology shift towards electric propulsion or a revolutionary shift to zero emission aircraft (i.e. hydrogen).

In summary, base case projections account for:

- population growth and associated growth in revenue passenger numbers
- Qantas's commitment for a 1.5% per year fuel efficiency improvement for 2023–2030 (with no further fuel efficiency beyond 2030)
- other commercial airlines complying with the IATA fuel efficiency improvement commitment of a 3% improvement on BAU by 2035.

Projections for private, charter and other non-commercial flights were based on NSW population projections to 2050, with a linear increase in emissions assumed with population. No other assumptions (fuel efficiency or technology shift) are made for projections in private and charter flights.

A summary of the estimated emissions by category is presented in Figure 17.

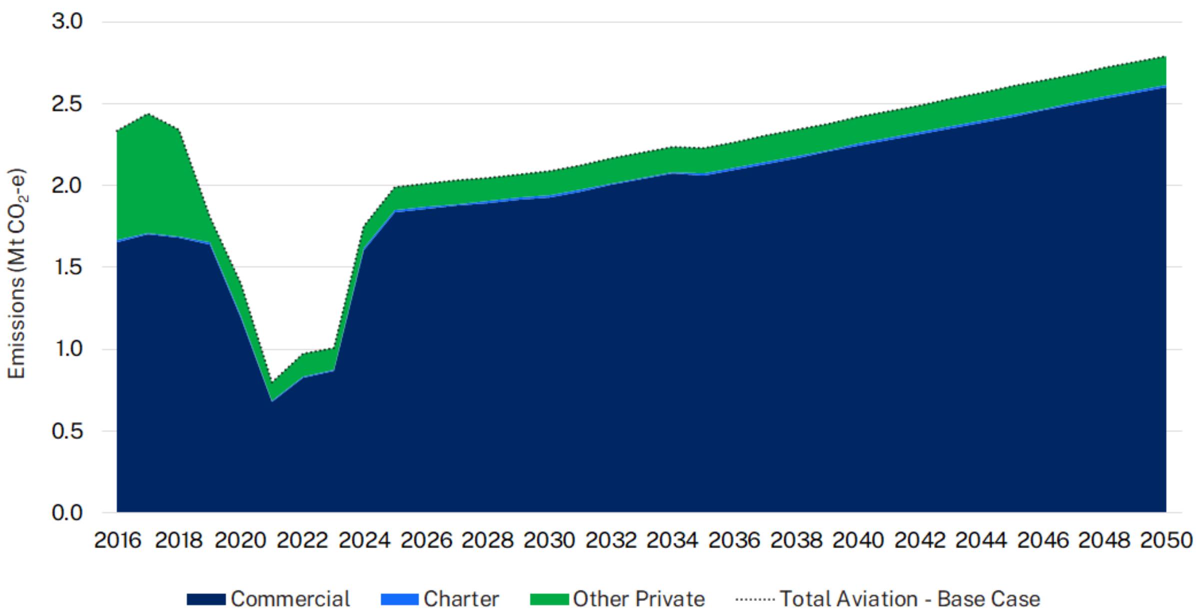

Figure 17 Emission estimates for subcategories within the aviation subsector

Railways

The railway subsector includes 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 electricity generation sector.

Activity data

Data used in the projection of NSW railway emissions are listed in Table 22.

Table 22 Data referenced for projection of railway emissions

Data reference	Description	Source
NSW population	NSW population projections based on Common Planning Assumptions to 2060–61	DPE 2022c
AES	Annual energy consumption in NSW for rail transport	DCCEEW 2022c
BITRE rail statistics	Kilometres travelled	BITRE 2021
ARTC and TfNSW – rail network data	Gross tonne kilometres (GTK)	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	Confidential data provided by the CER
NSW Greenhouse Gas Inventory	NSW rail emissions (2011–2020)	DCCEEW 2022f
TfNSW	Utilisation of passenger trains to allow for energy usage adjustment for passenger numbers	TfNSW 2022e
TfNSW	Train patronage – monthly figures	TfNSW 2022e

Base case projections approach

Emissions for passenger trains were projected based on NSW population projections to 2050, accounting for trends in passenger movements over the period 2016–2021. Historical passenger movements are taken from Opal data and used to derive average passenger movements per population (passenger/population ratio). The impact of the COVID-19 pandemic on passenger movements is observed in a significant drop in passenger/population ratios for 2020 and 2021.

The assumed COVID-19 recovery year is 2024, with future passenger numbers from this point projected based on the pre-COVID-19 average passenger/population ratio (average of data from 2016–2019). Prior to this, the lower 'COVID-19 period' passenger/population ratio is used for the period 2021–2023. The diesel consumption for passenger trains is then projected based a diesel intensity factor (kL per passenger movement), which is derived from historical diesel consumption data (2016–2020). The diesel intensity is also calculated for the pre-COVID-19 and COVID-19 periods.

Emissions for freight trains are estimated based on projected diesel consumption, derived based on commodity projections (GKT) and the historical fuel efficiency (L per GKT) for each commodity (derived from historical data 2016–2018). Fuel efficiency improvements for freight are also considered within the base case, with a 10% improvement in fuel efficiency assumed as a progressive linear annual improvement from 2020–2030. The abatement included for fuel efficiency is based on existing industry targets and commitments to decarbonise, for example:

- Aurizon have set a target of 10% emission intensity reduction by 2030, outlined in their 2020 Climate Strategy and Action Plan (Aurizon 2020)
- Pacific National have committed to 50 new C44 Evolution locomotives in their fleet between 2021 and 2026, resulting in 9% less emissions than existing NR class

locomotives and the installation of trip optimiser software on all existing NR class locomotives, with reported fuel savings of 6% (Pacific National 2021).

Domestic waterborne navigation

This subsector includes scope 1 emissions associated with all civilian (non-military) marine transport of passengers and freight, including coastal shipping (freight and cruise ships), interstate and urban ferry services, and other vessels and small pleasure craft movements in NSW. Fuel use in military vessels and international shipping is excluded. Similarly, energy usage at ports, marinas and other ancillary marine functions is included within other sector inventories.

Activity data

Data used in the projection of NSW navigation emissions are listed in Table 23.

Table 23 Data referenced for projection of navigation emissions

Data reference	Description	Source
NSW population	NSW population projections based on Common Planning Assumptions to 2060–61	DPE 2022c
AES	Annual fuel consumption in NSW for domestic (coastal) water transport	DCCEEW 2022c
BITRE statistics	Port based maritime activity	BITRE 2022b
	Australian aggregate freight forecasts	BITRE 2019
NGERS facility-level reports	kL of fuel combusted in NSW, emissions by type for water freight and passenger transport and water support services	Confidential data provided by the CER
NSW Greenhouse Gas Inventory	NSW domestic navigation emissions (2011–2020)	DCCEEW 2022f
Opal	Public transport on ferries trip data	TfNSW 2022d

Base case projections approach

Fuel use for domestic navigation is disaggregated into categories (coastal shipping, water passenger/ferries transport and other vessels/small pleasure craft). NGERS data includes fuel (and emissions) for water freight transport, water passenger transport and water transport support services. The AES provide total fuel consumption for water transport by fuel type (fuel oil, diesel and auto-gasoline). The AES include fuel used for military use, and this is therefore removed based on an assumption that 31.1% of diesel use in this subsector is military (DISER 2022b). When military fuel is excluded, the annual contribution of each fuel type to total fuel consumption in this subsector is ~10–20% fuel oil, ~35–40% diesel and 40–50% auto-gasoline.[9]

[9] Based on AES data from 2016–2020

STGGI emissions data is disaggregated by fuel type using these splits, resulting in a derived (back calculated) fuel consumption that is very similar to the AES. Fuel consumption is then assigned to the categories as follows:

- all fuel oil is assigned to coastal shipping (and taken from the STGGI normalised fuel consumption)
- diesel and gasoline for coastal shipping is taken from NGERS reported fuel consumption for water freight transport and support services
- diesel and gasoline for passenger/ferries is taken from NGERS reported fuel consumption for water passenger transport
- diesel and gasoline for other vessels and pleasure craft is the difference between total STGGI derived fuel and NGERS fuel assigned to the other categories.

Disaggregation of emissions into the categories above allows emissions projections to be derived separately, using different growth assumptions where appropriate. Emissions for ferries and other vessels and pleasure craft are projected based on NSW population projections to 2050, with a linear increase in emissions assumed with population. Emissions for coastal shipping are projected based on BITRE projections for coastal shipping to 2041 (BITRE 2022b), with a linear trend continued from 2042–2050.

A summary of the estimated emissions by category is presented in Figure 18.

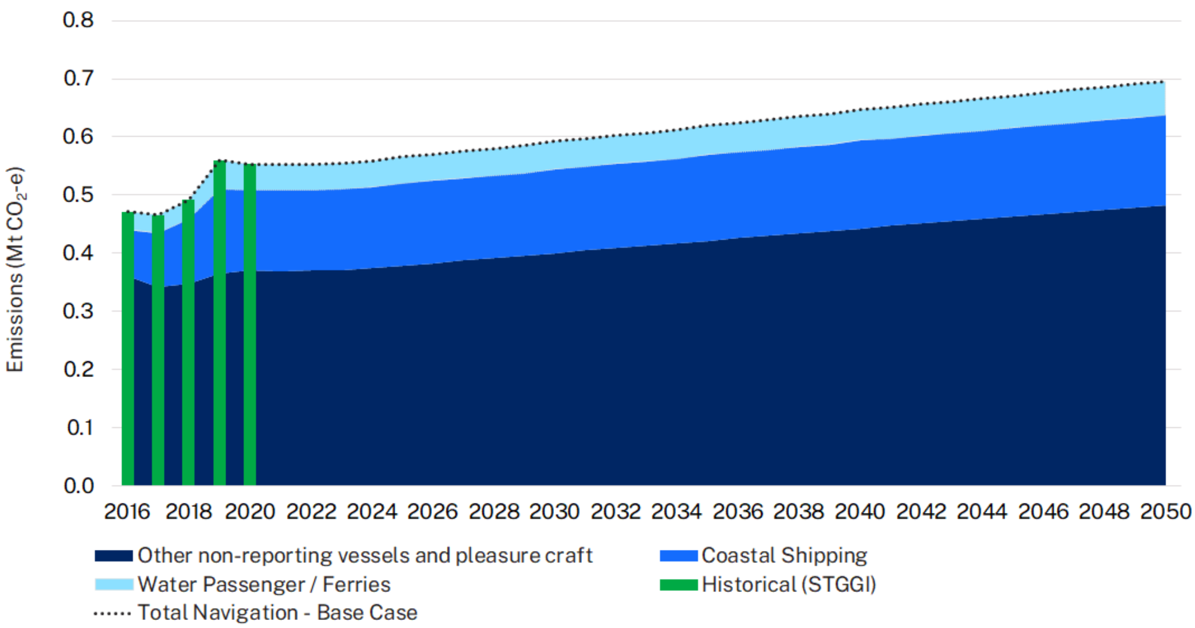

Figure 18 **Emission estimates for subcategories in the domestic waterborne navigation subsector**

Other transport sources (pipeline transport, off-road)

There are 2 subcategories included in this subsector: pipeline transport and off-road recreational 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, with the combustion of natural gas making up approximately 90% of the reportable scope 1 emissions from the sector. Two main gas pipeline operators report 100% of the natural gas consumption for the sector.

It is noted 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).

Activity data

Data used in the projection of NSW pipeline transport emissions are listed in Table 24.

Table 24 Data referenced for projection of pipeline transport emissions

Data reference	Description	Source
NSW population	NSW population projections based on Common Planning Assumptions to 2060–61	DPE 2022c
AES	Annual fuel consumption in NSW for 'Other transport, services and storage'	DCCEEW 2022c
NGERS facility-level reports	NSW emissions for pipelines and other transport	Confidential data provided by the CER
NSW Greenhouse Gas Inventory	NSW domestic navigation emissions (2011–2020)	DCCEEW 2022f

Base case projections approach

Base case emissions from pipeline transportation are projected based on NSW population projections to 2050, with a linear increase in emissions assumed with population.

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.

Off-road vehicles that are classified in 1.A.4 Other Sectors are dealt with elsewhere and are excluded from this subsector, for example:

- commercial/institutional off-road vehicles
- residential off-road vehicles such as lawn mowers
- agricultural forestry and fishing off-road vehicles
- military transport.

Activity data

Data used in the projection of NSW off-road recreational vehicles are listed in Table 25.

Base case projections approach

Base case emissions from off-road recreation vehicles are projected based on NSW population projections to 2050, with a linear increase in emissions assumed with population.

Table 25 **Data referenced for projection of off-road recreation vehicle emissions**

Data reference	Description	Source
NSW population	NSW population projections based on Common Planning Assumptions to 2060–61	DPE 2022c
AES	Auto-gasoline consumption in NSW for 'other transport services and storage'	DCCEEW 2022c
NGERS facility-level reports	kL of fuel combusted in NSW, emissions by type	Confidential data provided by the CER
NSW Greenhouse Gas Inventory	NSW emissions for 'other transportation' (2011–2020)	DCCEEW 2022f

Transport base case emissions projections

Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the NSW transport sector are shown in Figure 19. Transport emissions have increased year-on-year since 1990, with pre-COVID-19 emissions almost 50% higher than in 1990.

Road transport currently accounts for about 90% of transport sector emissions with light vehicles accounting for about 65% and the balance, primarily from road freight. Aviation emissions are the next largest source of transport emissions, with smaller contributions from other modes.

Future transport emissions are projected to be reduced due to ongoing COVID-19 impacts on travel behaviour, lower population growth compared to pre-COVID-19, and due to the market-driven uptake of EVs particularly within the light vehicle fleet. By 2050, base case transport emissions are projected to be of a similar order to 1990 levels with the percentage share of light vehicle emissions projected to reduce as freight and aviation emissions continue to increase in the 2030s and 2040s.

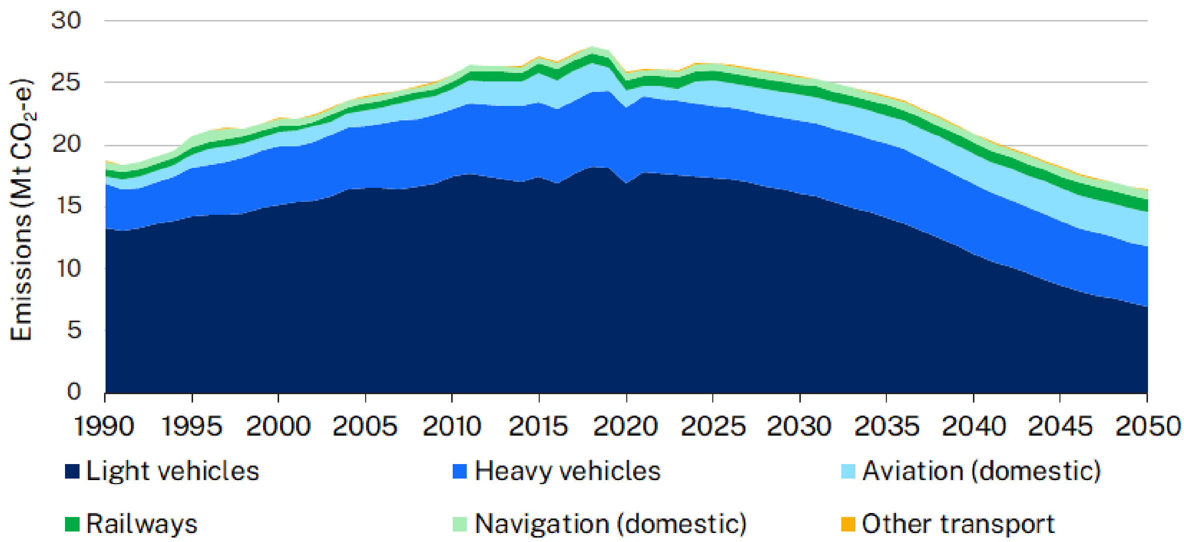

Figure 19 **Transport emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**

Current policy emissions projections

Programs under the Net Zero Plan and related major NSW Government policies that address transport emissions (Table 2) include:

- NSW Electric Vehicle Strategy – comprises actions to ensure more than 50% of new car sales are EVs by 2030 and includes rebates for EV buyers, fleet incentives for business and councils and investment in EV charging infrastructure
- Zero Emissions Bus Transition Strategy – provision for the transition of NSW's 8,000 strong bus fleet to zero emission buses by 2030 as announced by the NSW Minister for Transport in October 2019 (TfNSW 2022a)
- Transport Consumer Information – development of a comparative motor vehicle fuel economy star rating to better inform consumers about the environmental impact of their vehicle choices and assist their decision-making
- NSW Hydrogen Strategy – released in October 2021, this strategy sets out policies to drive decarbonisation in hard to abate sectors, including transport. Relevant 2030 stretch targets in the plan include the production of 110,000 tonnes of green hydrogen per year; achieving a hydrogen price under AU$2.80 per kg; provision of 100 refuelling stations; achieving 10,000 hydrogen vehicles in the NSW stock and including 20% of the NSW Government heavy vehicle fleet being hydrogen fuelled
- NSW Future Energy Strategy and Action Plan – outlines TfNSW's commitment to securing energy needs from sustainable sources and supports the transport sector's transition to net zero emissions by 2050. This includes using electric and hydrogen fuel cell vehicles and adopting systems that improve the operational efficiency of passenger and freight transport (TfNSW 2020a, 2020b)
- NSW Future Transport Strategy – outlines TfNSW's commitment to achieving net zero emissions from their operations and fleet by 2035, with actions including the procurement of 100% renewable energy; electrifying TfNSW's buses, ferries, corporate vehicles and non-passenger vehicle fleets; progressively identifying opportunities for strategic rail electrification; and supporting optimal use of green hydrogen. Addressing freight emissions is noted to be a priority in the strategy (TfNSW 2022b).

The NSW fleet and emissions models were applied to projected changes in emissions due to major programs. Emissions reductions were also forecast for future actions under Stages 2 and 3 of the Net Zero Plan under committed NSW CCF funding. Based on the extent of emissions in the transport sector and remaining opportunities for abatements, the projections assume that about 30% of the funding over 2030–2050 would be invested in driving further reductions in transport emissions with a focus on aviation and residual road transport emissions. Projections include emissions reductions for railways due to the TfNSW regional rail project, which aims to upgrade the regional fleet to operate in bi-mode configuration (using overhead power when operating on the electrified section of the network and diesel–electric motors when operating outside the electrified network) (TfNSW 2022b).

The integrated abatements in the road transport sector modelled to be achieved as a result of these programs are shown in Figure 20, with resultant current policy projections for this sector compared to base case projections in Figure 21. Emissions reductions continue to increase as the fleet turns over and the share of EVs and zero emission buses and trucks in the stock increases.

Under current policies and future funding, annual transport emissions are projected to reduce by about 2 Mt CO_2-e by 2030, with reductions of around 9 Mt CO_2-e by 2040. With increasing decarbonisation of the electricity grid, the potential for indirect (scope 2) emissions from grid electricity consumption will reduce significantly, with reductions in direct scope 1 emissions far exceeding indirect emissions.

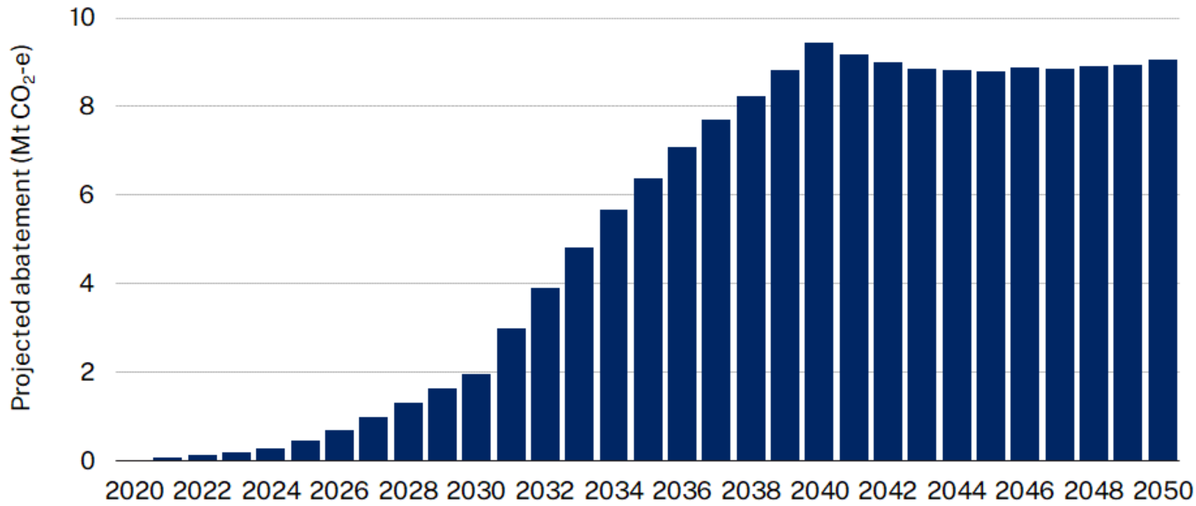

Figure 20 **Abatement of road transport emissions projected to be achieved by Net Zero Plan Stage 1 programs**

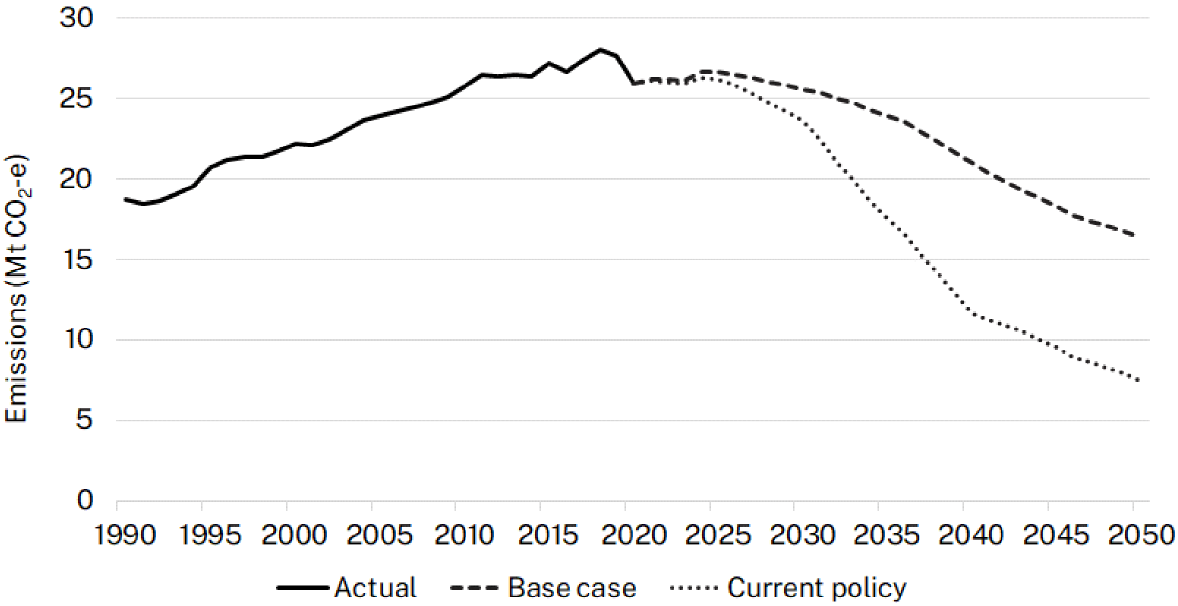

Figure 21 **NSW transport emissions as inventoried (1990–2020), with base case and current policy emissions projections (2021–2050)**

Inventoried emissions (1990–2020) and current policy emissions projections (2021–2050) for the NSW transport sector are shown in Figure 22. Light vehicles are projected to reduce significantly in terms of absolute emissions and percentage share of transport sector emissions, residual heavy duty vehicles and aviation are projected to become the dominant source of remaining transport emissions in the 2040s.

