Department of Planning and Environment

NSW Greenhouse Gas Emissions Projections, 2021

Methods paper

environment.nsw.gov.au

Cover photo: Windmills at Boco Rock Wind Farm, Nimmitabel. Sheep graze in the foreground. Jaime Plaza Van Roon/DPE

Published by:

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

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

ISBN 978-1-922899-55-2
EHG 2022/0460
September 2022

Find out more about your environment at:

www.environment.nsw.gov.au

Contents

List of tables

List of figures

Executive 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 emission objectives.

Emissions projections are prepared using the latest activity data and 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 actions under the Net Zero Plan Stage 1: 2020–2030.

Current policy projections are based on the base case scenario but account for emissions reductions projected to be achieved by funded programs implemented over 2020–2030 under Stage 1 of the Net Zero Plan. Funded programs under the plan that will deliver direct (scope 1) emissions reductions, and for which abatement estimates were available by June 2021, were accounted for within the 2021 current policy projections.

This methods paper outlines the assumptions and methods applied in preparing the 2021 base case and current policy emissions projections that informed the NSW Government's adoption of the 2030 target of achieving a 50% reduction in emissions below 2005 levels by 2030. These 2021 emissions projections were included in the Net Zero Plan Stage 1: 2020–2030 Implementation Update, published in September 2021, and in the NSW State of the Environment 2021, released in February 2022.

Emissions 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).

The 2021 current policy projections provide a lower bound (conservative) estimate of emissions reductions as they do not account for all actions under Stage 1 of the Net Zero Plan, nor do they include the impact of policies to be implemented under Stages 2 and 3 of the Net Zero Plan.

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.

Introduction

NSW is committed to achieving net zero 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 (SoE) reports. Capabilities were established within the department to:

- deliver state- and economy-wide emissions modelling and analysis to inform the NSW Government's net zero 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 with all sectors of the economy addressed including electricity, transport, agriculture, on-site fuel use, mining, industry, waste and forestry. Emissions projections are prepared using the latest activity data and 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.

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 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 projections are developed based on the base case scenario but account for emissions reductions projected to be achieved by funded programs implemented over 2020–2030 under Stage 1 of the Net Zero Plan. Funded programs under the plan that will deliver scope 1 emissions reductions, and for which abatement estimates were available by June 2021, were accounted for within the 2021 current policy projections.

NSW GHG emissions projections include a range of key data inputs, assumptions and methods. This methods paper outlines 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). 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.

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, d).

Emission factors used are generally consistent with the NSW Greenhouse Gas Inventory 2019, published in 2021 (DISER 2021c, f). 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
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) (IPCC 2014). Although the Sixth Assessment Report (AR6) released in August 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. Emissions are projected from 2020–2050, with reference made to inventoried emission estimates for 1990–2019 (latest inventory year published at the time projections were prepared) (DISER 2021f). Data inclusion cut-off is generally June 2021, with exceptions identified in the specific programs and sectors.

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 Commonwealth Government for the National Greenhouse Accounts to support reporting to the UNFCCC. The National Greenhouse Accounts include emissions from:

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

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

Programs for which emissions reductions are included

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 emission 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 2021 current policy projections account for funded programs under the Net Zero Plan that will deliver scope 1 emissions reductions, and for which abatement estimates were available by June 2021 for inclusion in the projections (Table 2). Emissions reductions to be achieved by other Net Zero Plan programs and other NSW Government actions, and progress being made by programs in achieving the abatement projected, will be accounted for within annual projection updates.

Table 2 Net Zero Plan programs with quantified scope 1 emission abatement estimates

Sector	Programs
Electricity generation	Electricity Infrastructure Roadmap (NSW Government 2020a) Energy Security Safeguard (NSW Government 2020b)
Industrial processes	Net Zero Industry and Innovation Program (NZIIP) (DPIE 2021c) Business Decarbonisation Support (DPIE 2021a)
Stationary energy	Net Zero Industry and Innovation Program Business Decarbonisation Support Safeguard Acceleration Program (NSW Government 2020b) NSW Net Zero Buildings Initiative (DPIE 2021e)
Fugitive emissions	Net Zero Industry and Innovation Program
Transport	NSW Electric Vehicle Strategy (NSW Government 2021) Zero Emission Bus Transition Strategy (TfNSW 2022) Transport Consumer Information Hydrogen Hubs (within NZIIP)
Waste	Organic waste[1] (DPIE 2022b)
Agriculture LULUCF	Primary Industries Productivity and Abatement (DPIE 2022a)

[1] Actions in the NSW Waste and Sustainable Materials Strategy 2041, Stage 1: 2021−2027 (DPIE 2022b).