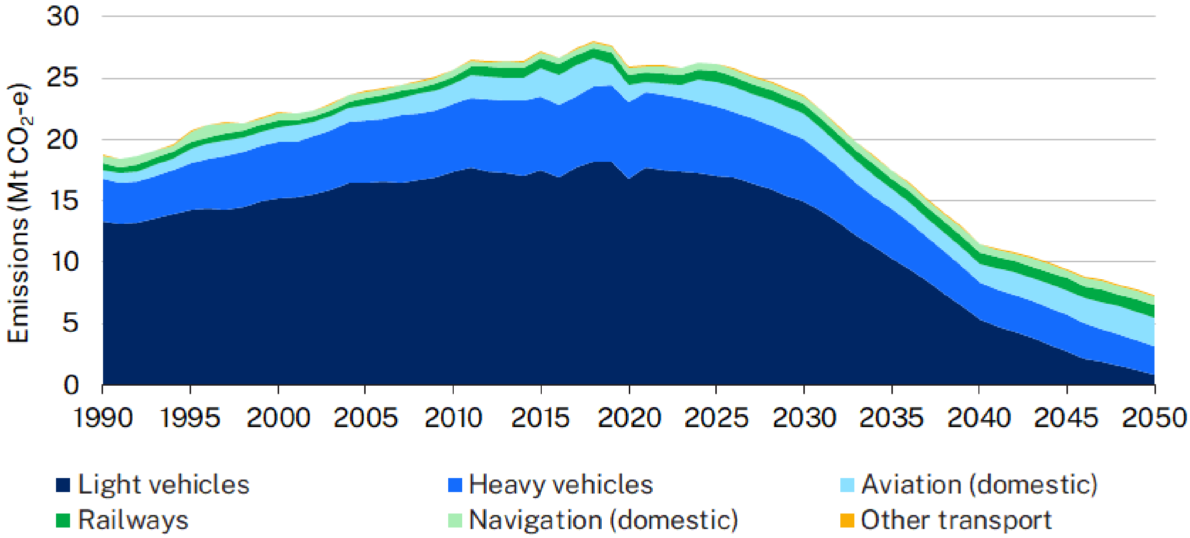

Figure 22 **Transport emissions by subsector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)**

Considerations for projection updates

Future projection updates will consider:

- integrated vehicle uptake modelling accounting for state and recent federal policies and market changes
- more detailed analysis of the pace of transition within the aviation industry, considering how industry commitments and technological advances will impact domestic aviation
- updated evidence of the ongoing impacts of COVID-19 on road transport and aviation
- alignment with passenger rail and passenger ferries projections from TfNSW, including the ongoing impact of work-from-home practices
- abatement within the navigation sector, including fuel efficiency and emissions standard improvements for outboard engines, electrification of commercial and recreational vessels and renewable energy shore power for White Bay and Glebe Island
- impacts of policies and programs not included in the 2022 projections, including actions under the recently released NSW Future Transport Strategy.

Fugitive emissions from fuels

Fugitive emissions from fuels refers to GHGs 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.

Base case emissions projections

Fugitive emissions are projected separately for coal mining, and oil and gas fugitives.

Data on recent fugitive emissions are sourced primarily from NGERS facility emissions. Coal fugitive emissions projections for each mine are modelled using ROM coal production forecasts provided by the Department of Regional NSW's Minerals, Exploration and Geoscience group (Department of Regional NSW 2022).

Gas fugitive emissions projections are based on the 2021 AEMO GSOO forecasts of gas supply, particularly the central case (scenario 1) (AEMO 2021).

The 2022 GSOO (AEMO 2022b) did not include a central case forecast. A comparison of the 2021 vs 2022 low gas price scenario gas production forecasts showed that the 2022 forecasts were on average 3% lower. As it was unclear how this change would affect the fugitive emissions from gas projects, the production forecasts were held at 2021 levels.

A more detailed description of the modelling for coal mining and oil and gas fugitives is given below.

Coal mining fugitives

Fugitive emissions from underground coal mines involve the release of CH_4 and CO_2 during:

- coal extraction where coal seams, overburden and underburden strata are fractured
- post-mining activities where residual gases within the coal are released during the handling, transportation and stockpiling of coal
- the flaring of coal mine waste gas
- the venting or other fugitive release of gas from the underground mine before coal is extracted from the mine.

Fugitive emissions from open-cut mines in NSW generally result from the extraction process but can involve the other sources of emissions described for underground mines.

Fugitive emissions may also occur from decommissioned underground coal mines. This may include leakage to the atmosphere through fractured gas bearing strata, open vents and seals over daily to decadal timescales. However, emissions will be reduced by flooding of the mine, which prevents desorption of gases from the remaining gas bearing strata in the decommissioned mine.

Active open-cut and underground coal mining

Coal mining fugitive emissions data are sourced by mine based on data reported under NGERS. Projections for these emissions are calculated as a function of future ROM coal production using mine-specific emission intensity factors based on the latest reported emissions and on ROM coal production forecasts.

Historical ROM coal production data is externally sourced from Coal Services Pty Ltd (Coal Services 2022). ROM coal production data is also obtained from the NGERS matters to be identified (MTBI) data as a cross-check. Fugitive emission intensity factors (based on the latest financial year reported) are calculated per mine as tonnes of CO_2-e/tonne of ROM coal.

Coal production is projected to 2050 using the Department of Regional NSW (Mining, Exploration and Geoscience) 'most likely' ROM coal production forecasts (June 2022). Sensitivity testing is conducted based on assumptions regarding potential minimum and maximum coal production scenarios. Future emissions are calculated for each mine by multiplying the latest fugitive emission factor by the projected ROM coal tonnages; this assumes continuous extraction of coal with no changes in the gassiness (i.e. CH_4 content) of the seams being worked.

Modelling approach

The fugitive emission factor $EF_{j,T}$ is derived according to:

$$EF_{j,T} = \frac{E_{j,T}}{Q_{j,T}}$$

where:

$EF_{j,T}$ = the emission factor in tonnes of CO_2-e per tonne of ROM coal produced by mine j and base year T

$E_{j,T}$ = the total fugitive emissions for mine j and base year T sourced from NGERS in tonnes of CO_2-e; this includes coal extraction related emissions, venting, flaring, and post-mining emissions

$Q_{j,T}$ = the quantity of ROM coal produced for mine j and base year T in tonnes, sourced from Coal Services.

For the projection of total fugitive emissions for facility j and year t (where t > T):

$$E_{j,t} = Q_{j,t} \times EF_{j,T}$$

where:

$E_{j,t}$ = the projected fugitive emissions for mine j and year t in tonnes of CO_2-e

$Q_{j,t}$ = the projected quantity of ROM coal produced for mine j and year t

$EF_{j,T}$ = the emission factor in tonnes of CO_2-e per tonne of ROM coal produced by mine j and base year T.

The $Q_{j,t}$ is obtained from the NSW Department of Regional NSW (Mining, Exploration and Geoscience) ROM coal production forecasts (Department of Regional NSW 2022).

Exceptions

For underground coal mining, NGER Methods 1–4 are allowable depending on the type of fugitive emission. For open-cut mining, Methods 1–3 are also allowable; however, Method 1 is based on a state average emission intensity factor (also based on ROM coal production) that can lead to inaccurate GHG estimates.

Three open-cut coal mines used Method 1 to report fugitive emissions to NGERS: Maules Creek, Mt Pleasant and Namoi Sunnyside. Following consultation with DISER, the department has adopted the DISER recommended emission intensities.

In general, fugitive emissions data for open-cut mines are checked for the NGER method used. If NGER Method 1 is used, advice is sought from DISER on the best approach and alternative emission factors are used.

Decommissioned coal mines

Decommissioned mine emissions are projected using a model utilising NGER Method 1 for decommissioned mines. The model uses historical emissions, coal production and date of closure. The input data for currently decommissioned mines was obtained from the MTBI dataset. For mines forecast to be decommissioned in the next 1–2 years, the variables had to be estimated. The variables include:

- date of mine closure – estimated as the last day of the financial year when the mine is to be decommissioned
- total coal mined – estimated using the total ROM coal produced for the mine provided by NSW Department of Regional NSW (Mining, Exploration and Geoscience; Royalties)
- mine gassiness – depends on the region in which the coal is mined – coal mined in western NSW tends to be less gassy whereas coal mined in the Southern Highlands or the Hunter Valley tends to be gassy
- flooding constant (F_{dm}) – emissions are proportional to the time that a mine is flooded. This variable is backsolved using the variables above and the last reported NGER emissions for the facility.

These variables are then used to calculate emissions (t CO_2-e) using NGER Method 1. For facilities with reported emissions and no historical coal production data available, a ratio of emissions by projected year over the base year (2019–20) for facilities with data is applied.

Modelling approach

Under NGER Method 1 the emissions for decommissioned underground mines are calculated by:

$$E_{dm} = \left(E_{t,dm} \times EF_{dm} \times (1 - F_{dm})\right)$$

where:

E_{dm} = the fugitive emissions of CH_4 from the mine during the year measured in t CO_2-e

$E_{t,dm}$ = the fugitive emissions from the mine for the last full year the mine was in operation measured in t CO_2-e

EF_{dm} = the emission factor for the mine

F_{dm} = the proportion of the mine flooded at the end of the year and must not be >1.

EF_{dm} is calculated by the following:

$$EF_{dm} = \int_{T-1}^{T} (1 + A \times t)^b - C \, dt$$

where:

T = the number of years since the mine was decommissioned

A, b and *C* are constants that depend on whether the mine is gassy or non-gassy.

F_{dm} is calculated by the following:

$$F_{dm} = \frac{M_{WI}}{M_{VV}} \times T$$

where:

M_{WI} = the rate of water flow into the mine in cubic metres per year – this can either be measured or have fixed values depending on whether the mine is located in the southern coalfields or in the Newcastle, Hunter, Western or Gunnedah regions

M_{VV} = the mine void volume in cubic metres

T = the number of years since the mine was decommissioned.

For currently decommissioned mines, E_{dm} is reported in NGERS, and EF_{dm} is calculated using data reported in the MTBI, namely the gassiness of the mine, F_{dm} and the mine closure date.

For mines soon to be decommissioned, the input data includes an estimate of mine closure date used for T, the appropriate average water inflow rates for M_{WI} and the total tonnes of ROM coal mined, divided by 1.425 to give the void size (M_{VV}). These parameters are then used to compute F_{dm} .

Key changes compared to the 2021 projections

In line with company announcements, the Dendrobium extension project was removed and operations at Mt Arthur were forecast to ramp-down for an expected 2030 closure. Other changes included scaling back the number of strategic release areas from 5 to one, and including the Hunter Valley Operations extension project.

The number of decommissioned underground mines was expanded from 29 to 47 in the current projections.

Oil and gas fugitives

This section focuses on the fugitive emissions produced by the gas industry as there is essentially no oil refining industry in NSW since the closure of the Kurnell oil refinery in 2014.

The fugitive emissions of CH_4 and CO_2 associated with gas supply relate to:

- natural gas exploration, which includes emissions from drilling, flaring during exploration and emissions from well completions and workovers
- natural gas production, which includes leakages from onshore wells and well-pad operations, onshore gas gathering and boosting equipment and stations, water production, including compressors, dehydrators, pipelines and treatment plants
- natural gas processing plant leakages
- natural gas transmission pipeline and storage leakages
- natural gas distribution pipeline leakages including emissions
- fugitive emissions of both CH_4 and CO_2 from venting and flaring from gas production and processing.

For gas transmission pipelines, fugitive emissions are fixed as these emissions only depend on the length of the pipeline; for example, the MSP and the EGP.

For gas distribution networks, the forecast fugitive emissions depend on the annual terajoules (TJ) of utility gas sales. For the largest distribution network in NSW, the Jemena Gas Network (JGN), information on future forecasts in utility gas sales are being requested from Jemena. For the purpose of the 2022 projections, the average of the 6 years of NGERS fugitive emissions data (2015–16 to 2020–21) was taken as constant over the projection period.

For most other smaller distribution networks, future trends in utility gas sales are similarly not known, with emissions fixed at the average of the 6 years of NGERS fugitive emissions data over the projection period.

The fugitive emissions forecasts included 3 key developments: 1) the PKGT, 2) the NGP and 3) the Queensland–Hunter Gas Pipeline (QHGP). The PKGT and NGP were assumed to commence operations in 2023 and 2025, respectively. Fugitive emissions data for the NGP and PKGT were obtained from EIS available in the public domain. The EIS provided emissions data for maximum production values.

The main gas production forecasts for the NGP and PKGT were modelled using the AEMO GSOO Central Case (scenario 1) (AEMO 2021) after reviewing the available data in GSOO 2022 as discussed above. The fugitive emissions were scaled according to the fraction of production in a given year compared to maximum production.

In the case of the NGP, the base case assumes imported grid electricity based on a decarbonising grid with the NSW Electricity Infrastructure Roadmap being implemented.

The QHGP was assumed to be delivering gas in 2025, and it is assumed it will be delivering gas from the NGP (and Queensland) to Sydney. According to the EIS (DPIE 2019), there will be no gas compression in NSW and therefore the emissions are only due to pipeline fugitives (which depend only on the length of the pipeline and are therefore constant over time).

The AEMO GSOO 2021 projections extend to 2040, with emissions forecast to 2050 held constant at 2040 values.

Base case fugitive emissions projections

Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the NSW fugitive emissions sector by subsector are shown in Figure 23. Emissions are expected to grow over this decade due mainly to increased coal mining activity and natural gas developments. Without abatement, fugitive emissions from fuel are projected to reach 17.1 Mt CO_2-e in 2030.

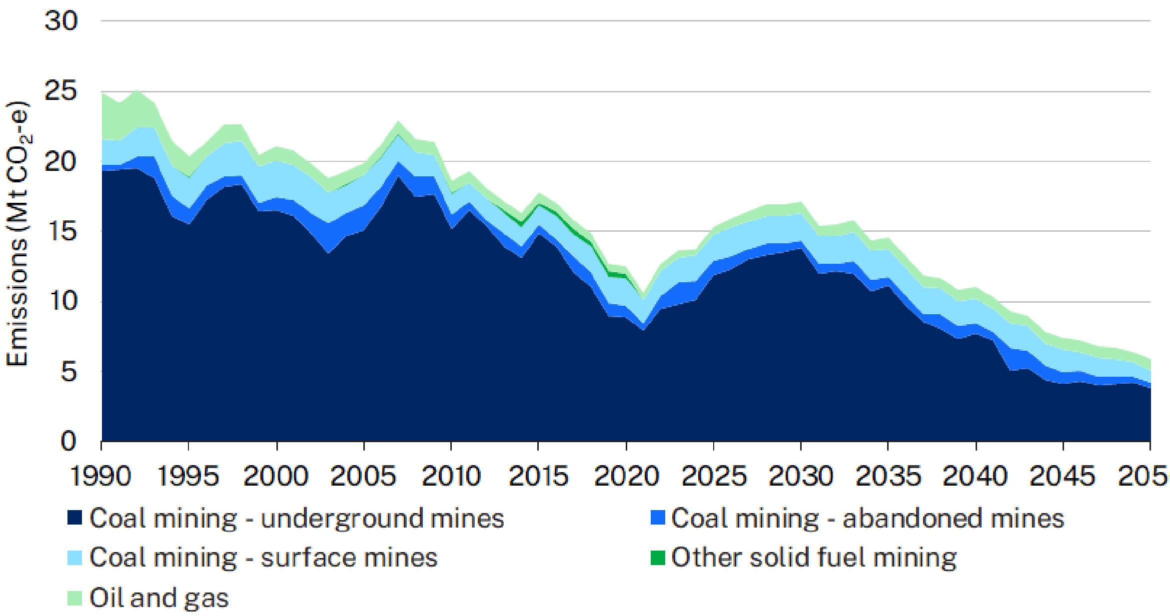

Figure 23 **Fugitive emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**

Coal and gas fugitive emissions are projected to be higher than published in 2021 (Figure 24). This is due to higher emission intensities being used in the projections for coal mine extension projects with published site-specific measurements, and fugitive emissions from potential decommissioning of the mine being addressed more comprehensively.

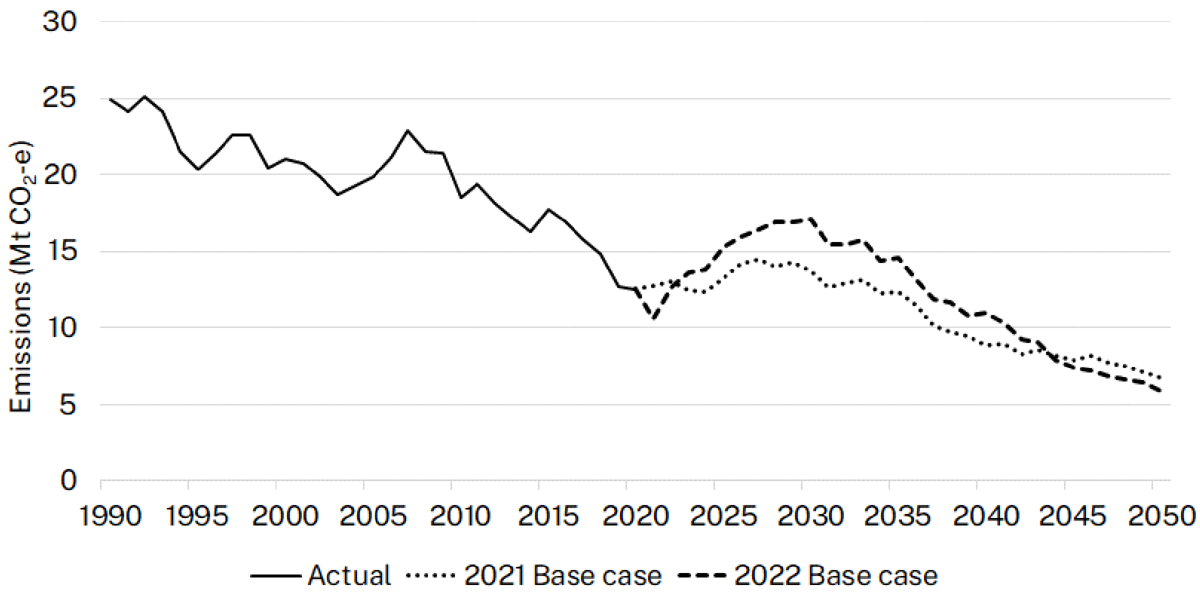

Figure 24 **Comparison of 2021 and updated 2022 base case fugitive emissions projections**

Current policy emissions projections

Opportunities to abate fugitive emissions have been identified for NSW coal mines in recent studies commissioned by NSW agencies. In a 2021 assessment of abatement opportunities at NSW's gassiest underground coal mines (Palaris 2021), gas drainage and ventilation air methane (VAM) abatement opportunities were identified at 8 underground coal mines. The study found 80 Mt CO_2-e of abatement in mines under BAU, and 110 Mt CO_2-e of potential additional abatement over the life of these mines. It recommended a transition to longer-term emissions forecasting, mine planning and abatement, maximising CH_4 gas capture and utilisation, and/or CH_4 destruction through flaring. A key recommendation was for mines to pre-drain CH_4 gas from coal seams as early as possible.

A more recent study (Palaris 2022) identified opportunities for abating fugitive emissions at underground and open-cut mines. After considering cost, technology readiness, scalability, emissions reduction potential, viability and lead times for implementation, the study recommended the consideration of:

- pre-drainage and gas flaring (2-year horizon) and gas utilisation (5-year horizon) at open-cut mines
- optimisation of pre- and post-drainage (2-year horizon), improved ventilation strategies (5-year horizon) and VAM abatement technologies (10-year horizon) at underground mines.

Abatement of fugitive emissions is within the scope of NZIIP (Table 2), and particularly the High Emitting Industry focus area, with priorities including:

- Priority 1 – deploy opportunities to reduce industrial emissions ($200 million); for example, pre-mining and/or goaf gas drainage with power generation or flaring
- Priority 2 – accelerate strategic abatement opportunities ($105 million); for example, VAM abatement
- Priority 3 – develop low carbon infrastructure and industrial precincts ($55 million).