The 2021 current policy emissions projections included in the Net Zero Plan Stage 1: 2020–2030 Implementation Update, published in September 2021, and in the NSW State of the Environment 2021, released in February 2022, provide a lower bound (conservative) estimate of emissions reductions as they do not account for all actions under Stage 1 of the Net Zero Plan, nor do they include the impact of policies and programs to be undertaken under Stages 2 and 3 of the Net Zero Plan. The NSW Hydrogen Strategy, NSW Waste and Materials Strategy 2041 and the National Parks and Wildlife Service Carbon Positive by 2028 Plan, by example, were announced after the completion of the 2021 projections and emissions reductions have not been captured for all actions under these strategies.

Many initiatives under Stage 1 of the Net Zero Plan are focused on delivering innovative technologies, goods and services to support deeper cuts in post-2030 NSW emissions. The full impact of the NSW Clean Technology and Hydrogen programs on post-2030 emissions reductions will be more comprehensively reflected in future updates to NSW emissions projections to be published in NSW State of the Environment reports.

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

A high-level review of the department's base case and current policy emissions projections for NSW was undertaken by the national emissions inventory team within the then Commonwealth Department of Industry, Science, Energy and Resources (DISER) and found to be consistent with the projections being prepared for Australia.

The assumptions, inputs and approaches for the department's base case and current policy emissions projections, including program-specific abatement forecasts, were also subject to a detailed peer review by independent expert reviewers external to government. This peer review concluded that the *approach, method and projections were appropriate for projecting potential carbon emissions and program impact for 2030 and 2050.* Improvements recommended by the peer reviewers are being addressed in the preparation of the 2022 projection update as noted in the concluding subsection of each sector chapter.

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.

Base case emissions projections

Base case emissions projections exclude the impact of the NSW Electricity Infrastructure Roadmap (NSW Government 2020a) announced in November 2020 and the Energy Security Safeguard (NSW Government 2020b). Reference is therefore made to modelling and analysis for the Australian Energy Market Operator (AEMO) 2020 Integrated System Plan (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 National Electricity Market (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 2020c). 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 2020c), 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 1. 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.

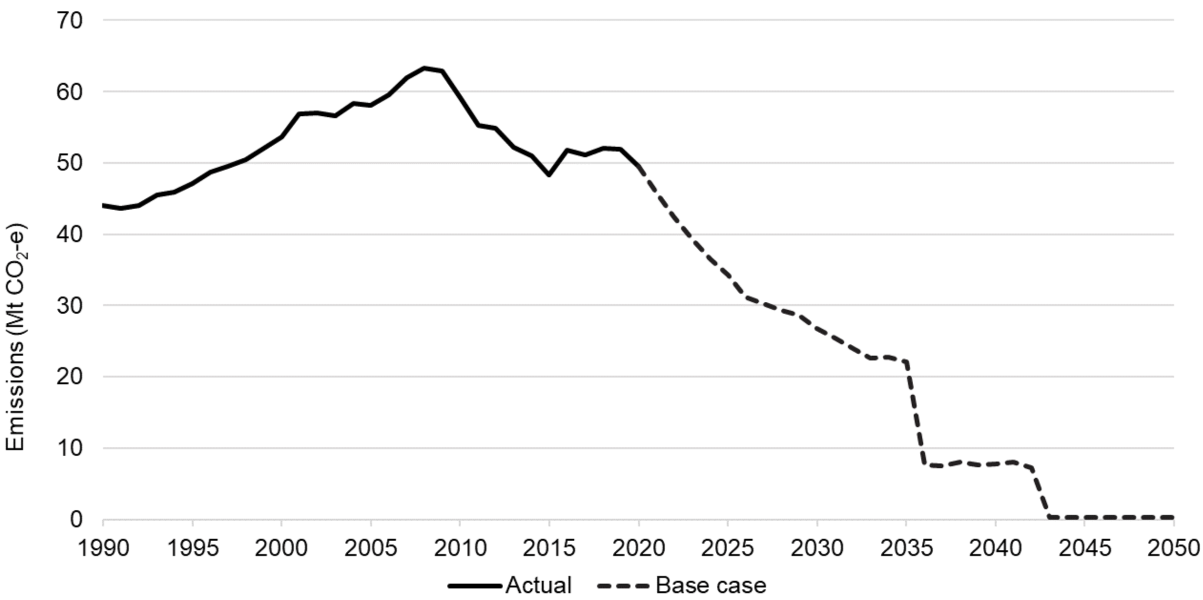

Figure 1 NSW public electricity generation emissions as inventoried (1990–2020), with base case emissions projections (2021–2050)

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); for example, according to the AEMO Quarterly Energy Dynamics for Q2 and Q3 2020:

- Electricity demand in NSW decreased by 2.6% over Q2 2020, with the greatest decrease during April (5% below average) when strict restrictions were implemented for the whole month. Smaller demand reductions were recorded during May and June (1% below average) due to cooler weather and the gradual relaxation of restrictions.
- NEM emissions reduced to their lowest levels on record in Q2 and Q3 2020 (0.71 and 0.7 t CO_2-e/MWh, respectively) due to lower coal-fired generation, reduced demand in Q2 and increased renewables output.