The CINSW funded South32 VAM abatement demonstration facility project will support progress towards VAM abatement in the sector. This project includes site trials and demonstration of a full-scale next-generation thermal VAMMIT unit with a safe ducting system at South32 Illawarra Metallurgical Coal. Project outcomes include full-scale VAMMIT demonstrated with improved safety and commercial viability.

The 2022 current policy projections assume the anticipated NSW EPA Climate Change Policy and Action Plan and the reform of the Safeguard Mechanism by the Australian Government will support the adoption of available technologies leveraging current investments under NZIIP and CINSW.

Based on a mine-by-mine analysis of the extent of mine emissions, the remaining mine life and findings from technical feasibility studies, emissions reductions of 3–4 Mt CO_2-e per year were estimated to be achievable from this sector. VAM abatement at gassy underground mines contributes significantly to this estimate and if this measure is applied after 2032 the estimated abatement will primarily materialise in the 2030s and 2040s.

Technological advances could result in opportunities for abatement to occur earlier and may support further abatement opportunities such as options for achieving greater abatement at open-cut mines. The current policy projections ambitiously assume earlier initiation of VAM abatement (e.g. 2028) will be plausible at some gassy underground mines under NZIIP incentives and revised policy settings, bringing forward abatement forecasts (Figure 25). It is further assumed that future actions under Stages 2 and 3 of the Net Zero Plan under committed NSW CCF funding are able to deliver deeper abatement. The resultant current policy projections for this sector compared to base case projections are shown in Figure 26.

If this abatement does not materialise under NZIIP by 2030, the associated funding will have been directed elsewhere, and realising emissions reductions in other sectors. The department's annual update of sector emissions projections will account for such revisions.

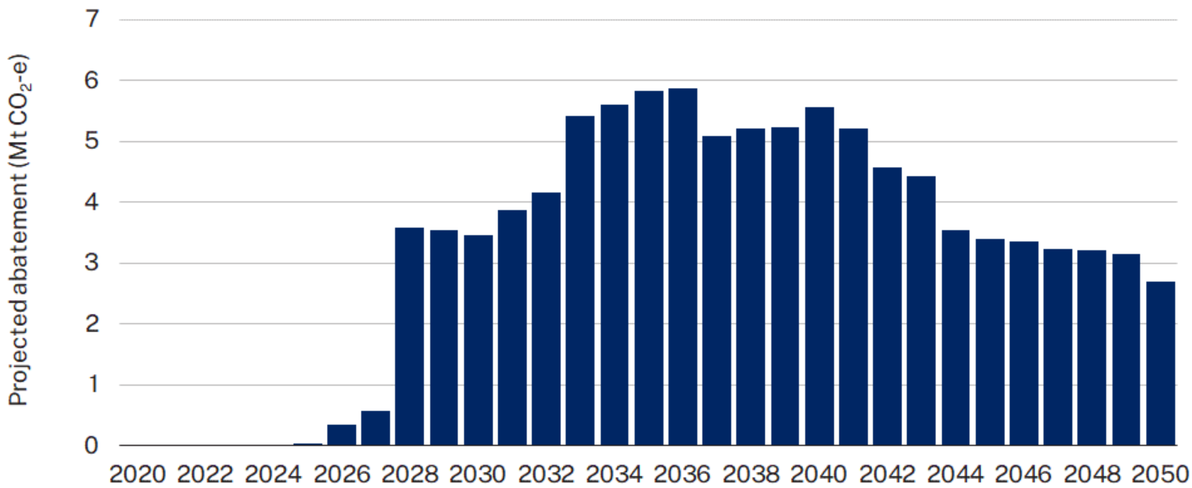

Figure 25 **Abatement of fugitive emissions from underground coal mining projected to be achieved by Net Zero Plan Stage 1 programs**

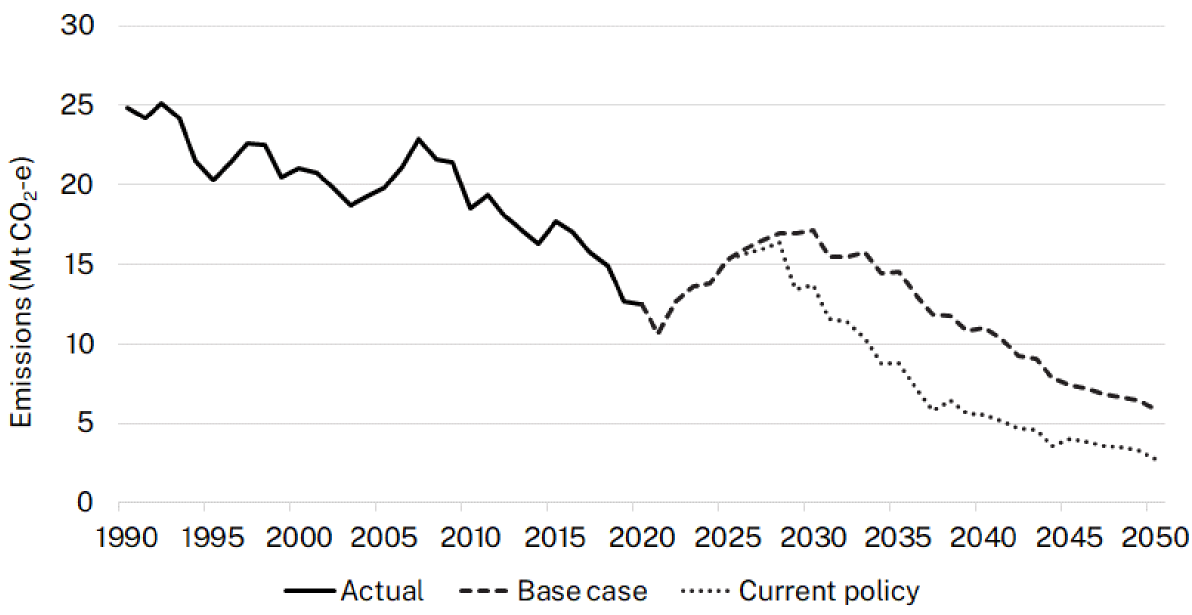

Figure 26 **NSW fugitive emissions (including coal and oil and gas) as inventoried (1990–2020), with base case and current policy emissions projections (2021–2050)**

Inventoried emissions (1990–2020) and current policy projections (2021–2050) for the NSW fugitive emissions sector by subsector are shown in Figure 27.

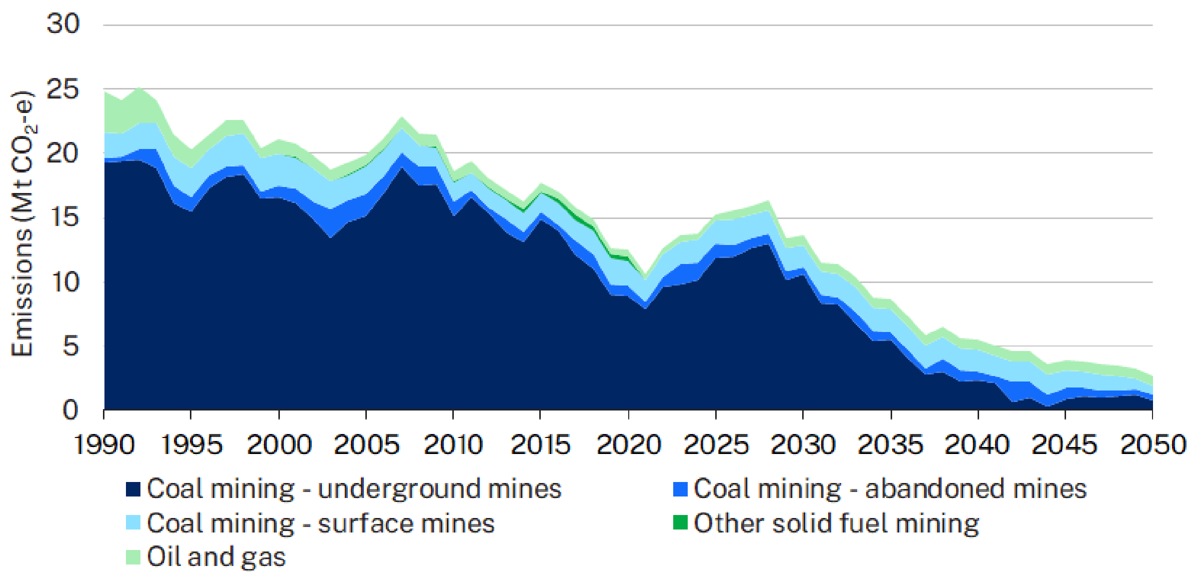

Figure 27 **Fugitive emissions by subsector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)**

Considerations for projection updates

Future projection updates will:

- consider the latest NGERS data, EIS information for new projects and updated coal and gas production and consumption forecasts (considering forecasts from major gas suppliers if available)
- revisit assumptions regarding the likely uptake of incentives to abate coal mining fugitives under NZIIP, and the potential for further abatement as a result of revised policies and market trends
- revisit the estimated fugitive emissions reductions to be achieved from the full-scale VAM abatement project at South32's Illawarra coal mine, co-funded by CINSW (Department of Regional NSW 2022)
- consider the impact of new corporate commitments announced and potential changes to the Australian Government's Safeguard Mechanism on the emission intensity projections for coal and gas fugitives.

Industrial processes and product use

Base case IPPU emissions projections have been substantially refined by:

- integrating the latest NGERS data, EIS information for new projects and commodity forecasts
- incorporating sectoral efficiency and productivity improvements (in place of assuming the emission intensity of future production will remain constant)
- considering corporate carbon reduction commitments.

A detailed overview of the revised approach applied is therefore provided below.

In this section 'BAU' refers to business-as-usual projections, with no abatement applied. The base case projections integrate abatement estimated to occur as a result of firm corporate commitments and federally funded emissions reduction projects.

Projections approach

Bottom-up model

Facility-specific projections were applied for industries in NSW for which facility-level production data are available.

The emissions are calculated according to the formula:

$E_t = E_{t-1}\ \Delta production$

where:

E_t = emissions in year t (tonnes CO_2-e)

E_{t-1} = emissions in the previous year

$\Delta production$ = percentage change in production between year t and year t–1.

Top-down model

A top-down model is applied when the bottom-up model is not valid. Application of the top-down model depends on the emission source and the availability of data. This uses either revenue projections or population projections; for example:

- revenue projections from IBISWorld (IBISWorld 2022), based on IBISWorld revenue growth rates
- population projections (DPE 2022c), where the emissions are calculated according to the formula:

$\mathrm{E_t} = \mathrm{E_{t-1}}\ \Delta population$

where:

$\Delta population$ = percentage change in population between year t and year t–1.

Chemicals industry

This includes ammonia and nitric acid production, and consumption of acetylene, anaesthetics and aerosols.

Historical IPPU emissions were collated from NGERS facility data for the sector.

Ammonia production

For ammonia production 2 growth scenarios were considered for the Orica Kooragang Island facility (the largest ammonia production facility in NSW): a steady growth scenario (capped at 0.345 Mt p.a.) and a domestic growth scenario.

The domestic growth scenario was selected as the main BAU scenario because the planned ammonia plant expansion and upgrade plan will likely increase the ammonia and ammonia nitrate production (Orica AEMR 2021).

Published information from Orica was used in the domestic growth scenario assuming that ammonia production will grow linearly from ~0.310 Mt p.a. in FY 2021 to 0.385 Mt p.a. in FY 2030. Production is capped at 0.385 Mt p.a. from FY 2030 (Orica AEMR 2021).

Current GHG emission intensities for FY 2021 are assumed to remain constant until FY 2050.

The base case projection is developed based on the BAU projection, but accounting for firm abatement commitments (Orica CAR 2021) as show in Table 26. Reference is made in the table to a potential future technology identified within Orica's decarbonisation pathways analysis; this measure is not included in the base case projection.

Table 26 Firm abatement commitments for ammonia production

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Carbon capture, utilisation and storage (demonstration plant)	Demonstration plant to be built by end of 2023 (Orica 2021) (Subsequent Carbon Capture, Use and Storage applications, 2028–2050)	Demonstration plant will have access to 0.25 Mt CO_2 captured from Orica's operations Total reduction 40,000 tonnes CO_2-e p.a. based on similar projects (MCi 2019)	$14.6 million Australian Government funding for MCi to establish a mineral carbonation mobile demonstration plant at the Orica site (MCi 2021)

Orica's Climate Action Report (Orica CAR 2021, p.24) discusses switching from natural gas to hydrogen produced from renewable electrolysis as a promising opportunity to eliminate emissions over the long term. However, Orica notes that it will depend on the cost-effective supply of large quantities of renewable electricity, the extent and speed of cost reductions for electrolysis and growth to commercial scale.

The production of green ammonia via switching to hydrogen is considered a pathway opportunity rather than base case or current policy abatement. Table 27 summarises green ammonia opportunities identified for the Orica Kooragang Island facility.

Table 27 Green ammonia opportunities for Orica Kooragang Island

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Green ammonia (switch from natural gas to renewable hydrogen)	2041–2050	Total emissions reduction of 0.3 Mt CO_2-e p.a.	Discussed by proponent (Orica CAR 2021); no firm commitment

Nitric acid production

For nitric acid production, 2 growth scenarios were considered for the Orica Kooragang Island facility (the largest nitric acid production facility in NSW): a steady growth scenario based on DCCEEW's Australia's emissions projections 2020 for chemicals (DISER 2020a) and a domestic growth scenario (capped at 0.605 Mt p.a.). The domestic growth scenario was selected as the main BAU scenario because of the planned nitric acid plant expansion (Orica AEMR 2021).

From FYs 2022–2030, DCCEEW's 2020 emissions projection are used. For FYs 2031–2050, published information from Orica is used. This assumes that the additional nitric acid plant will be completed in 2030, and production of nitric acid will grow linearly from 2031 to reach 0.605 Mt p.a. in 2050. The maximum capacity is 0.605 Mt p.a. (Orica AEMR 2021).

Table 28 DCCEEW forecasts for chemical industry, percentage change in production

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
2.4%	2.4%	1.0%	0.4%	0.5%	0.9%	0.9%	0.9%	0.4%	0.5%

Note: As per the stationary energy emissions projections for chemicals, for FYs 2022–2031, Australia's 2020 chemical industry emissions projections (DISER 2020a) are used instead of the 2021 projections (DCCEEW 2022a). This is because the 2021 projections had included the Emissions Reduction Fund EnviNOx project at the Orica Kooragang Island facility with production from other smaller facilities factored in.

The base case projections are developed based on the BAU projection, with no additional abatement identified for nitric acid production.

Note that:

- continued operation of selective N_20 catalyst abatement at Orica is already accounted for through lower emission intensities based on recent NGERS data
- the proposed Kooragang Island Decarbonisation Project involving EnviNOx implementation to deliver a 48% reduction in site emissions is co-funded by the NSW Government and is therefore accounted for within current policy projections.

Acetylene, anaesthesia and aerosols

For acetylene, anaesthesia and aerosols, a population projection approach is used for the BAU projections. There is no specific facility emissions data under NGERS; therefore NSW data from the STGGI (DCCEEW 2022f) for carbide processing was used as the basis for the calculation. The data is scaled by the annual percentage change in NSW population (DPE 2022c) as per DCCEEW projection methods.

The base case projection is the same as the BAU projection since there are no abatement commitments for these subsectors.

Metals industry

This sector covers the aluminium industry through production and consumption of carbon anodes and fluorocarbon gases. It also covers iron and steel (coke consumption) and lead-alloys.

Iron and steel production

Several BAU emission scenarios have been considered, based on the percentage change in output from the key production facility (BlueScope Port Kembla). Scenarios considered included the TfNSW commodity demand forecasts (TfNSW 2022g) and the BNEF NEO 2021 growth scenario (BNEF 2021a).

The OCE projection scenario (for FYs 2022–2027) and domestic growth scenario (using the OCE CAGR (FYs 2028–2050) were selected as the BAU main scenario. This projection better reflects the future production capacity and provides a central estimate between the upper (TfNSW 2022g) and lower limit (BNEF NEO 2021; BNEF 2021a) scenarios.

The main scenario for steel production is identical to that assumed for stationary energy related iron and steel emissions. The current GHG emission intensity for FY 2021 is assumed as a constant until FY 2050.

For FYs 2022–2027, a combination of data from the OCE were used (OCE REQ (June 2022) and OCE REQ (March 2022) forecasts) covering 2025–2027 for forecasting iron and steel production in NSW as shown in Table 29.

Table 29 OCE forecasts for iron and steel percentage change in production

2022	2023	2024	2025	2026	2027
–7.3%	–1.0%	–0.4%	0.003%	0.0007%	0.0001%

From FYs 2028–2050, a domestic growth scenario is assumed with new production expansion continuing. The steel production growth rate is assumed to be equal to the OCE CAGR of 0.9%, as stated in the OCE REQ March 2022 forecast (DISER 2022e).

The base case projection is developed based on the BAU projection but takes into account corporate abatement commitments.

A review of GHG emissions abatement actions for Port Kembla Steelworks identified actions already implemented, such as increased use of scrap steel in production (BlueScope CAR 2021). The emissions reductions of these actions are already accounted for within the BAU projections. This is reflected in the NGERS data, where the emission intensity calculated for 2020–21 is about 2% lower than in 2018–19. The BAU projection was therefore taken to be the base case projection.

Reference is made in Table 30 to the green steel technology identified for the Port Kembla Steelworks (i.e. a pathway opportunity); however, this measure is not included in the base case projections.

Table 30 Green steel opportunities for Port Kembla Steelworks

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Green steel – Hydrogen DRI, (DRI–Melter-BOF or DRI-EAF)	2041–2050 (Breakthrough technologies possible after 2030)	64% reduction of residual emissions after the base case abatement	BlueScope in its 2021–22 Sustainability Report (BlueScope 2022b) notes that it: • is installing and commissioning a 10 MW hydrogen electrolyser to explore and test green hydrogen in its blast furnace

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
			operations at Port Kembla Steelworks (possible blending with natural gas) • is exploring the establishment of a hydrogen hub in the Illawarra region • has commenced a concept study on producing low emissions iron through the use of Direct Reduced Iron (DRI) from Pilbara iron ores. The intention is to develop this DRI using green hydrogen, produced from renewable electricity

Aluminium production

The major emission source in this subsector is from aluminium production. The emissions projections are based on the percentage change in output from the Tomago aluminium facility. Scenarios considered included a steady production scenario and the BNEF NEO 2021 growth scenario (BNEF 2021a).

A domestic growth scenario was chosen based on OCE forecasts (FYs 2022–2027) and a CAGR from FYs 2028–2050. For FYs 2022–2027, a combination of data from the OCE were used (OCE REQ (June 2022) and OCE REQ (March 2022) forecasts) covering 2025–2027 for forecasting aluminium production in NSW as shown in Table 31.

Table 31 OCE forecasts for aluminium percentage change in production

2022	2023	2024	2025	2026	2027
–0.87%	2.87%	–0.44%	1.32%	1.30%	0.00%

For FYs 2028–2050, the domestic growth scenario (OCE CAGR) assumes that new production expansion will continue. The aluminium production growth rate is assumed to be equal to the OCE CAGR of 0.6% for FYs 2022–2027, as stated in the OCE REQ (March 2022) forecast (DISER 2022e).

Tomago Aluminium's current production capacity is near 0.6 Mt p.a., and the allowed full capacity is 0.6 Mt p.a. (TAC AER 2021). Despite there not being any further development plans, the future production capacity was assumed to grow based on the domestic growth scenario. The current GHG emission intensity for FY 2021 is assumed as a constant until FY 2050.

Base case projection is developed based on the BAU projection, with abatement commitments shown in Table 32.

Table 32 Abatement commitments for aluminium

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Reduce perfluorocarbon (PFC) emission	2022–2050	Total reduction increases 0.6% p.a. and stays at 6% from 2030 PFC emissions account for 12% of the total scope 1 emissions; assumes that 50% of PFCs will be captured	Safeguard Mechanism website (CER 2020d) Tomago Aluminium has several PFC emissions reduction trials underway and has committed to installing an upgraded version of its pot control system in 2020 that has the potential to reduce PFC emissions in operations

Lead production

The scale of emissions from lead recycling is relatively small in the metal industry. One facility converts used lead acid batteries into metallic lead for reuse. The lifetime of a lead acid battery is assumed to be 5 years. To forecast the production of recycled lead, a simple model was used based on the percentage change in number of vehicles.

To forecast the change in recycling rates for used lead acid batteries, the linear regression of the change in the number of registered motor vehicles in Australia is used. This data is obtained from the ABS 2021 MVC (ABS 2022). The emissions for a domestic growth scenario projection are calculated according to the formula:

$$E_t = E_{t-1}\, \Delta number\ of\ vehicles\ (t-5)$$

where:

E_t = emissions in year t (tonnes CO_2-e)

E_{t-1} = emissions in the previous year

$\Delta number\ of\ vehicles\ (t-5)$ = the percentage change in the number of vehicles between year t–6 and year t–5. This time delay refers to the 5-year lifetime of a lead acid battery.

A review may be required in the future. The growth of EVs might lead to a switch from lead acid to lithium-ion batteries.

Mineral products

This sector includes cement clinker use, lime production, glass production (use of carbonates), magnesium production, soda ash use, iron and steel (use of carbonates), ceramic production and other unspecified use of limestone and dolomite.

The sector is split into the 8 subsectors listed above and NGERS facility emissions data aggregated for each subsector.

Cement clinker production

The BNEF NEO 2021 growth forecast for cement clinker production in Australia (BNEF 2021a) was adopted as the proxy for modelling the BAU growth in cement and lime production.

Boral’s Berrima cement facility production is used as the basis for the BAU main scenario projection. The current production capacity is 1.09 Mt p.a. of cement, the maximum capacity is 1.56 Mt p.a. Clinker production is 1.4 Mt p.a. (Boral 2022a).

Given the continuous growth of the Australian population and construction activities, it is assumed that the future cement clinker production gradually increases to 1.96 Mt p.a. in 2050, according to BNEF NEO 2021 scenario (BNEF 2021a).

The current GHG emission intensity for cement clinker production at the Boral Berrima facility in FY 2021 is assumed constant until FY 2050.

The base case emissions projections are developed based on the BAU projections and consider abatement commitments discussed in Boral's 2022 Sustainability Report (Boral 2022b) as shown in Table 33.

Table 33 Abatement commitments for cement clinker production

Abatement commitment	Estimated FY for implementation	Estimated scope 1 abatement	Details/funding
Clinker substitution and other process improvements	2022–2050	Reductions range from 3% in 2022 up to 14% by 2048	Corporate commitment
Carbon capture, utilisation and storage (pilot plant for mineral carbonation)	2028–2050	Total reduction starts at 50,000 t CO_2-e in 2028 up to 100,000 t CO_2-e p.a. in 2030 by applying Low Emissions Intensity Lime And Cement (LEILAC) technology	$30 million from the Australian Government's Carbon Capture, Use and Storage Development Fund, collaboration with Calix (Calix 2022)

Other subsectors

The forecast for iron and steel (use of carbonates) is correlated to the production projection of iron and steel (see iron and steel subsector under Metals industry). Using the BAU main scenario projection, the percentage change in iron and steel production is assumed to be the same as the percentage change in use of carbonates. The current GHG emission intensity for FY 2021 is assumed as a constant until FY 2050.

The remaining 5 subsectors are forecast to experience following revenue/production growth rates given in Table 34 based on IBISWorld forecasts (IBISWorld 2022) to FY 2026.

Table 34 Revenue and production for mineral product subsectors

	2021	2022	2023	2024	2025	2026
Glass production	–10.3%	–0.8%	1.5%	2.9%	2.5%	2.2%
Magnesium production	–	–	–	–	–	–
Unspecified limestone and dolomite use	–	–	–	–	–	–
Soda ash use	–10.3%	–0.8%	1.5%	2.9%	2.5%	2.2%
Ceramics	–7.3%	8.0%	5.7%	1.5%	0.2%	2.5%

After FY 2026, a linear regression was applied to extend the projection to FY 2050. The exceptions to the above are magnesium production and unspecified limestone and dolomite use. For magnesium production, emissions are a fixed value over time as only one relatively small facility in NSW produces magnesium (based on data provided by DCCEEW). Only 2 relatively small facilities in NSW contribute to emissions from unspecified limestone and dolomite use, so these are also held fixed over time.

Product uses as a substitute for ozone depleting substances

This sector comprises emissions of synthetic gases from the use of halocarbons in refrigeration and air conditioning, foam blowing, fire extinguishers, aerosols/metered dose inhalers and solvents. A complete description of the sector is given in the 2020 National Inventory Report (DISER 2022b).

Historical emissions of halocarbon substances are estimated based on the STGGI data, with the NSW share of the total mass of HFCs in Australia attributed based on the percentage of the state's population.

Based on the Cold Hard Facts report (DAWE 2020, 2021) the Australian Government is phasing-down the importation of equipment with halocarbon refrigerants. HFC consumption is being phased-down from 2018 towards a target to be achieved in 2036. The target, capped by the Australian Government, is 15% of the average of HFC imports and 75% of average hydrochlorofluorocarbon (HCFC) imports for 2011–2013.

As detailed data on HFC and HCFC containing stock (e.g. air conditioners and refrigerators) is not available for NSW, DCCEEW's emissions projections from 2022–2035 were adopted, with an assumed linear trend in emissions for 2036–2050. According to DCCEEW (2022b), the projections also account for the impact of proposed measures to inform refrigeration and air-conditioning equipment owners of the benefits of regular maintenance. These measures will reduce refrigerant leaks, improve the energy performance of refrigeration and air-conditioning equipment, and reduce emissions from HFCs.

Other – non-energy

Non-energy products from fuel and solvent use

Facility data for this subsector is not captured under NGERS; therefore, the tonnes of lubricant used is based on data provided by DCCEEW. Emissions are calculated using the relevant energy content and emission factors. For projections to 2050, 2020 emissions are adjusted for annual percentage changes in NSW population (DPE 2022c).

Other product manufacture and use

The subsector covers sulfur hexafluoride leaks from electrical switchgear, emissions of N_20 from aerosol products and anaesthesia and polymer use. Facility data for this subsector is not captured under NGERS; therefore, recent historical emissions were obtained from DCCEEW. Projections to 2050 used 2020 as the base year and future emissions were calculated by adjusting for annual percentage changes in the NSW population (DPE 2022c).

IPPU – base case projections

Updated base case emissions for IPPU are projected to be lower than published in 2021 (Figure 28). Despite preference given to more conservative domestic growth scenarios as the basis for IPPU base case projections, the updated projections are lower due to emissions reductions due to firm corporate commitments and federally funded projects being accounted for.

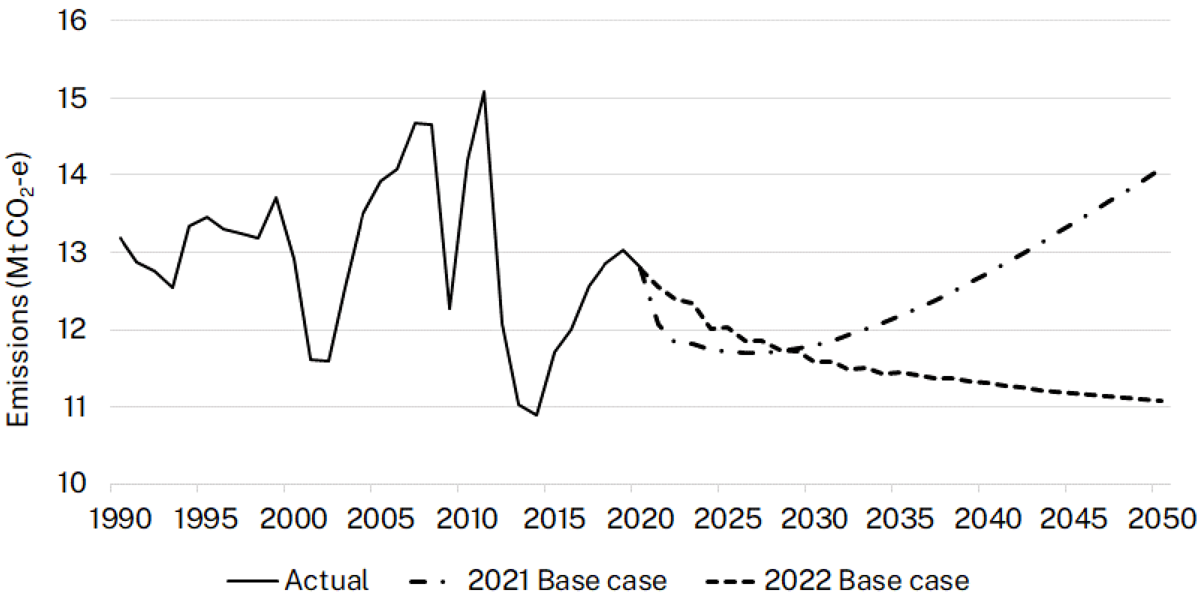

Figure 28 **Comparison of 2021 and updated 2022 base case emissions projections for IPPU**

Base case IPPU emissions projections

Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the NSW IPPU sector by subsector are shown in Figure 29.

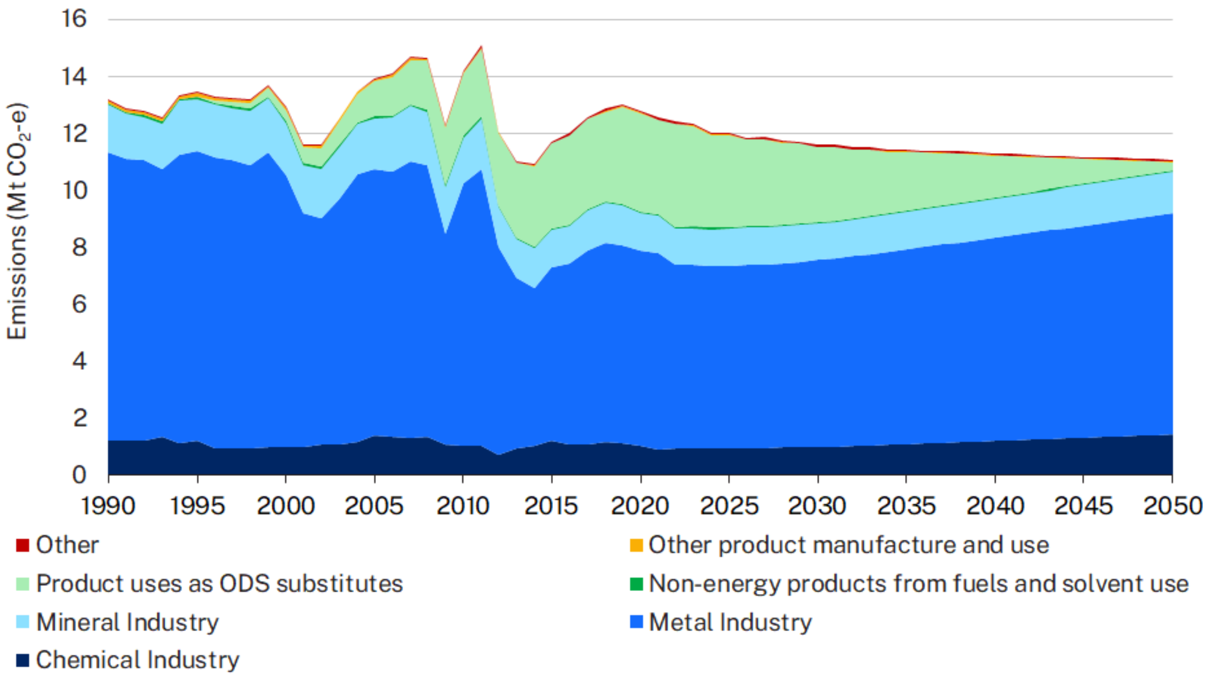

Figure 29 **IPPU emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**

This sector currently produces about 10% of NSW emissions. Metal production (iron, steel, ferro-alloys, aluminium and others) account for more than half of the sector's emissions, with smaller contributions from the minerals and chemicals industries.

Abatement identified as base case includes reduction of PFCs in aluminium production. For cement production, clinker replacement, process improvements and CO_2 sequestration (e.g. through mineral carbonation processes). For ammonia production, a demonstration scale mineral carbonation plant was proposed for the Orica Kooragang Island facility.

No base case abatement was identified for iron and steel IPPU emissions. Rather significant process changes through the use of the hydrogen DRI process (a pathway opportunity) for example, was needed to achieve significant emissions reductions. Similarly, another pathway opportunity was found in green ammonia (switching from natural gas to hydrogen). The large iron and steel and ammonia production facilities are pursuing research and development-scale investigations of the various 'green' production technologies, but no firm commitment to full implementation has been made at this stage.

Another major emission source is halocarbon replacements for ozone-depleting substances, such as refrigerant gases in imported equipment, which has accounted for about a quarter of sector emissions in recent inventory years. The Australian Government has a program to phase-down the import of goods containing halocarbons with high global-warming potential. The NSW Government has no complementary measures for reducing HFCs at this time.

Without NSW Government action, future emissions for the IPPU sector are projected to be relatively static in the near term, increasing by about 1% to 2030. Assuming no significant shift in the emission intensity of industrial processes, sector emissions are projected to grow in line with commodity forecasts in the longer term.

Current policy emissions projections

Industrial process emissions within manufacturing are specifically addressed by NZIIP, including the High Emitting Industry, New Low Carbon Industry Foundations and Clean Technology focus areas. The Business Decarbonisation Support program supports emissions reductions within primarily medium to large energy users in industrial and commercial sectors, and the Hydrogen Strategy will also support abatement within this sector (Table 2).

Detailed abatement modelling was undertaken for each program, accounting for program funding allocations and annual expenditure profiles, specific actions under each program, abatement costs ($/t CO_2-e abated) and forecasts of likely private investment to be leveraged. Current policy abatement for IPPU also included the EnviNOx N_2O abatement project at the Orica Kooragang Island facility, which is supported by the NSW Government. Additional emissions reductions were also projected for the IPPU sector under Stages 2 and 3 of the Net Zero Plan under committed CCF funding based on top-down modelling.

The projections assume earlier implementation of green steel at BlueScope Port Kembla and green ammonia at Orica Kooragang Island supported by investment under the NSW Hydrogen Strategy, the National Hydrogen Strategy and associated federal funding, corporate commitments and plans (refer to earlier sections), and breakthrough technologies for local steelmaking. Abatement of up to 3–4 Mt CO_2-e for green steel after 2040 and about 0.3 Mt CO_2-e for green ammonia, starting in 2035, is assumed in the projections.

The abatement in the IPPU sector modelled to be achieved as a result of these programs is shown in Figure 30, with resultant current policy projections for this sector compared to base case projections in Figure 31.

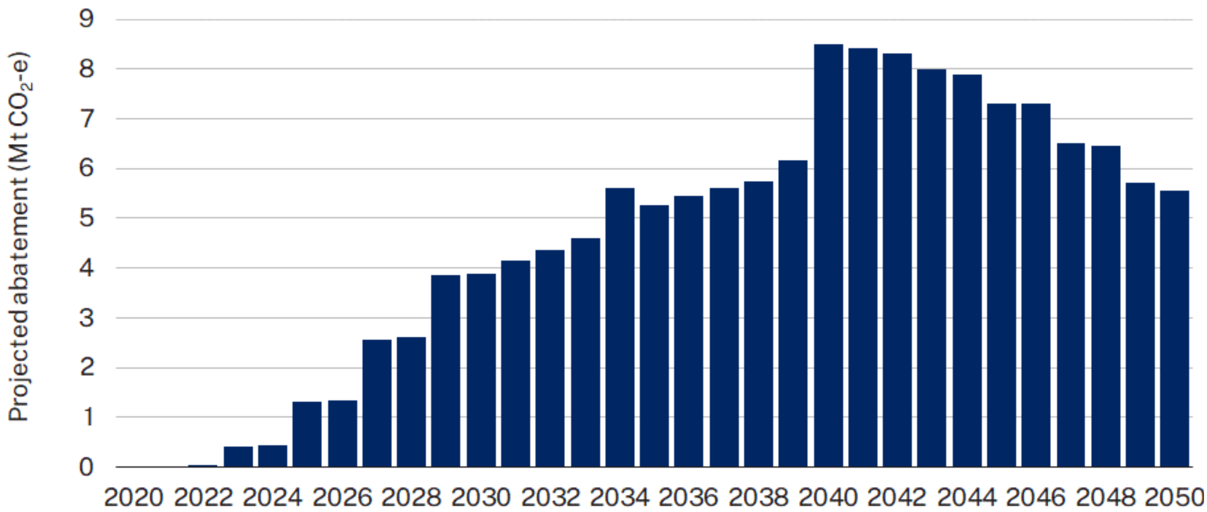

Figure 30 **Abatement of IPPU emissions projected to be achieved by Net Zero Plan Stage 1 programs**

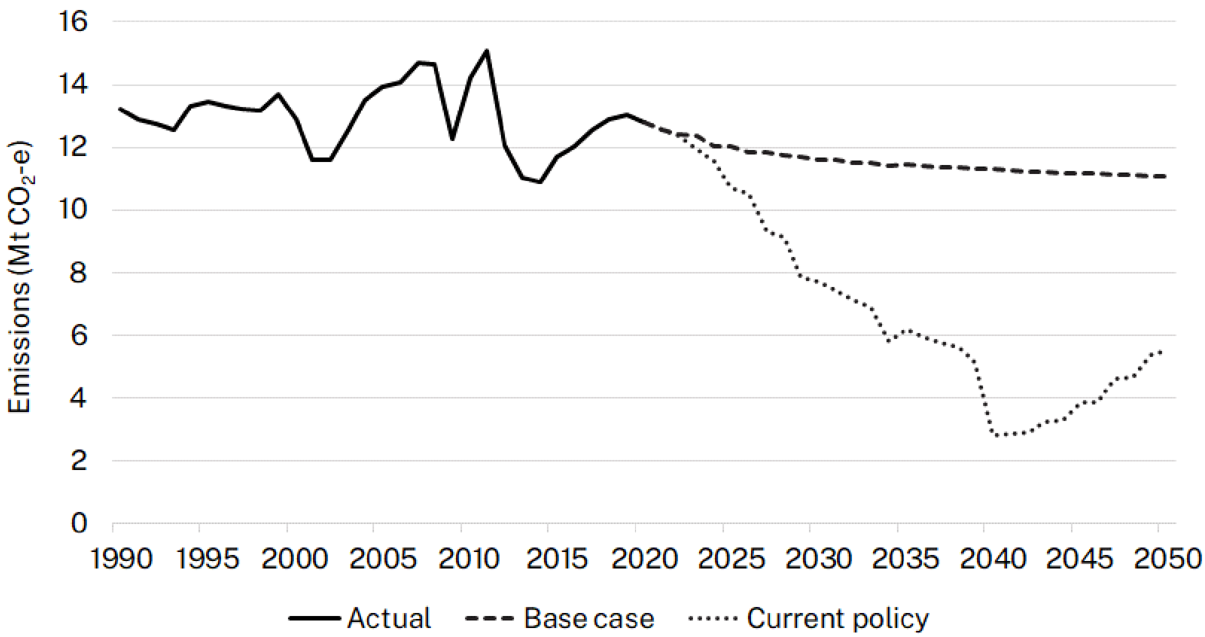

Figure 31 **NSW IPPU sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)**

Considerations for projection updates

Future projection updates will consider:

- the latest NGERS data, EIS information for new projects and commodity forecasts
- incorporating sectoral efficiency and productivity improvements (in place of assuming the emission intensity of future production will remain constant)
- review of assumptions regarding the potential ongoing market impact to be delivered under Stage 1 of the Net Zero Plan
- potential implications of growing corporate carbon reduction commitments
- potential market impact of growing demand for low carbon building materials and the European Union Carbon Border Adjustment Mechanism.

Agriculture

Emissions from agriculture comprise emissions from livestock and crop production. They include emissions from enteric fermentation, manure management and agricultural soils. These emissions are predominantly N_2O and CH_4.

Base case emissions projections

Emissions from the agriculture sector are projected using bottom-up modelling. The model used is generally similar to the model developed by DISER (DISER 2021) for the years where outlook data is available from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), and the Organisation for Economic Co-operation and Development (OECD) and Food and Agriculture Organization of the United Nations (FAO) (OECD 2021). The emission commodities/sectors and subsectors covered in the National Inventory Report are included in this agricultural projection (Table 35).

Table 35 Emission subsectors included in the projections for each agricultural commodity

Sector	Emissions subsectors included
Sheep	Enteric fermentation, manure management, agricultural soils
Dairy	Enteric fermentation, manure management, agricultural soils
Grain fed beef	Enteric fermentation, manure management, agricultural soils
Grazing beef	Enteric fermentation, manure management, agricultural soils
Pigs	Enteric fermentation, manure management
Other animals	Enteric fermentation, manure management, agricultural soils
Crops/pastures	Agricultural soils, field burning of agricultural residues, rice cultivation
Lime and urea	Liming and urea application
Fertilisers	Agricultural soils

Livestock and crop activities

The data and methods used to project livestock and crop activities to 2050 are summarised in Table 36. NSW activity was projected using predominantly the commodities outlook data from ABARES (ABARES 2022a, 2022b). The outlook data from ABARES provided crop and livestock forecasts to 2026. This was supplemented with outlook data from OECD-FAO (OECD 2021), which provided selected crop outlooks to 2030. Historical activity data was based on the National Inventory Report 2020 (DISER 2022b).

The outlook data provided by OECD-FAO and ABARES were aggregated at national level.

National outlook activity was apportioned to NSW by applying a 2020 ratio of NSW to Australia activity. This assumed that NSW projected activity is proportional to its baseline contribution to Australia's total activity for the commodity.

For beef cattle, 5% of the total ABARES projected livestock number was partitioned to feedlot cattle based on historical ratios of annual feedlot to grazing beef cattle numbers.

For pigs, only sow numbers were projected by ABARES. As the ratio of the subclasses of pig were relatively stable over time, it was used to estimate the total number of pigs. The total number of pigs was a multiple of 7.7 to the number of sows.

Table 36 Data and method used to project activity to 2050

Sector/commodity	Available outlook years	Remaining years
Beef cattle – pasture, dairy cattle, sheep, wheat, cotton, sorghum, barley	ABARES (2022a) for 2021–2023 ABARES (2022b) for 2024–2027	Regression to the long-term (2010–2020) mean
Pig	ABARES (2022b) for 2021–2027	
Beef cattle – feedlot	ABARES (2022b) for 2021–2027	Wood et al. (2021) growth rates
Rice, sugar cane, oilseeds, maize	OECD-FAO (2021) to 2030	Regression to the long-term (2010–2020) mean
Other animals, other crops, pasture and inorganic fertilisers applied to pasture and horticulture	No outlook data but historical activity data is available. Apply regression to the long-term (2010–2020) mean	

Post-outlook years, a linear regression to the long-term average (2010–2020) was applied. An exception was made for feedlot cattle, which was projected to increase as farmers seek a more drought resilient approach to beef cattle production (DISER 2021b). For feedlot cattle, we applied Wood et al. (2021) beef cattle growth rates for 2028–2050.

Emission intensity by subsector and commodity

An emission intensity was calculated for each subsector using emissions for the subsector divided by the activity for the commodity/sector for the year 2020. The emission intensity of each subsector is initially assumed to remain constant for the projected period to reflect BAU; for example, emission intensities for livestock subsectors were calculated as:

$$EI_{livestock} = \frac{E_{subsector}}{N}$$

where:

$EI_{livestock}$ = emission intensity for livestock

$E_{subsector}$ = emissions from agricultural soils, enteric fermentation or manure management in 2020

N = number of livestock in NSW as reported in STGGI.

For crops, the emission intensity for each subsector by crop type was calculated as:

$$EI_{cr} = \frac{E_{subsector}}{Y}$$

where:

E_{cr} = emissions from cropping

$E_{subsector}$ = emissions from agricultural soils, field burning of agricultural residues, or inorganic fertiliser[10]

Y = yield for crop in NSW as reported in STGGI.

[10] This applies only to sugar cane and cotton, where crop-specific emissions data are available.