The impact of COVID-19 on electricity demand was 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 NSW Government announced the Energy Security Safeguard in 2019 and funding was subsequently allocated to fast-track and streamline its implementation. The Safeguard includes expanding and extending the existing Energy Savings Scheme 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 emissions from electricity generation. Neither modelling study is considered more accurate than the other, with forecasts taken to represent an appropriate range for our emissions reduction estimates. The abatement trajectory for current policy emissions from the NSW electricity generation sector is therefore expressed as a central estimate and range (Figure 2). 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).

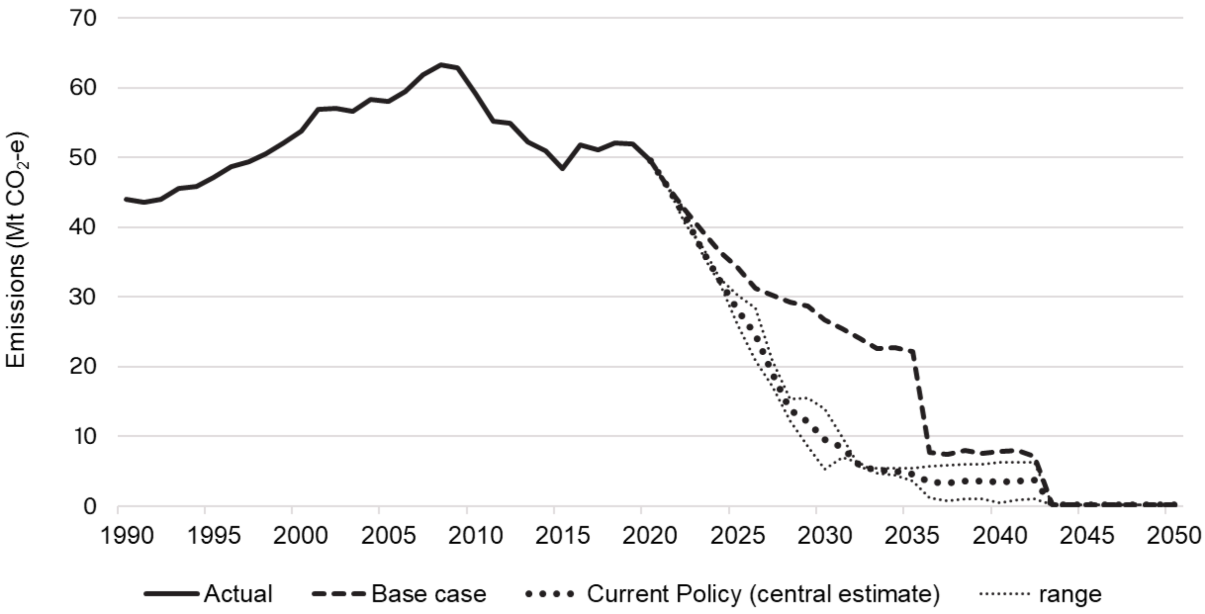

Figure 2 NSW electricity generation emissions as inventoried (1990–2020), with base case and current policy (central estimate, range) emissions projections (2021–2050)

Future considerations

Future trends in energy consumption and generation, as published in the AEMO ESOO 2021 and the AEMO 2022 ISP were not available at the time of compiling this methods paper and the associated 2021 emissions projections and will be considered in future updates.

Further modelling will be commissioned to assess the base case (counterfactual) emissions excluding the impact of the NSW Electricity Infrastructure Roadmap.

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 accounted for the abatement projected to be achieved due to programs under the Net Zero Plan addressing stationary energy related emissions (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 on-site 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 (stationary and mobile) 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 2019–20 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 within the Department of Regional NSW.

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 projections also included 2 key developments: 1) the Port Kembla Gas Terminal (PKGT) and 2) the 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 2022a). 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).

To estimate future stationary energy emissions for the NGP, it was assumed that on-site gas-fired electricity was the base case. 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

The general approach taken was to aggregate facility-level emissions data to sector level and then project it forward as whole based on annual sector-level changes in revenue forecasts to the mid-2020s. For future emissions to 2050, a linear trend was assumed based on mid-2020s emissions.