Emissions by subsector and commodity

Emissions were calculated by multiplying the projected activity and emission intensity for each subsector:

$$E_{ts} = a_t * EI_s$$

where:

E_{ts} = emissions from subsector at time t

a_t = activity from commodity or sector at time t

EI_s = emission intensity of a subsector in 2020.

For urea application and inorganic fertiliser applied to irrigated and non-irrigated crops, we assumed the use of fertilisers for these sectors will change in response to crop productivity. Wheat, sugar cane, barley, rice and sorghum are 5 key crops that account for 73–85% of crop yield in NSW. They were used as a proxy to estimate the rate of change for emissions related to urea application and inorganic fertiliser applied to irrigated and non-irrigated crops.

The emissions for each commodity or sector are the sum of its emissions subsectors:

$$E_t = \sum_s E_{ts}$$

where:

E_t = total commodity or sector emissions at time t

E_{ts} = emissions at time t from each sector.

Historical activity data was unavailable for liming, sewage sludge applied to land and mineralisation due to loss of soil carbon. For these sectors, it was assumed that emissions will return to the long-term (2010–2020) average in the absence of suitable proxies.

Gaps and limitations

The impact of climate change on agricultural commodities in NSW is difficult to account for due to the lack of spatially-explicit emissions and activity time series data. Without such data, it is not possible to analyse the regional impact of climate on agricultural productivity. Additionally, production may move to areas where conditions may be more variable. Currently, these impacts are indirectly accounted for through setting the long-term average emissions or activity as represented by the years 2010–2020. This decade recorded substantially more temperature and rainfall extremes than the preceding decade (BOM and CSIRO 2020) and includes an agricultural drought period.

Livestock related emissions account for 84–94% of the NSW agricultural emissions from 1990–2020; therefore accurate livestock projections, particularly for sheep and beef cattle, are important for projecting agriculture emissions. Given the absence of available data, peer reviewers were accepting of the linear projection of agricultural activities beyond 2027, but highlighted it as an area for further analysis when preparing updated projections.

A BAU outlook from this study was compared with results from analysis based on the Land Use Trade Off (LUTO) model produced by CSIRO for the NSW Intergenerational Report 2021 (Wood et al. 2021). The LUTO 2021 model estimates agricultural outputs given a range of environmental (rainfall, temperature), economic and social (productivity assumptions, domestic land-use policy, global outlook and emissions abatement effort) scenarios. NSW agriculture emissions from this study were slightly lower than those based on the LUTO base case scenario and the department's projections in 2021 (Figure 32). Emissions are projected to be 21.5 Mt CO_2-e and 20.7 Mt CO_2-e in 2050 by LUTO 2021 and DPE 2021 respectively, compared to 20.5 Mt CO_2-e based on the DPE 2022 BAU outlook.

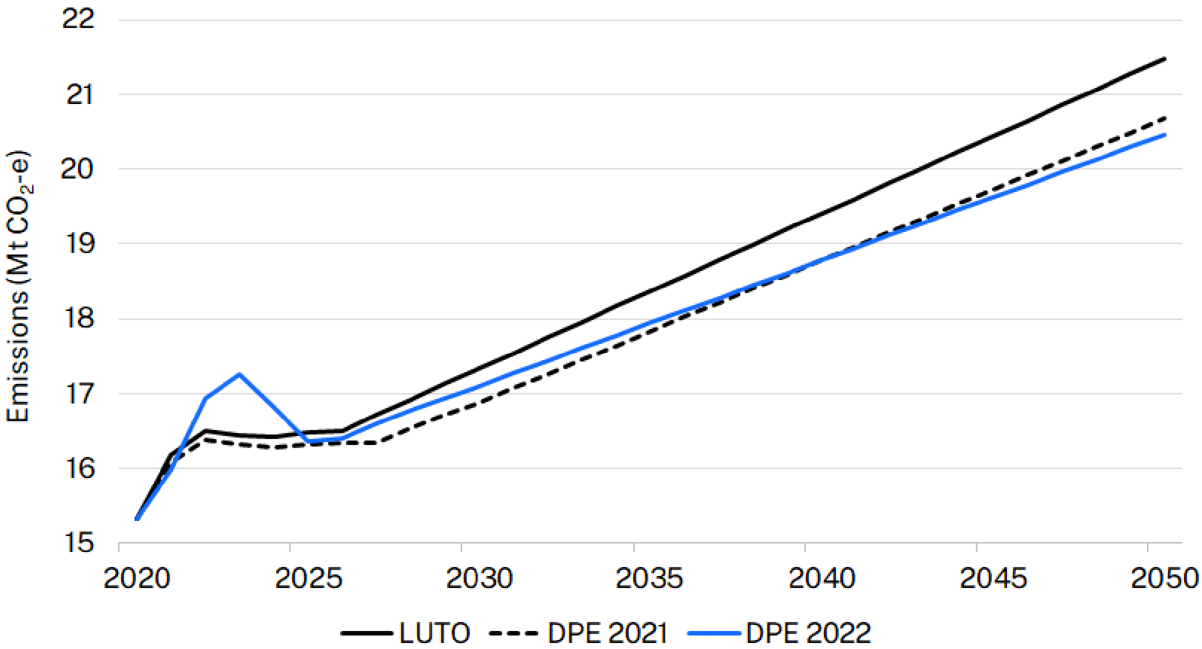

Figure 32 **Comparison of total NSW agriculture sector emissions based on long-term BAU emissions projections (this report) with previous year department projections (DPE 2022a) and the LUTO model base case from 2021**

Base case agriculture emissions projections

Emission intensities were initially held constant for all commodities in the projections to provide BAU emissions projections (as represented in Figure 32). For base case emissions, emission intensities were subsequently reduced by 10% for cattle and sheep to reflect recent policy directions by major industry bodies, such as Meat and Livestock Australia, the National Farmers Federation, and Dairy Australia. Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the NSW agriculture sector are shown in Figure 33 by commodity.

Emissions from agriculture vary from year to year due to the influence of climate and particularly drought on livestock numbers and crop production. Cattle and sheep production accounted for approximately three-quarters of NSW agriculture emissions in 2020, mainly due to the CH_4 generated as these ruminant animals digest their food. Enteric fermentation is projected to remain the major source of agricultural emissions to 2030, with emissions increasing in the near term as the state recovers from the recent drought.

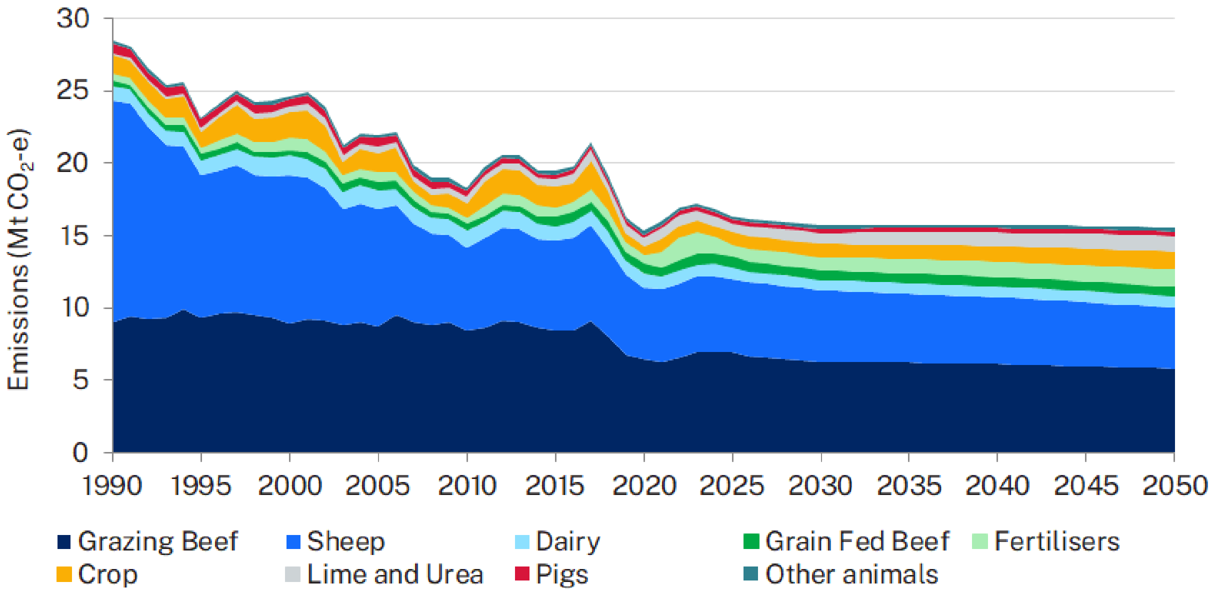

Figure 33 **Agriculture emissions by commodity showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**[11]

Current policy emissions projections

The current policy projections for agriculture assume the NSW Government will play a significant role in supporting supply chains (where necessary) and expanded access of NSW farmers to environmental markets and Environmental, Social and Governance (ESG) investment streams through the Primary Industries Productivity and Abatement Program (PIPAP), the Sustainable Farming Program[12] and actions under Stages 2 and 3 of the Net Zero Plan under committed NSW CCF funding. Based on the extent of emissions in the agriculture sector and remaining opportunities for abatements, the projections assume that about 30% of the funding over 2030–2050 would be invested in driving further reductions in this sector. Support for abatement within the agricultural sector is assumed to leverage existing federal government focus and funding and corporate commitments.

Enteric CH_4, primarily from cows and sheep, represents the largest source of emissions within the IPCC agriculture sector (75% of emissions in 2020). A major agricultural producer with large livestock herds, NSW is considered to have the market scale necessary to accelerate the commercialisation and adoption of low emissions technologies and practices (OCSE 2020). There are opportunities to reduce these emissions through activities such as improved herd management, feed additives and vaccines; however, some options are not commercially available and there has been limited uptake of existing Emissions Reduction Fund methods (CCA 2020). With more countries implementing emissions reduction strategies for their livestock herds, if NSW marketed low emission livestock products (e.g. meat, dairy and wool), this would provide a competitive advantage for NSW farmers in high value exports (OCSE 2020).

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[11] Note, base case emissions projections in this figure differ from the BAU projections in Figure 32 due to the inclusion of industry bodies' committed emission intensity reductions.

[12] The Sustainable Farming Program is not likely to directly target enteric CH_4 emissions but is anticipated to help support this measure by encouraging and accrediting sustainable farming practices and expanding access to ESG investment and premium markets.

Almeida and Hegarty (2021) assessed strategies for abating enteric CH_4 emissions of relevance to NSW. This detailed study found significant, feasible potential to abate enteric CH_4 emissions from feedlot and dairy cattle through dietary modification, with lower levels of abatement for other cattle and sheep. The study concludes feasible abatement in 2030 of up to 90% for feedlot and dairy cattle and up to 30% for grazing beef with moderate to high confidence depending on the dietary supplement used. This assessment considered ease of implementation, commercial availability, abatement effectiveness and adoption rates; and assumed a market incentive that removes cost barriers and the removal of any regulatory barriers where these exist.

Under current policy, technologies to abate livestock emissions such as through herd management and dietary modification are assumed to be adopted by 90% of beef feedlots and dairy farms and 30% of pasture beef by 2035. Lower adoption rates and abatement efficiencies and later abatement start dates are assumed for pasture beef given that dietary supplement technologies are still under development for grazing cattle and sheep. The projected abatement is within the estimated feasible abatement of enteric CH_4 emissions in NSW (DPI 2020) and abatement levels considered viable for feedlot cattle in Australia (Ridoutt et al. 2022).

The abatement in the agriculture sector modelled to be achieved within the 2021 projections is shown in Figure 34, with resultant current policy projections for this sector compared to base case projections in Figure 35.

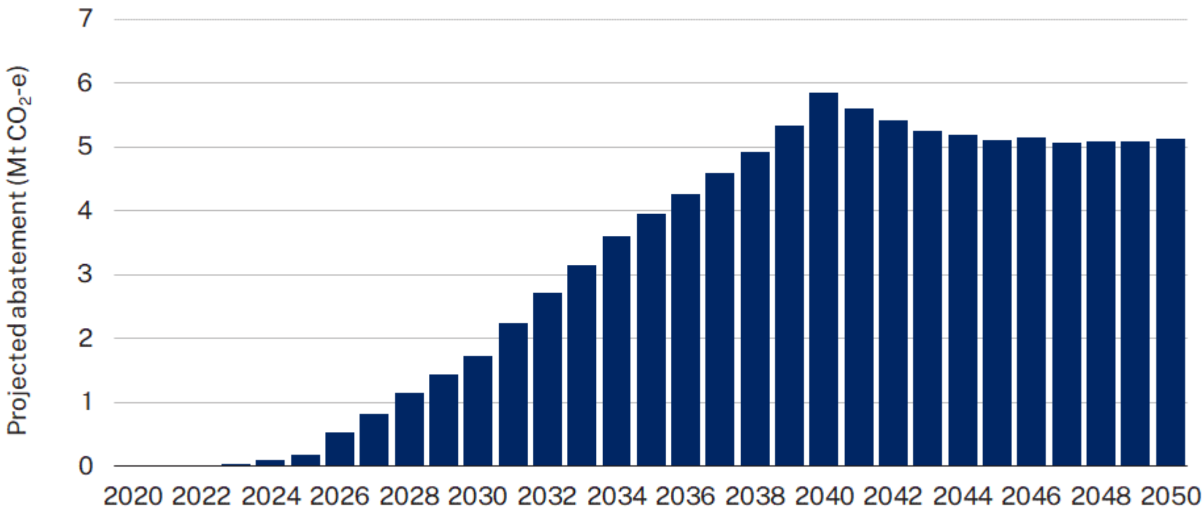

Figure 34 **Abatement of agriculture sector emissions projected to be achieved by Net Zero Plan Stage 1 programs**

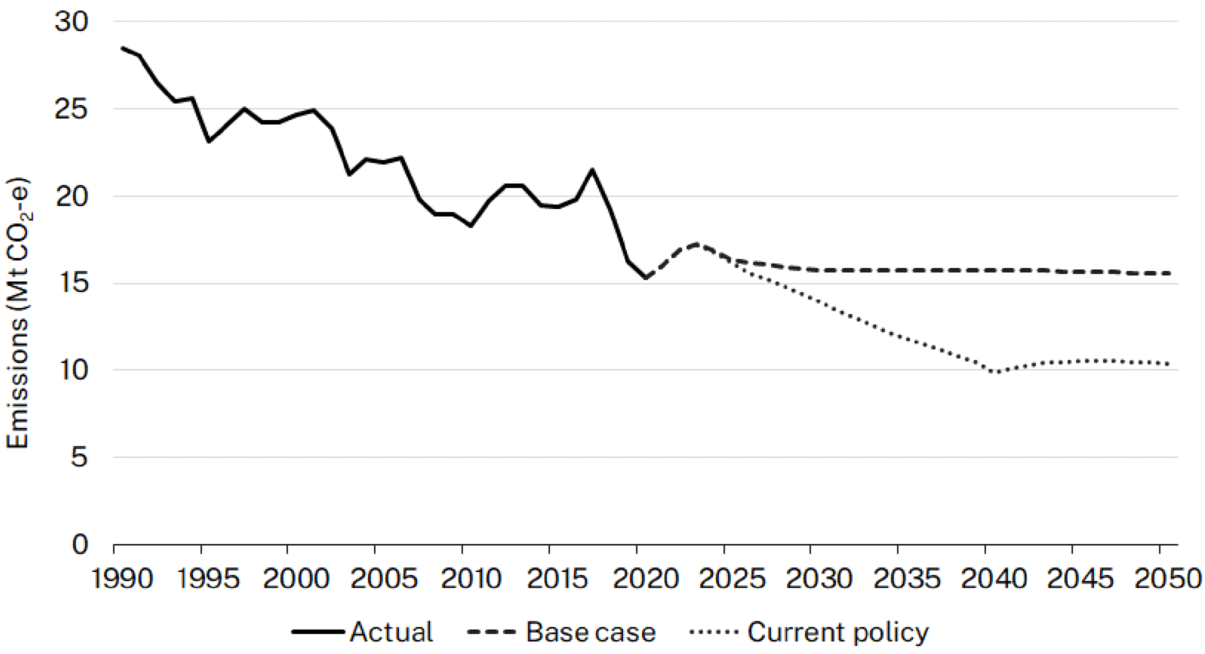

Figure 35 **NSW agriculture sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)**

Considerations for projection updates

Future projection updates will consider the latest outlook data for agricultural commodities and improved projections for post-2027 considering holding capacities, arable land limitations and climate impacts. Modelling updates will also incorporate further modelling for NSW Government programs, considering new information on emerging technologies and growing corporate carbon reduction commitments.

Land use, land-use change and forestry

The LULUCF sector accounts for emissions and removals from several sources, including forest land, cropland, grassland, wetlands, other land 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.

Land-use classification within the LULUCF sector is derived from ABARES catchment-scale land-use data. 'Forest land' is defined as having trees with a minimum height of 2 m, crown canopy of at least 20%, and coverage of not less than 0.2 ha (DISER 2022c). Forest land excludes woody horticulture, which is classified as cropland under this sector.

Land utilised for continuous cropping and crop–pasture rotation forms part of the cropland category. LULUCF subcategory 'cropland remaining as cropland' does not account for non-CO_2 emissions; these emissions are accounted for in the agriculture sector (DISER 2022c).

Grassland includes shrubs of woody vegetation (sub-forest forms) and areas of varying grassland ecosystems (type, climate, management) (DISER 2022c).

Residential and industrial infrastructure, towns, cities and road networks are included in the settlements classification (DISER 2022c).

Wetlands are based on data from the Bureau of Meteorology Australian Hydrological Geospatial Framework (BOM AHGF; BOM 2022) and Directory of Important Wetlands in Australian (DIWA; DCCEEW 2021); these being areas of perennial lakes, reservoirs, swamps, major water courses and existing wetlands (DISER 2022c).

Other land relates to areas where the above land-use classification cannot be met and includes areas such as bare soil and rock (DISER 2022c).

Base case emissions projections

LULUCF sector emission estimates for NSW were provided by DCCEEW up to and including 2035, based on modelling using the Full Carbon Accounting Model (FullCAM) (DCCEEW 2022b). FullCAM is a modelling framework comprised of integrated sub-models for estimating impact to carbon stocks and emissions under varying land use, land-use change and forestry management practices and temporal conditions. Detailed methods are described in the National Inventory Report (DISER 2022b, 2022c, 2022d).

For all LULUCF subsectors inventory data for 2021 were not yet released at the time of this methods paper, hence 2021 subsector estimates are derived as an average of 2020 inventory estimates and the DCCEEW 2022 projections.

For projections post-2035 subsector emissions/sequestration were linearly forecast to 2050 for all subsectors except forest land. Projections for forest land were assumed to return to the long-term minimum sequestration rates in 2050 of –8.15 Mt CO_2-e, with linear interpolation of values between this value and the DCCEEW projection for 2035.

Activity data

The harvesting activity in native forests, including multiple use forests and private native forests, is a key driver of carbon flux. Over recent years, harvesting in the native forest sector has reached historically low levels (Gavran 2020) (Figure 36). Given the extent and severity of the 2019–20 wildfires affecting native forests areas (DPIE 2021b), and the absence of updated commodity forecasts reflecting the change in forest conditions at the time of modelling, this projection assumed that log harvest volumes will linearly regress to the longer-term average (2010–2020) by 2030 (DISER 2022c) and remain stable at 2030 levels to 2050.

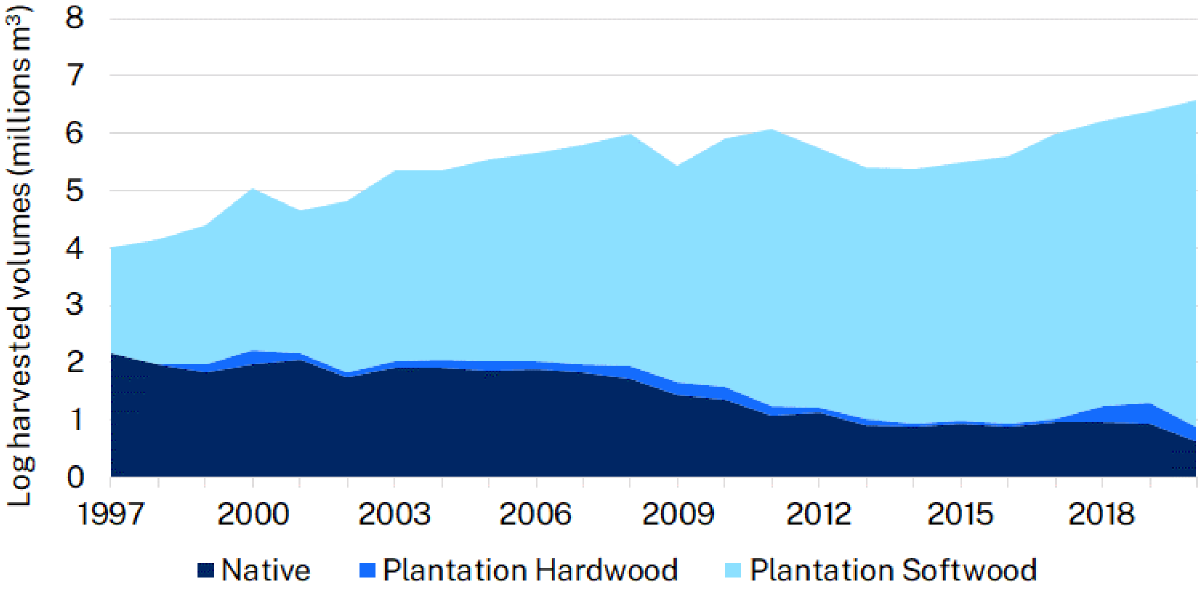

Figure 36 **Historical log harvested volumes from native forestry and plantations (1997–2020)**

Plantations included within forest land include softwood and hardwood plantations. The log harvest volumes from softwood plantations have increased over the past 23 years, whereas native and hardwood plantations have steadily declined and remained relatively low over the same period (Figure 36). The maximum estate size of plantation was reached in 2016 at 394,400 ha (Gavran 2020). DCCEEW projections for 2022 log harvest volumes were not available at the time of preparing the 2022 methods paper.

Based on analysis by the Australian Government, most forest conversion activity in Australia is for the purpose of maintaining pastures for grazing activities (DCCEEW 2022b). Some forest conversion occurs to support cropping as well as smaller land-use conversions for settlements, infrastructure and reservoirs. The land clearing projection was developed based on recent trends in land clearing activity for grassland and cropland. Most clearing activity in Australia is associated with the re-clearing of regrown forest vegetation (DCCEEW 2022b), and reflects economic considerations by famers and landholders and livestock markets. Land clearing restrictions have seen primary forest conversion stabilise at low levels over the past decade compared to the historic record (Figure 37).

Primary forest conversion is assumed to remain at low levels based on the historic record, and regrowth and re-clearing activity is assumed to respond to changes in the number of livestock based on projections for the agriculture sector (DCCEEW 2022b). A 10-year cycle of re-clearing of regrowth is applied. The rate of re-clearing is relatively stable based on historical data, which indicates a cyclical need to re-clear areas on the fringe of agricultural regions where adjacent forests contribute to forest regeneration on such fringe land (DISER 2021b).

For agricultural land (cropland and grassland), management practices and crop type are assumed to remain unchanged over the projection period. Activity levels are assumed to return to long-term averages (2010–2020) over the projection period (DCCEEW 2022b).

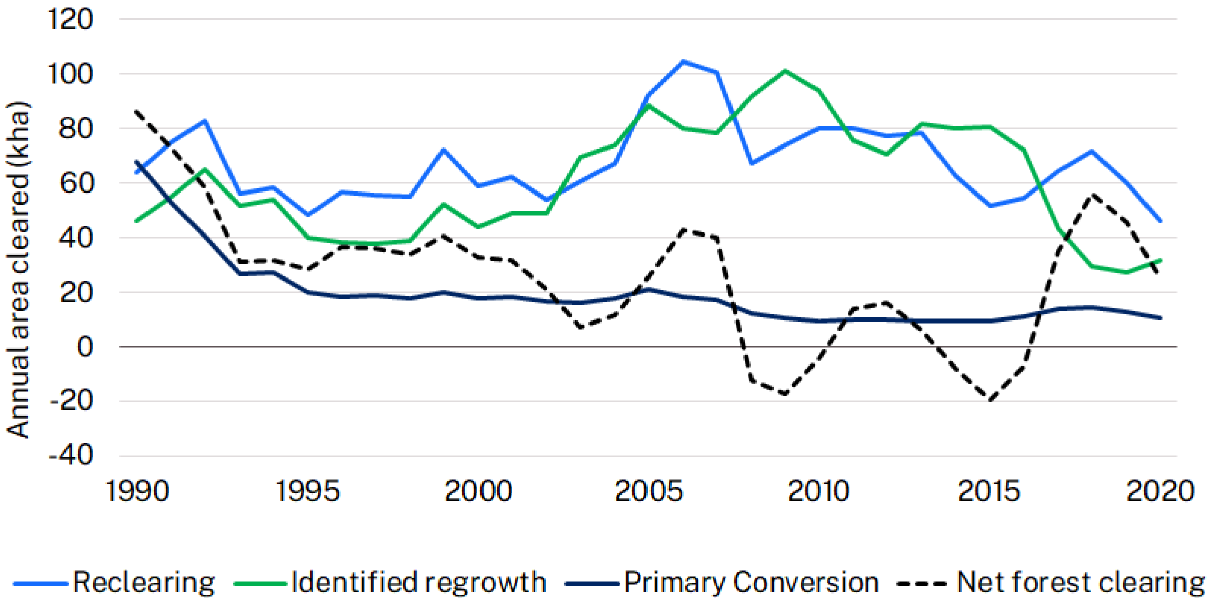

Figure 37 **Historical primary conversion, re-clearing and regrowth (1990–2020)**

For other land, including wetlands and settlements, activities are assumed to return to long-term averages (2010–2019) (DCCEEW 2022b).

Harvested wood products are estimated as the production plus imported materials minus exported materials (DISER 2022c, p.154). Activity from harvested wood products is projected based on forecast wood production and recycling rates.[13]

Base case projections take into account abatement under Australia's carbon crediting scheme (DCCEEW 2022a, 2022b).

Base case LULUCF emissions projections

Base case emissions projections for the LULUCF sector are shown in Figure 38, with further detail provided below on the assumptions and methods underpinning the projections.

Land clearing is a source of emissions within the LULUCF sector accounted for under 'land converted to other land use', including grasslands and croplands (agriculture), wetlands and settlements. Economic considerations are an important driver of this land clearing. Most forest conversion activity is to maintain pastures for grazing activities, although some forest conversion does occur to support cropping and with smaller conversions to provide for settlements, infrastructure and reservoirs (DCCEEW 2022b).

Carbon sequestration is predominantly due to forest land remaining forest land, which includes native forestry and pre-1990 plantations, and sequestration from regrowth occurring on land converted to forest land. In recent years, since 2012, sequestration has been greater than emissions, resulting in the LULUCF sector being a net sink of emissions.

The shift of the LULUCF sector from a net source of emissions to a net sink contributes to reductions in the state's overall net emissions. Under the base case scenario, the emissions sink is projected to decline over the long term. As shown in Figure 38, emissions from the LULUCF sector are –3.1 Mt CO_2-e for 2020. The net sink is projected to increase by 5.1 Mt resulting in –8.2 Mt CO_2-e by 2022, but will gradually decline to -3.7 Mt CO_2-e by 2030 and –2.9 Mt CO_2-e in 2035, based on DCCEEW 2022 projections.

[13] DISER internal analysis.

The impact of current La Ninã conditions on soil carbon stocks is accounted for in the current decade within the DCCEEW projections. Beyond 2035, the projection is based on a 10-year linear trend with minimal change in emissions/net sink gain, where the average climate conditions are assumed (DCCEEW 2022b).

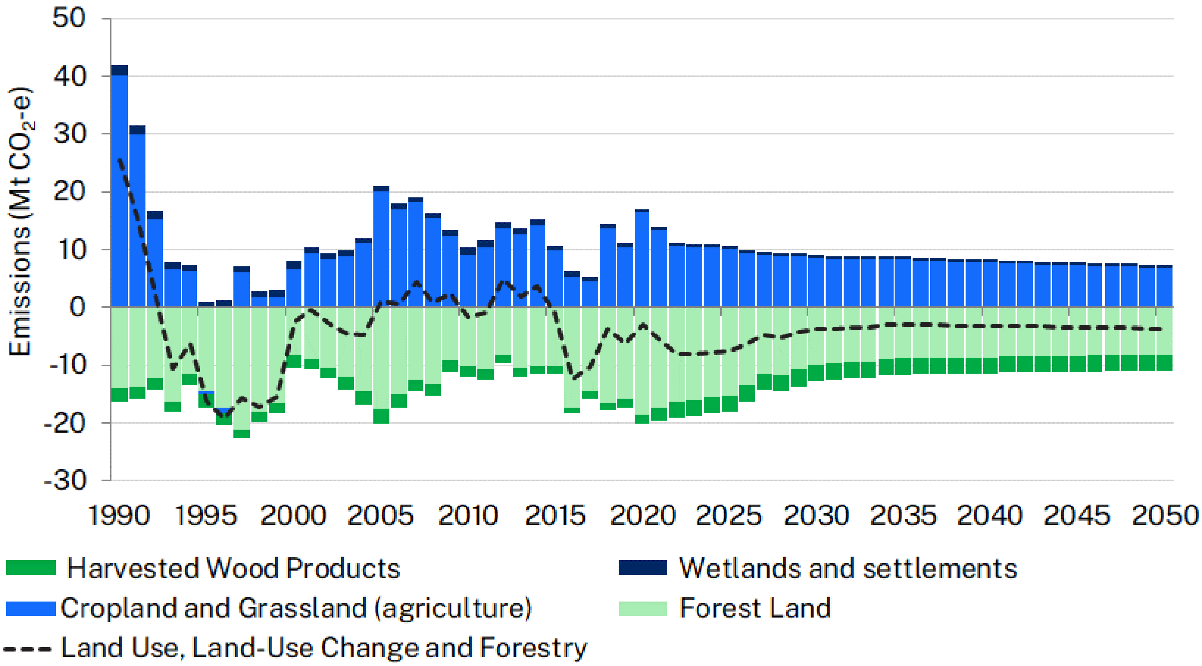

Figure 38 **LULUCF emissions and sequestration showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**

Gaps and limitations

The current projections do not explicitly account for the impact of climate change on land sector emissions in NSW. Some of these impacts are indirectly and partially accounted for through setting the long-term average activity as represented by the years 2010–2019. This decade recorded substantially more temperature and rainfall extremes than the preceding decade (BOM and CSIRO 2020) and included an agricultural drought period.

Current policy emissions projections

The current policy projections for the LULUCF sector consider announced policies under Stage 1 of the Net Zero Plan and related NSW Government actions (Table 2). This includes the Productivity Improvement and Abatement Program, the NSW Sustainable Farming Program, the NSW Blue Carbon Strategy 2022–2027 and the NSW National Parks and Wildlife Service Carbon Positive by 2028.

Modelling was undertaken to estimate enhanced carbon sequestration within the LULUCF sector potentially achievable under the PIPAP based on the early program design. Sequestration opportunities were considered across all land tenures in NSW, including private farmland, public lands and Aboriginal-managed lands.

The NSW Blue Carbon Strategy 2022–2027 provides a roadmap to support blue carbon projects in NSW (DPE 2022f). Blue carbon is the term used to describe carbon captured and stored by marine and coastal ecosystems. Blue carbon ecosystems, which include seagrass, mangroves and saltmarsh, can store substantially more carbon per area than land-based forests and, if undisturbed, can store this carbon in soils for many years.

Projects that restore blue carbon ecosystems, such as the reintroduction of tidal flows to restore coastal wetlands, can help deliver significant emissions reductions and may enable carbon credits to be earned. Abatement under the strategy was conservatively assumed to be of a similar order to the sequestration potential estimated for the Everlasting Swamp (DPE 2022F).

The NSW National Parks and Wildlife Service has committed to being net zero and carbon positive by 2028. Abatement under this commitment was assumed to be of a similar order to the sequestration modelled for the Koonaburra human induced regeneration project and the Environmental Plantings pilot projects as documented in the strategy (NSW Government 2022e).

Other recent policies addressing land management with implications for land sector emissions and sequestration include the Local Land Services Act amendment, new Land Management (Native Vegetation) Code (DPE 2022g) and the NSW Natural Capital Statement of Intent (NSW Government 2022f). The new Land Management (Native Vegetation) Code supports landholders to manage their land to ensure more productive farming methods and systems, while responding to environmental risks. Some clearing under the Land Management Code will require land to be set aside, which will be listed in a new public register. Higher impact clearing will require approval from a new Native Vegetation Panel, and landholders will be required to assess and offset the biodiversity impacts of approved clearing. Current policy settings were assumed to reduce forest land clearing/re-clearing by 15% below 2011–2020 forest conversion rates by 2035.

The abatement in the LULUCF sector estimated to be achieved through enhanced sequestration under current policy settings is shown in Figure 39. The resultant current policy projections for this sector compared to base case projections are shown in Figure 40. NSW Government policies were modelled to enhance carbon sequestration by the land sector to help offset emissions from other sectors. Much of the abatement is modelled for PIPAP, which, based on current modelling assumptions for the program, begins to decline from 2030 and results in a drop off in abatement from 2035.

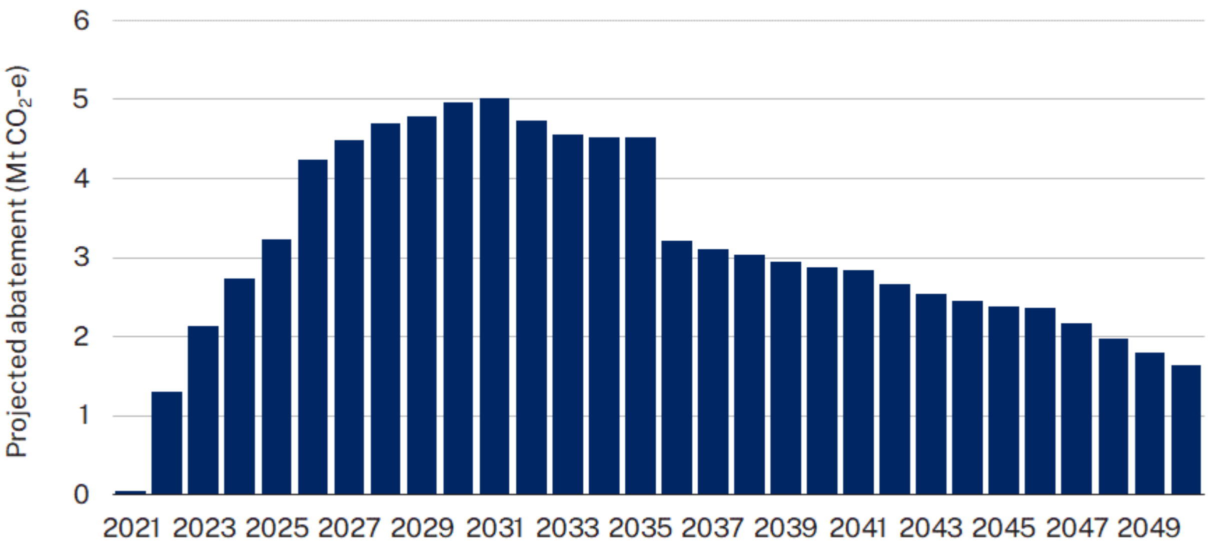

Figure 39 **Enhancement of LULUCF sector carbon sequestration projected to be achieved under current policy**

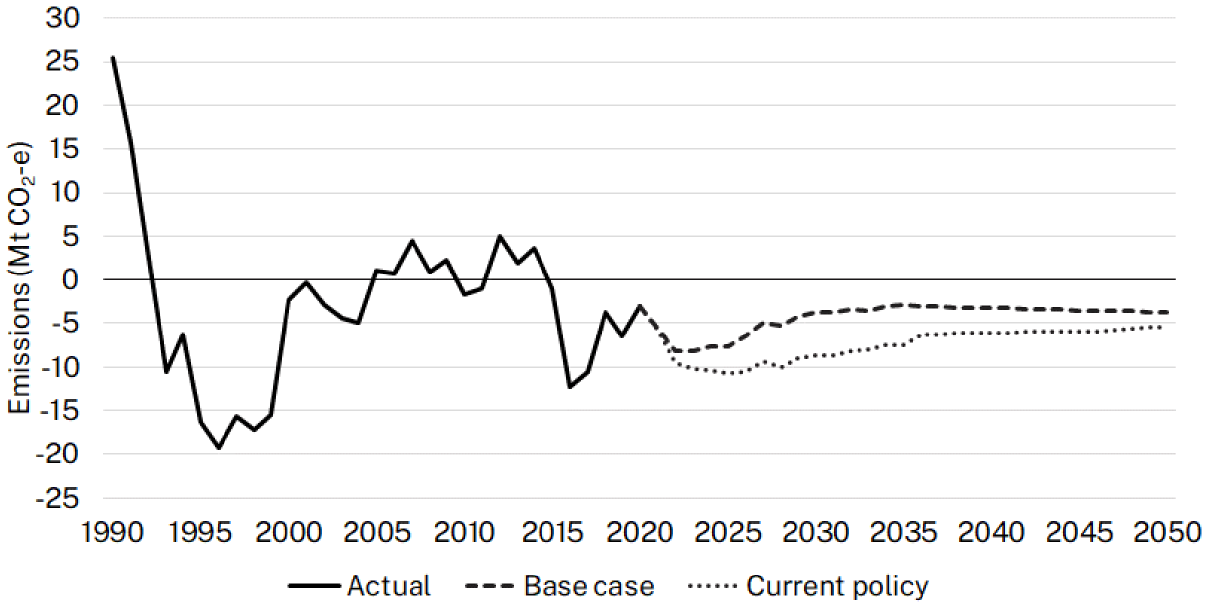

Figure 40 **NSW LULUCF sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)**

Considerations for projection updates

Future projection updates will consider:

- latest data and model improvements, including options to account for land clearing for cropping areas, settlements and wetlands
- use of Sentinel 1 and 2 remote sensing imagery for refined land-use classification
- revised carbon sequestration modelling considering changes in the design of the PIPAP and its remodelling that will be concluded by mid-2023, and opportunities for enhanced sequestration under the NSW Sustainable Farming Program announced in June 2022.

Over the longer-term, projection improvements will aim to include climate change projections within FullCAM modelling.

Waste

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

Emissions from solid waste disposal are the largest source, contributing 74% of total waste emissions in NSW in 2020 (NSW STGGI data, 2022) and detailed emissions projections have been undertaken for this sector.

Domestic wastewater treatment is the next largest source, contributing a further 15% of waste emissions in 2020. Industrial wastewater treatment accounted for about 9% with biological treatment and incineration being minor sources (<3% of waste sector emissions).

Base case emissions projections

Solid waste disposal

This section addresses emissions generated from the disposal of solid waste to landfill from domestic, commercial and industrial sources. Emissions are predominantly CH_4, generated from the anaerobic decomposition of the organic matter. The NSW Net Zero Plan includes a target of net zero emissions from organic waste by 2030.

The BAU emissions from landfilled solid waste considers the projected growth in waste without additional abatement apart from gas capture technology and waste diversion and recycling programs already in place. The growth in waste is driven by population and economic growth.

Modelling approach

The method for calculating solid waste to landfill emissions is based on the formula:

$$E_{SW} = i + b + \left(CH_4(g) - CH_4(c)\right)$$

where:

E_{SW} = solid waste emissions

i = emissions from solid waste incineration

b = emissions from biological treatment

$CH_4(g)$ = solid waste CH_4 generated

$CH_4(c)$ = solid waste CH_4 captured.

According to the NSW STGGI data over the period 2015–2020, emissions from incineration and biological treatment of waste accounted for 0.1% and 2% of total waste sector emissions, respectively. Detailed modelling was therefore not done for these sources.

The method for calculating GHG emissions is based on a first-order decay model, in particular the CER's Solid Waste to Landfill model (CER 2020b). This requires knowledge of the annual mass of waste deposited to landfills, the split in waste streams (i.e. %Municipal Solid Waste (MSW), %Commercial & Industrial (C&I) and %Construction & Demolition (C&D)) and the mixture composition of these streams in terms of %food, %garden, %wood, %paper, %nappies, %sludge, %rubber, %leather and %inert waste.

The modelling relies on historical waste disposal data provided by DCCEEW (formerly DISER) and more contemporary data from the NSW EPA Waste and Resource Reporting

Portal (WARRP) (EPA 2022c).[14] It also relies on DCCEEW's estimates of gas capture (i.e. transfer of landfill gas off site for power generation, landfill gas flaring or landfill gas captured on site) at each landfill site.

DCCEEW has gathered waste disposal data for 26 specific landfills in NSW, most of which are currently in operation. Some of these landfills are closed but continue to emit CH_4. Most of the landfill data post-2009 has been captured from NGERS reporting, but pre-2009 data has been captured from other unspecified sources. The landfills are relatively large and most currently report under NGERS having triggered the NGER facility GHG emissions threshold. The modelling is based on the approach that a small number of landfills are responsible for the bulk of waste disposal in NSW and hence generation of GHGs. The WARRP data shows that the 26 large landfills are responsible for 62% and 59% of waste disposed in NSW in 2019–20 and 2020–21, respectively. The modelling assumes no new landfills, and that the 26 landfills listed will continue to operate out to 2050.

For the remaining smaller landfills (about 270 landfills according to recent NSW EPA WARRP data), DCCEEW's approach is to lump these landfills together under the name 'residual NSW'. These smaller landfills do not produce sufficient emissions individually to trigger the NGER facility reporting threshold; therefore, to model emissions from these smaller landfills the waste disposal tonnages are aggregated and modelled as one facility. DCCEEW has provided an estimate of landfill gas captured for 'residual NSW'; in 2020–21 the capture efficiency was 18%.

Data limitations and quality

Data limitations and factors affecting the data quality are:

- Most local councils are not constitutional corporations and therefore do not report under NGERS. The last data captured from councils was in 2013 under the former carbon pricing scheme. Thus, DCCEEW does not have access to recent council landfill disposal data and hence their GHG estimates are unknown.
- DCCEEW excludes Virgin Excavatable Natural Materials (VENM) from their inventories. VENM refers to quarried natural materials such as clay, gravel, sand, soil or rock fines, which are largely inert. Thus, there are significant discrepancies in the overall waste disposal data reported by DCCEEW and the NSW EPA WARRP. Over FYs 2015–2020, DCCEEW reported total waste disposed in NSW was 1.5–2.0 million tonnes lower than reported under the NSW EPA WARRP.
- Data reported under the NSW EPA WARRP only extends back to 2015–16. First-order decay modelling based on this data alone is not possible. According to the IPCC, to use a first-order decay model to calculate landfill gas emissions for a landfill to reasonable accuracy, 3–5 half-lives of data are required (IPCC 2000). As an example, the decay rate, *k*, of food in NSW, assumed to be in a mostly dry temperate climate, is 0.06 yr^{-1} giving a half-life of 12 years (noting that $t_{1/2} = \ln 2/k$); therefore 36–60 years of landfilling tonnage and composition data would be needed.
- The WARRP data does not include the age of the landfill; therefore, attempting to estimate the age and deposition history of a landfill can lead to large errors in contemporary landfill GHG emissions.
- The WARRP data does not collect landfill gas capture information.
- The landfill histories for the 26 specific landfills (27 including residual NSW) in the DCCEEW dataset cannot be verified due to lack of historical record keeping and data availability.

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[14] Detailed individual landfill data is strictly confidential.

Activity data inputs for GHG emissions projections

- DCCEEW historical (FYs 1940–2014) waste stream data (i.e. tonnes of MSW, C&I, and C&D) are from the DCCEEW solid waste spreadsheet model. FYs 2015–2020 use the NSW EPA WARRP data.
- Waste disposal projection data beyond 2020–21, use assumptions outlined in the department's Research and Insight Team's Waste Generation Model (summarised below). Note that the projected solid waste disposal tonnages from the Waste Generation Model (top-down perspective) do not exactly equal the projected solid waste disposal tonnages when the totals for individual landfills are summed (bottom-up perspective). This is due to limited information being available on the growth rates in waste tonnages disposed in individual landfills.
- DCCEEW historical gas capture data (FYs 1940–2020) are from the DCCEEW solid waste spreadsheet model.
- Gas capture beyond 2020–21, uses a similar methodology to that outlined in the *Emissions Projections from the Waste Sector* report prepared by Blue Environment (2019). The annual CH_4 capture efficiency per landfill (i.e. CH_4 captured (t CO_2-e)/ CH_4 generated (t CO_2-e)) is calculated according to the formula:

  CH_4 capture efficiency t = CH_4 capture efficiency (t–1)(1 + growth rate)

  where the growth rate = 0.25% p.a.

  The CH_4 capture efficiency in 2018–19 (obtained from DCCEEW's dataset) is the initial value for gas capture; that is, the (t–1) value.
- Given the complexity of forecasting the change in waste stream mixes at each landfill, they are held constant at 2017–18 values (provided by DCCEEW); that is, the %food, %garden, %paper, %wood, %textiles, %sludge, %nappies, %leather and rubber and %inert in the MSW, C&I and C&D wastes are held constant.
- For years 2021–22 out to 2049–50 the WARRP waste data are projected according to the NSW EPA's Waste Projection Model (v1.5) assumptions:
  - For MSW, this means a decrease of 10.7% between 2020–21 and 2021–22, and beyond a 0.4–1.1% (average 1.0%) increase p.a. in waste mass in line with projected growth in NSW population to 2041 (DPE 2022c). To 2050, the rate of increase is held constant at the 2041 value of 0.9%.
  - For C&I waste, the rate of increase is in line with the projected increases in GSP (average 2.3% p.a. from 2022–2050).
  - For C&D waste, the rate of increase is in line with projected increases in building activity, an average of 1.4% from 2021–2041. These forecasts were based on a combination of historical gross fixed capital formation – dwelling and non-dwelling construction for NSW (ABS 2020a), and NSW Treasury forecasts for construction to 2025. A long-range growth rate of 1.9% was applied from 2030 and held constant to 2050.

Base case projections

The base case scenario takes the department's population and economic growth rate projections as the basis for the GHG emissions projections from 2022–2050. Modest improvements in gas capture rates as per DCCEEW projections are assumed, based on the Blue Environment (2019) methodology.

The department's version of the CER's Solid Waste Calculator is used to model CH_4 generated per landfill in units t CO_2-e p.a. based on historical and projected waste deposition data and the waste mix information for each of the 26 individual landfills and 'residual NSW'. All landfills are considered to be in temperate (dry) regions except for one landfill in the Wollongong local government area and 'residual NSW', which were assumed by DCCEEW to be temperate (wet).

To calculate the 'residual NSW' waste disposal for 2015–16 to 2020–21 WARRP data were used, with all waste disposal summed across the approximately 300 landfills in NSW and the waste disposed of at the 26 landfills that are individually modelled subtracted. DCCEEW waste mix percentages as at 2017–18 are adopted and held constant to 2050.

The annual CH_4 captured, flared or transferred (units t CO_2-e) at each landfill was deducted from the annual CH_4 generated. The net CH_4 emissions at each landfill are then summed to produce p.a. net CH_4 emissions for NSW. Based on the previous method, the overall gas capture rate for all NSW landfills is currently 42% for 2020–21, and is projected to increase to 54% by 2050, with an average projected rate of 49% over the period 2022–2050.

Wastewater emission sources

The assumptions, data and method for projecting wastewater emissions has been substantially updated, with detail provided on the updated method below.

The department engaged ARUP Australia Pty Ltd to develop and apply methods to derive spatially projected wastewater treatment emissions by local government area (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 both domestic/ commercial and industrial wastewater treatment. When aggregated, the domestic, commercial and industrial wastewater treatment emissions approximate total NSW STGGI emissions.

The assessment follows the guidelines specified by NGER (Measurement) Determination 2008 (CER 2021), 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 onsite 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 requires 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.

Background for domestic/commercial wastewater treatment emissions

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 2021b).

Most of the Australian population's domestic and commercial sewage discharge is treated at municipal wastewater treatment plants. According to the National Inventory Report (DISER 2021b), 'approximately 5 per cent of the Australian population is not connected to the domestic sewer and instead utilise onsite 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 2006), 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 solid waste disposal 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 2006) and NGER guidelines. DCCEEW 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 37 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 276 kt CO_2-e or 54% of NSW domestic and commercial wastewater treatment emissions (total of 512 kt CO_2-e 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.

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

Data sources

Foundational datasets used in the estimation and disaggregation of wastewater treatment emissions are listed in Table 37.

Table 37 Data used in the estimation of wastewater treatment emissions

Data reference	Description	Resolution	Source
DPE 2022c	Population projections	Annual NSW population projections by LGA to 2041 extended to 2050	2020 NSW Common Planning Assumption (Population) Projections
NSW LGA boundaries	NSW LGA spatial data	Administrative boundaries for LGAs	Data.gov.au NSW LGA Geoscape Administrative Boundaries
NSW STGGI 2019–20	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)
DCCEEW industrial facility data	Industrial facility identification	Identification (name, location) of facilities by sector in NSW	DCCEEW collated data from facility reporting
NPI data 2016–2020	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
DCCEEW 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	DCCEEW collated data from utility reporting
DCCEEW commodity production data	Historical national commodity production rates by industry sector	Annual commodity production (in litres or tonnes)	DCCEEW collated data from facility reporting

The following was noted when compiling the data to support emissions 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.

Population growth metric

The future population projections for the years 2020–2041 are based on the Australian Statistical Geography Standard (ASGS) 2020 LGA population projections as provided by DPIE at project inception. These population projections were developed by the department from the NSW Treasury's NSW Common Planning Assumptions as published in March 2022 (DPE 2022c).

The future population projections for the years 2041–42 to 2049–50 were not available. To calculate population growth, the population forecast data supplied by the department (NSW Annual Population Projections, and the ASGS 2020 LGA population projections) were used. The growth rate was calculated using a CAGR formula for the period 2016–2040 and applying it annually to 2049–50. The formula applied is:

$$Annual\ population\ growth\ rate = \left[\left(\frac{EV}{BV}\right)^{\left(\frac{1}{NY}\right)} - 1\right] \times 100\%$$

where:

EV = the End Value in the population data supplied by the department, being 2040

BV = the Base Value in the population data supplied by the department, being 2016

NY = the number of years in the forecast period.

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 41). 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 p.a.).

The PFD for N_2O emissions developed for this assessment is a simplification of a typical wastewater treatment process (Figure 42). 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 p.a.).

Emissions from sludge transferred off site are considered solid waste emissions and not part of the scope of this methodology.

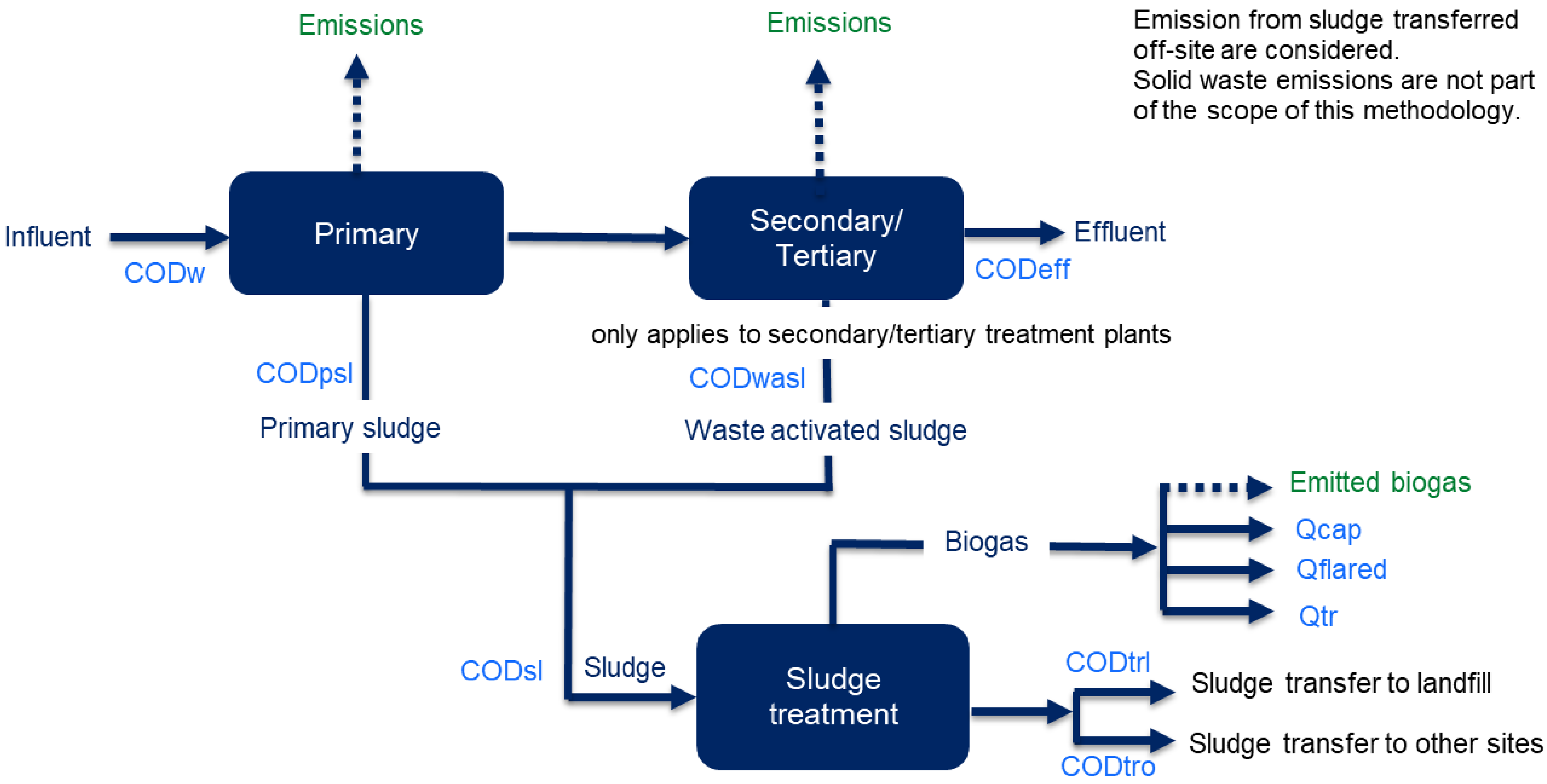

Figure 41 **Pathways for CH_4 emissions from domestic and commercial wastewater handling**

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

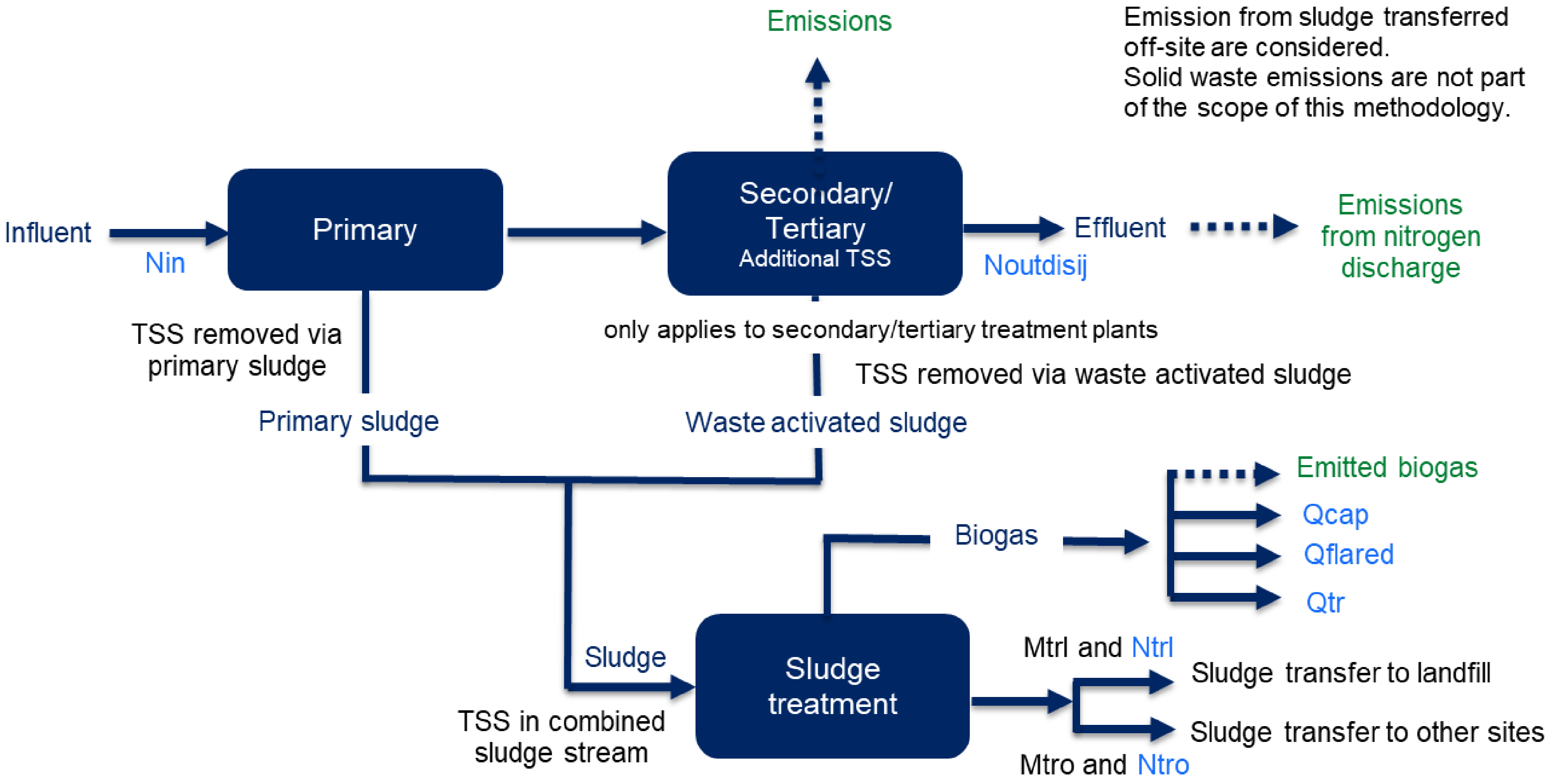

Figure 42 **Pathways for N_2O emissions from domestic and commercial wastewater handling**

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 2020 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 redistribute the resulting emissions to population by LGA. A summary of the method is given in Table 38.

For populations 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 wastewater treatment works 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.

Table 38 Methodology summary – spatial aggregation of LGA population

Component	Details
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

Step 4 – inventory projection and scope 1 separation

Once the emissions inventory has been disaggregated by LGA, the department's projections (DPE 2022c) were used to project the inventory into future years using the population growth metric discussed earlier.

Background for industrial wastewater treatment emissions

The NGER (Measurement) Determination 2008 (CER 2021) methods for industrial wastewater rely on annual commodity production (in tonnes) per sector, as opposed to Equivalent Population serviced for the domestic/commercial sector.

This information is largely unavailable at a facility level and is not captured in the NPI database. There are only a small number of facilities in the DCCEEW data that have allocated commodity production figures.

The key input is, thus, the commodity production figures provided by DCCEEW at a national level.

The commodity production figures for 2016–2019 were provided by DCCEEW at a national level. Not all figures were provided on a tonnes p.a. basis. The inputs and the data transformations required are outlined in Table 39.

Table 39 Data transformations for historical national commodity production

Sector	Data transformation
Beer	Input figures adapted from department-provided annual production figures (in L) using assumed conversion of 1.015 kg/L
Dairy	Input figures adapted from department-provided annual production figures (in L) using assumed conversion of 1.0305 kg/L
Fruit and vegetable	Figures provided separately as Fruit and as Vegetable sectors; sum of figures provided as tonnes p.a. used as inputs
Meat	Figures provided as tonnes p.a. and used as-is for model input
Organic chemicals	Figures provided as tonnes p.a. and used as-is for model input
Paper	Figures provided as tonnes p.a. and used as-is for model input
Sugar	Figures provided as tonnes p.a. and used as-is for model input

The NSW-based commodity production figures per sector were calculated by applying a NSW share of employment for each sector as a percentage-based factor. The adopted value for each sector is 28%, except for organic chemicals, where 32% was adopted.

The historical facility-level employment numbers are available from the NPI database. These are used as an indirect measure of each facility's production rate. This method inherently assumes that there are no gained efficiencies in employment vs production rate (i.e. direct correlation assumed).

The employment numbers were assumed for certain facilities, such as those not captured in the NPI database, based on investigations on each facility or by adopting historical numbers where available in the NPI database before 2016.

Emission estimation method – industrial wastewater

The industrial sectors assessed are listed in Table 40. These sectors are consistent with sectors outlined in the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (CER 2021). Sectors with 2-, 3- or 4-digit Australian and New

Zealand Standard Industrial Classification (ANZSIC) codes comprise subsectors that are considered for the assessment.

Table 40 Industrial sectors for assessment

Sector	ANZSIC code
Dairy	113
Paper	1510
Meat and poultry	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 DCCEEW 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. The method is described below.

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 2006). 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.

Step 4 – inventory projection

The commodity production estimates were used to project the GHG emissions into future years.

Commodity forecasting approach

Commodity production data is largely unavailable at a facility level. To enable both future projection and spatial disaggregation of the industrial emissions, an economic analysis was undertaken to project the commodity production values at a facility level using data that is publicly available.

The commodity forecasting approach is summarised in Table 41.

Table 41 Methodology summary – economic forecasting of sector growth and commodity production

Component	Details
Inputs	Gross Value Added (GVA) for agricultural industrial activities ABS general population of Australia 2011–2016 employment figures for the 116 identified facilities
Calculations	GVA per person GVA per sector CAGR of sector activity
Summary	Agricultural GVA represents industrial activity for the 8 assessed sectors National GVA represents NSW GVA National GVA represents sector-specific GVA Employment growth directly represents facility commodity production
Outputs	Sector growth rate for projecting employment growth and hence commodity production

The limitations of this methodology are:

- by linking employment growth directly to commodity production, it does not account for efficiencies gained in industrial employment (i.e. in the event that fewer employees are required to maintain commodity production in the future)
- GVA figures were generated for the overall agriculture industry, which does not account for sector-specific economic dynamics
- GVA figures were averaged across the Australian general population, which does not account for sector-specific or state-specific value generation per employee.

Without commodity production rates disaggregated by facility, this approach was determined, through consultation with the department and technical experts, to be a suitable high-level estimation method based on the data available. Estimating commodity production rates for each of the 116 identified facilities, and based on their individual production activities, would be timeline-prohibitive and thus an approach that is unlikely to achieve a significantly greater level of accuracy.

It is also important to note that industrial activity changes rapidly, with shifts in economic investment and output constantly occurring. No facility is expected to behave similarly in 2050 as it does now. Beyond 2030, any projections will be of lower confidence because of the uncertain nature of long-term projections.

Economic forecasting outputs

The key output of the economic forecasting is the CAGR of employment figures for each sector. The results of the economic analysis are presented in Table 42, which are incorporated into the model as factors.

Table 42 CAGR results for each industrial sector

Sector	CAGR of sector
Dairy	–4.01%
Paper	7.41%
Meat	0.00%
Organic chemicals	–0.93%
Sugar	–4.40%
Beer	4.58%
Wine	–2.09%
Fruit and vegetable	–9.43%

The growth rates from Table 42 are applied to each facility, thus providing a forecast of employment numbers annually from 2020–2050.

Data limitations and quality

Emissions are affected by uncertainties and inaccuracies within the industrial facility data collected by DCCEEW, 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 DCCEEW 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.

Other waste sources

As a first approximation, biological treatment and incineration emissions were projected to 2030 based on national emissions projections for these sectors multiplied by the ratio of NSW emissions to national emissions for each sector for the latest GHG inventory year (2020), with the 2021–2030 trend continued to 2050 (DISER 2021a, 2022c).

Base case waste sector emissions projections

Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the NSW waste sector by subsector are shown in Figure 43.

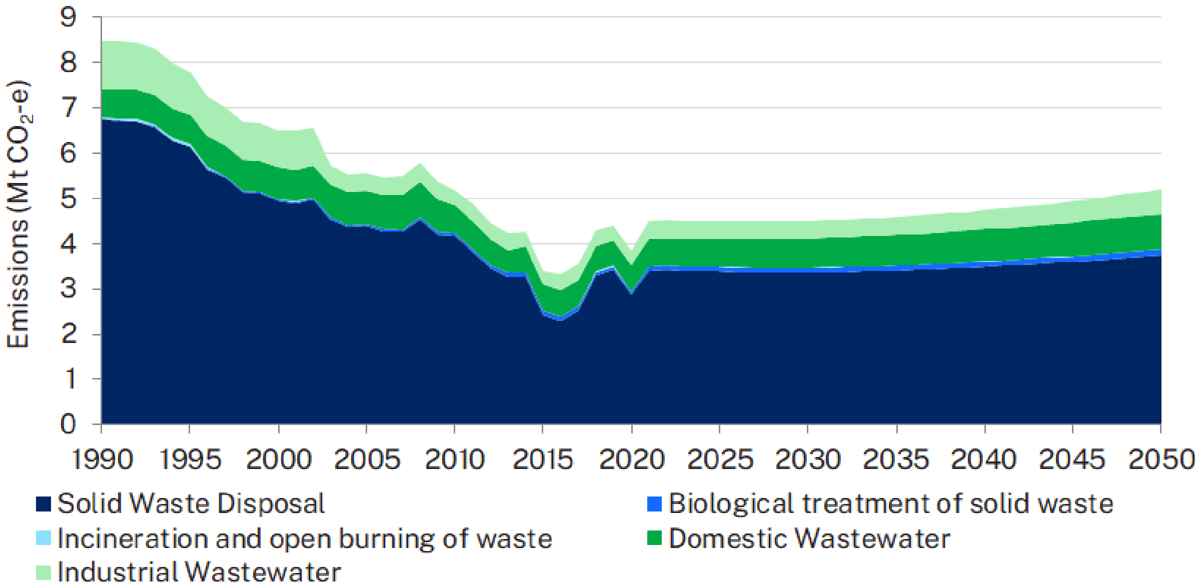

Figure 43 **Waste emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)**

Three-quarters of recent waste emissions are due to solid waste disposal, with much of the remainder from domestic and industrial wastewater. The decrease in past emissions was due in part to the use of landfill gas capture technology, which allows the gas to be used for power generation, transferred off site or flared on site (where the CH_4 is combusted to CO_2, a much less potent GHG). The fall in emissions was also due to reduced waste generation per capita and increased recycling rates and diversion of waste away from landfills.

The step change in emissions for the projected future years is due to the department using the higher waste volumes from the NSW EPA's WARRP data as inputs into the solid waste projections and more detailed modelling of wastewater treatment works, as described in the previous section. Detailed modelling of wastewater treatment emissions in 2022 show that emissions projections from 2022–2050 for industrial wastewater are greater compared to the projections made in 2021.

Current policy emissions projections

A target of net zero emissions from organic waste by 2030 has been set under the Net Zero Plan (DPIE 2020). To achieve this target, a key measure is to reduce the quantity of organic waste being landfilled. The recent Waste and Sustainable Materials Strategy 2041: Stage 1 2021–2027 targets reducing the quantity of food organics (FO) and garden organics (GO) being sent to landfill (DPIE 2022b). The specific targets are:

- 10% reduction in waste generated per person by 2030
- 50% reduction in organics disposed to landfill by 2030.

The strategy also states that the NSW Government will:

- require landfill gas capture for landfills over a certain size and all expanded or new landfills with exemptions for certain circumstances
- require net zero emissions for landfills that are subject to an environment protection licence, by a prescribed timeframe.

To complement these regulatory measures, the NSW Government will invest $7.5 million to support the installation of landfill gas capture infrastructure and will explore the introduction of a waste levy rebate for landfills that have landfill gas capture infrastructure installed (DPIE 2022b).

To achieve net zero emissions, offsets may also be required where the above measures fall short of the net zero target.

Preliminary abatement modelling was undertaken for the 2022 projections addressing the specific targets noted above; however, information on set targets related to further landfill gas capture and information on future net zero requirements for landfills was not available at the time the projections were being done.

The following assumptions were thus applied in the preliminary abatement modelling:

- The target was assumed to be a 50% reduction specifically in FO and GO sent to landfill, with other organics such as nappies, sludge and textiles, etc. not reduced. The measures were assumed to commence in 2022 and the target achieved in 2030.
- A 10% reduction in waste generated per person was assumed and taken to be indicative of a 10% reduction in all waste types to be disposed of in NSW landfills.
- The current rate of landfill gas capture varies between an actual 42% in 2021 to a projected 54% in 2050, with an average of 49% over that period. As a possible scenario for the 2022 projections, an overall increase of the landfill gas capture rate to 75% by 2035 (MRA Consulting 2020) was included, beyond which the gas capture rate remains relatively steady to 2050. Individual landfill gas capture rates were adjusted based on (1) historic gas capture volumes, (2) available information on current gas capture capacity and (3) recent actual gas capture volumes.

The abatement in the waste sector modelled to be achieved (as outlined in the assumptions above) within the 2022 projections is shown in Figure 44, with resultant current policy projections for this sector compared to base case projections in Figure 45. The steep increase in abatement to 2035 is predominantly driven by an increase in CH_4 capture from solid waste to landfill disposal, from the current 56% to 75%, supported by the 50% reduction in food and garden organic waste to landfill by 2030. Beyond 2035 gas capture rates were modelled to remain constant (from 75–78%).

Inventoried emissions (1990–2020) and current policy emissions projections (2021–2050) for the NSW waste sector by subsector are shown in Figure 46. As noted for the base case projections, the step change in emissions for the projected future years is due to the department using the higher waste volumes from the NSW EPA's WARRP data as inputs into the solid waste projections and more detailed modelling of wastewater treatment works. Past emissions reduced due to reduced waste generation per capita, increased recycling rates and the diversion of waste away from landfills. These trends are projected to be further supported under the Waste and Sustainable Materials Strategy 2041: Stage 1 2021–2027 announced in June 2021 (DPIE 2022b). Confirmed targets within the strategy related to implementing further landfill gas capture and requiring landfills subject to environment protection licences to be net zero, will be addressed in future projections.

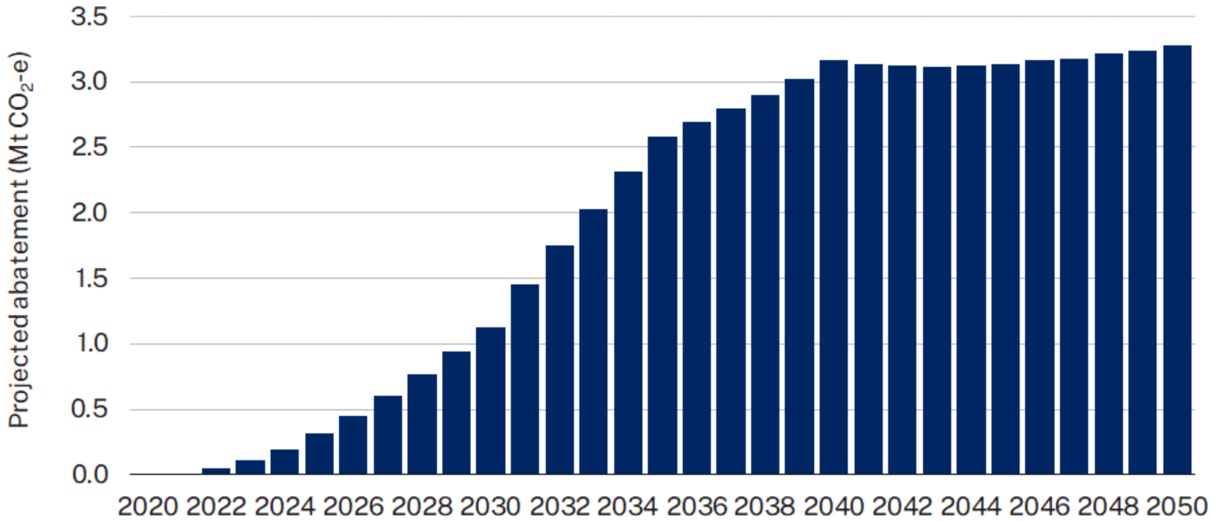

Figure 44 **Abatement of waste sector emissions projected to be achieved by Net Zero Plan Stage 1 programs**

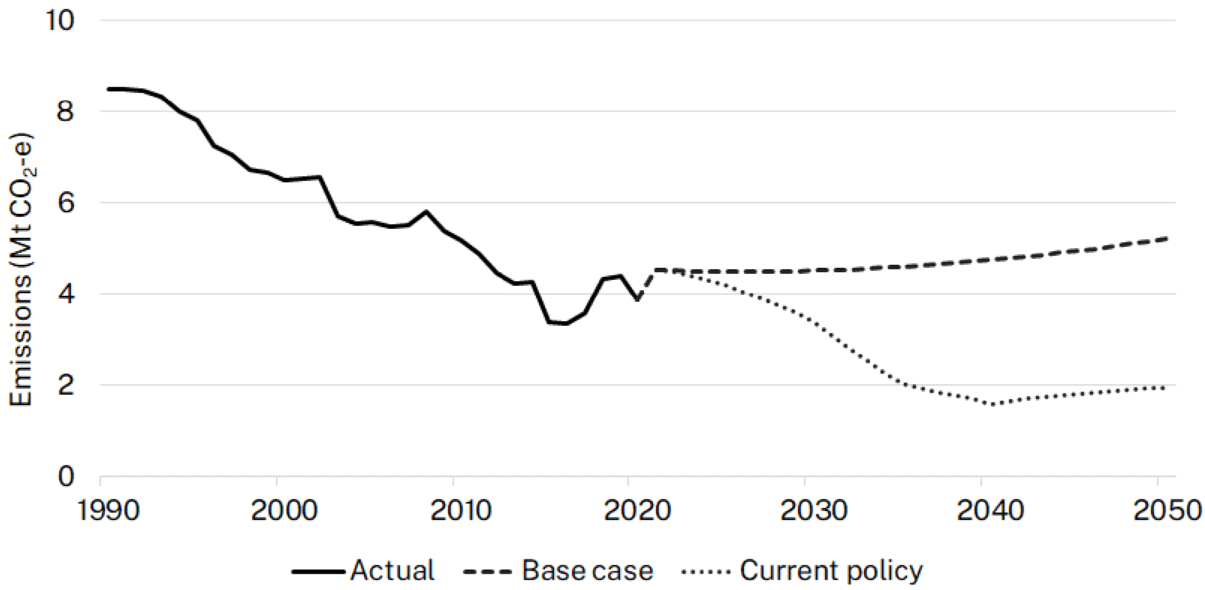

Figure 45 **NSW waste sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)**

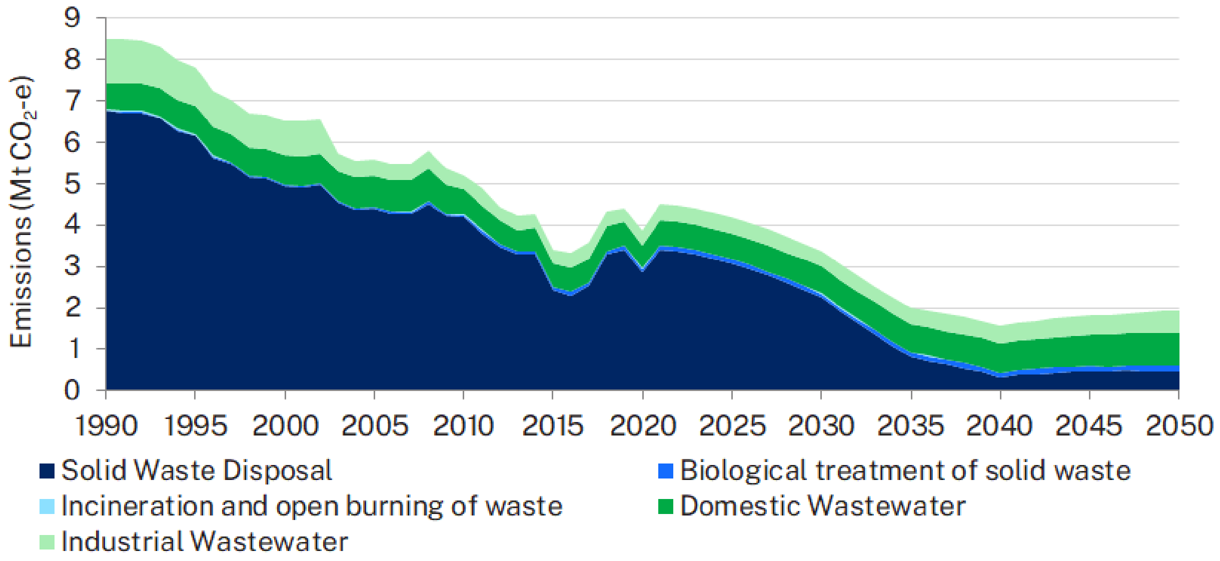

Figure 46 **Waste emissions by subsector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)**

Considerations for projection updates

Future projection updates will consider:

- latest NGERS, waste disposal and population projection data
- measures to increase data sources for council landfills and small landfills, including improving information on waste streams and management practices
- the full impact of the NSW Waste and Sustainable Materials Strategy on waste sector emissions as landfill gas capture targets are finalised.

Projection uncertainty

Emissions projections are inherently uncertain involving incomplete data, expert judgement and assumptions about future trends in global and domestic economies, policies and technologies. A qualitative assessment was undertaken of uncertainties in the 2021 emissions projections for each sector, accounting for the availability and quality of activity data and emission factors or carbon intensities applied (Table 43).

Table 43 Criteria for assessing the level of confidence in the NSW emissions projections

Projection inputs	High confidence	Medium confidence	Low confidence
Activity projection quality	Modelled activity projections using robust assumptions	Modelled activity projections using reasonable assumptions	Assumed trends in activity rates; and/or High-modelled uncertainties in activity rates; and/or Uncertain activity rates
Emission factors/ carbon intensities	Specific emission factors/carbon intensities, with projected changes based on robust assumptions	General emission factors/carbon intensities, with projected changes based on reasonable assumptions	Default emission factors/ carbon intensities

A description of the level of confidence in the emissions projections based on a qualitative assessment of uncertainties is given in Table 44.

Table 44 Level of confidence in base case NSW emissions projections

Sector/subsector	Projections to 2035	Projections 2030–2050
Electricity generation	Medium to High	Medium
Stationary energy (excluding electricity)	Medium	Low
Road transport	Medium	Medium to Low
Rail, aviation and water transport	Medium	Low
Fugitives – operational coal mines	High	Medium
Fugitives – other mining	Medium	Low
IPPU	Medium	Low
Agriculture	Medium	Low
LULUCF	Medium	Low
Waste	Medium to High	Medium

The overall level of confidence in emissions projections is considered ‘medium’ for projections to 2035 and ‘low’ for projections over 2035–2050. Despite detailed modelling and reasonable assumptions being generally applied, lower levels of confidence are assigned to some sectors due to uncertainties in the base case related to the pace of the global energy transition.

Current policy projections include only measures associated with Medium to High levels of confidence in the nearer term, with the sector focus and effectiveness of abatement under future stages of the Net Zero Plan being less certain.

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Glossary and shortened forms

Term	Shortened form	Description
Abatement		Reduction of greenhouse gas (GHG) emissions, either their degree or their intensity
Action		A sub-component of a NSW Government program developed to reduce GHG emissions
Activity		A process that generates GHG emissions or uptake. In some sectors it refers to the level of production or manufacture for a given process or category
Actual		With reference to emissions, observed or past GHG emissions as opposed to forecasted or projected
ANZSIC code		A level of classification in the ANZSIC (Australian and New Zealand Standard Industrial Classification) system
Assessment Report 5	AR5	Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change
Assessment Report 6	AR6	Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change
Australia New Zealand Standard Industrial Classification	ANZSIC	A classification system developed by the Australian Bureau of Statistics and Statistics New Zealand to organise information from entities based on their main activity
Australian Bureau of Agricultural and Resource Economics and Sciences	ABARES	The research arm of the Australian Government Department of Agriculture, Fisheries and Forestry that provides professionally independent data, research, analysis and advice to inform decisions affecting Australian agriculture, fisheries and forestry
Australian Energy Market Operator	AEMO	Manages electricity and gas systems and markets across Australia
Base case		Projected emissions that do not take into account NSW Government policies, programs and actions to abate GHG emissions; includes corporate commitments
Base year		A historical datum against which an entity's emissions are tracked over time (e.g. year)
Business-as-usual	BAU	Projected emissions that do not take into account NSW Government policies, programs and actions to abate GHG emissions; excludes corporate commitments
Carbon dioxide	CO_2	A naturally occurring gas produced through the burning fossil fuels, biomass, as a result of land-use changes (LUC) and industrial processes (e.g. cement production). It is the main anthropogenic GHG that affects the Earth's radiative balance and the reference gas against which other GHGs are measured. It has a global warming potential (GWP) of 1
Category		A property of each reported activity; a broad group associated with the reported activity that is producing emissions, consuming or producing energy

Term	Shortened form	Description
Clean Energy Regulator	CER	An Australian Government body responsible for accelerating carbon abatement for Australia
CO_2 equivalent	CO_2-e	The universal unit of measurement to indicate the GWP of each GHG, expressed in terms of the GWP of one unit of CO_2. It is used to evaluate the climate impact of releasing, or avoiding the release of, different GHGs on a common basis
Current policy		Projected emissions that build upon the base case but also take into account NSW Government policies, programs and actions to abate GHG emissions
Department of Climate Change, Energy, the Environment and Water	DCCEEW	An Australian Government department
Department of Industry, Science, Energy and Resources	DISER	An Australian Government department
Department of Planning and Environment	the department	A NSW Government department, previously known as the Department of Planning, Industry and Environment
Department of Planning, Industry and Environment	DPIE	A NSW Government department, now known as the Department of Planning and Environment
Emission		The release of GHGs into the atmosphere
Emission factor	EF	The quantity of GHGs emitted per unit of a specified activity
Emissions intensity	EI	The total emissions divided by either the total energy content of the fuel, the total energy used in a sector or the total production for a sector
Enteric fermentation		A ruminant digestive system process by which plant material is broken down by bacteria in the gut under anaerobic conditions
Environment Protection Authority	EPA	The primary environmental regulator for NSW
Flaring		The combustion of unwanted or excess gases and/or oil at an oil or gas production site, gas processing plant or oil refinery
Forecast		A prediction or estimate of future events
Fuel type		The specific fuel or energy commodity
Global warming potential	GWP	The relative warming effect of a unit mass of a gas compared with the same mass of CO_2 over a specific period

Term	Shortened form	Description
Greenhouse gas	GHG	Atmospheric gases responsible for causing changes to global climate. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20). Less prevalent but very powerful GHGs are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)
Gross state product	GSP	A measure of the value of all goods and services produced within a state
Hydrofluorocarbons	HFCs	Often used as refrigerants, HFCs are a GHG used as substitutes for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)
Industrial processes and product use	IPPU	A GHG inventory sector that includes emissions from a range of industrial sources; includes GHGs from chemical reactions (other than combustion that is generally for energy purposes), and from the use of synthetic gases such as halocarbons
Intergovernmental Panel on Climate Change	IPCC	The international body responsible for assessing the state of knowledge about climate change to increase international awareness of climate change science and provide guidance to the international community on issues related to climate change
Land use, land-use change and forestry	LULUCF	A GHG inventory sector that covers emissions and removals of GHGs resulting from direct human-induced land use, land-use change and forestry activities
Local government area	LGA	An administrative division that a local government is responsible for
Long-term		In the context of emissions projections within this report, the period from 2030–2050
Market impact	MI	The change in the price of a commodity or asset caused by the trading of that commodity/asset
Matters to be identified	MTBI	Matters to be identified by entities and/or by particular sources of emissions specified under regulations 4.10, 4.11, 4.13, 4.14, 4.15, and 4.17 of the National Greenhouse and Energy Reporting Regulations 2008
Methane	CH_4	One of the GHGs to be mitigated under the Kyoto Protocol and a major component of natural gas and associated with hydrocarbon fuels
Metropolitan		A region with a densely populated urban centre surrounded by less populated areas
Modelling		Using abstract or mathematical models to assist with calculations and predictions
National Greenhouse Accounts		National GHG inventories submitted by the Australian Government to meet its reporting commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol to that Convention

Term	Shortened form	Description
Navigation		All civilian (non-military) marine transport of passengers and freight. Domestic marine transport consists of coastal shipping (freight and cruises), interstate and urban ferry services and small pleasure craft movements
Near-term		In the context of emissions projections within this report, the period from 2021–2030
Nitrous oxide	N_2O	One of the GHGs to be mitigated under the Kyoto Protocol, mainly from agricultural practices (soil and animal manure management), but also from sewage treatment, fossil fuel combustion, and chemical industrial processes. NO_2 is also produced naturally from a wide variety of biological sources in soil and water
Ozone depleting substance	ODS	A compound that contributes to stratospheric ozone depletion; includes CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride, and methyl chloroform. These compounds are very stable in the troposphere and only degrade under intense ultraviolet light in the stratosphere. Upon breaking down they release chlorine or bromine atoms, which depletes ozone
Program		A framework to manage strategic goals and associated funding to achieve the NSW Government’s emissions reduction targets under the Net Zero Plan and focused on specific GHG inventory sectors
Projection		The potential future evolution of a quantity or set of quantities computed with the aid of a model. Projections are based on assumptions concerning, for example, future socio-economic and technological developments that may or may not occur
Reporting		The presentation of data to internal and external users that include regulators, the general public or specific stakeholder groups
Scenario		A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about relationships and the key driving forces. Scenarios are neither predictions nor forecasts; they are used to provide a perspective on the implications of developments and actions
Scope		Used to structure direct and indirect GHG emissions from activities, based on where they occur relative to the activity
Scope 1 emissions		GHG emissions into the atmosphere as a direct result of an activity, or series of activities
Scope 2 emissions		GHG emissions occurring as a consequence of the indirect consumption of an energy commodity, such as the use of grid-supplied electricity, heat, steam and/or cooling within the relevant boundary
Scope 3 emissions		Indirect GHG emissions other than scope 2 that are generated in the wider economy

Term	Shortened form	Description
Sector		Similar to the UNFCCC classification of sectors, sectors for emissions reporting under the Net Zero Plan include 'Electricity generation', 'Stationary energy' (excluding electricity generation), 'Transport', 'Fugitives', 'Industrial processes and product use' (IPPU), 'Agriculture', 'Land use, land-use change and forestry' (LULUCF) and 'Waste'
Solvent		An organic liquid used for cleaning or to dissolve materials
Source		Any process or activity that releases a GHG, aerosol or a precursor of a GHG into the atmosphere
State of the Environment report	SoE	A NSW Government report
Stationary energy		Sector that includes the combustion of fuels within an apparatus in a fixed location that is designed to raise heat and use it as such, or as mechanical work
Subcategory		A subdivision of a subsector
Subsector		A subdivision of a sector
United Nations Framework Convention on Climate Change	UNFCCC	The entity that established an international environmental treaty in 1994 to combat human interference with the climate system. Parties to the convention have agreed to work towards achieving the ultimate aim of stabilising 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'
Vehicle kilometres travelled	VKT	Aggregate sum of the kilometres travelled by all vehicles within the relevant domain, which may be across all vehicles in the state, or for only specific vehicle types and/or regions
Venting		The release of gas into the atmosphere without combustion, either at the production site, refinery or stripping plants, to dispose of non-commercial gas or to relieve system pressure