Facility-level GHG emissions data from industry reporting under the NGERS were obtained from the CER for use in the study. Projections used the latest available (2019–20) aggregated facility emissions as the base year data. The approach uses revenue forecasts to the mid-2020s for each commodity or sector from market analyst reports (e.g. IBISWorld provide forecasts to 2025–26 (IBISWorld 2022)) and the Office of the Chief Economist's (OCE) commodity forecasts (forecasts are provided to 2022–23) (DCCEEW 2022c). 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.

In addition to NGERS data, data was obtained from the AES (DCCEEW 2022a) to ensure agreement with the data reported within the NSW Greenhouse Gas Inventory for specific sectors.

Iron and steel

In the near term to 2025, the OCE in its June 2021 Resources and Energy Quarterly forecast (DISER 2021e) expected modest growth in the production of steel in Australia as shown in the table below.

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Iron and steel	3.0%	3.7%	0.01%	–	–	–

The emissions projections for the sector use the 2019–20 NGERS facility emissions data as the basis, aggregated to sector level, and projected forward to 2022–23 according to the percentage changes in the table above. From 2022–23 to 2049–50, a linear forecast is used based on 2019–20 to 2022–23 emissions. The general formula is:

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

where:

$\mathrm{E_t}$ = annual emissions in year t (tonnes CO_2-e)

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

$\Delta production$ = percentage change in production between year t and year t–1 up to 2022–23.

Note: A cross-check against the State and Territory Greenhouse Gas Inventory or STGGI (DCCEEW 2022b) for iron and steel revealed a gap due to the exclusion of coke oven gas in NGERS accounting. Therefore, the STGGI data was used to estimate emissions from the use of coke oven gas by taking the difference between the STGGI data and the aggregated emissions for the sector.

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 STGGI and projected forward using iron and steel production projections above.

Non-ferrous metals

In the near term to 2022–23, the OCE in its June 2021 Resources and Energy Quarterly forecast low growth in the production of aluminium in Australia as shown in the table below.

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Aluminium	0.67%	–0.52%	0.08%	–	–	–

According to the OCE for aluminium and alumina production in Australia, there are no planned expansions or major disruptions expected at existing operations. This suggests little change in production in the short to medium term. Emissions projections were calculated as per iron and steel emissions described above.

Chemicals

The chemicals and petrochemicals industry in general were forecast to experience annual growth according to the revenue projections from IBISWorld (IBISWorld 2022).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Chemicals	–3.25%	2.34%	1.83%	1.43%	0.88%	1.26%

Note: 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. The STGGI data were therefore used as the basis. Emissions projections were calculated as per iron and steel emissions except linear projections were based on data from 2019–20 to 2025–26.

Non-metal minerals

This sector covers glass and glass products, ceramics, cement and lime and other non-metallic minerals. The emissions for the industry were forecast using IBISWorld revenue forecast data averaged over the above subsectors (IBISWorld 2022).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Non-metal minerals	–8.48%	3.39%	2.49%	1.90%	0.35%	2.19%

Emissions projections are calculated as per chemical industry emissions.

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).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Pulp, paper and print	–2.8%	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).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Food processing, beverages and tobacco	–6.92%	3.93%	4.35%	1.13%	1.05%	1.09%

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).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Other manufacturing	–12.31%	0.43%	0.92%	1.50%	0.57%	1.54%

For construction, growth forecasts were based on 2019 NSW Treasury construction activity forecasts taken from department construction and demolition waste calculations. These forecasts were based on a combination of historical gross fixed capital formation – dwelling and non-dwelling construction for NSW (ABS 2021), and NSW Treasury forecasts for construction to 2024. A linear trend of the above historical data was used to develop total construction forecasts to 2041. The rate was then held constant to 2050.

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Construction	–1.89%	–0.22%	2.49%	2.44%	0.0	0.6%

In this case, the linear forecast commenced in 2023–24.

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).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Other metal mining	–0.47%	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).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Textiles	–7.38%	0.88%	–0.13%	–0.29%	–0.51%	–0.32%

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 2019, making up about a third of total NSW stationary energy (excluding electricity generation) emissions with emissions in the residential, commercial and institutional sectors accounting for about 68% of these 'other sector' emissions.

'Other sector' 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 2020d, 2021c).

Emissions from buildings are primarily driven by gas use in residential and commercial buildings. Such emissions are projected to fall due to energy efficiency measures. The projections are based on annual gas consumption projections from AEMO (AEMO 2019, 2020b) and wood and wood waste fuel use projections from DISER (DISER 2020b). The AEMO gas demand forecasts were adjusted to incorporate the impacts of energy efficiency from the Federal Climate Solutions Package (Commonwealth of Australia 2019) and measures announced in the 2020–21 Federal budget (DISER 2020d). The projections for stationary energy emissions from primary industries take into account the average rate of change in diesel consumption derived from NGER data.

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 3. 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.

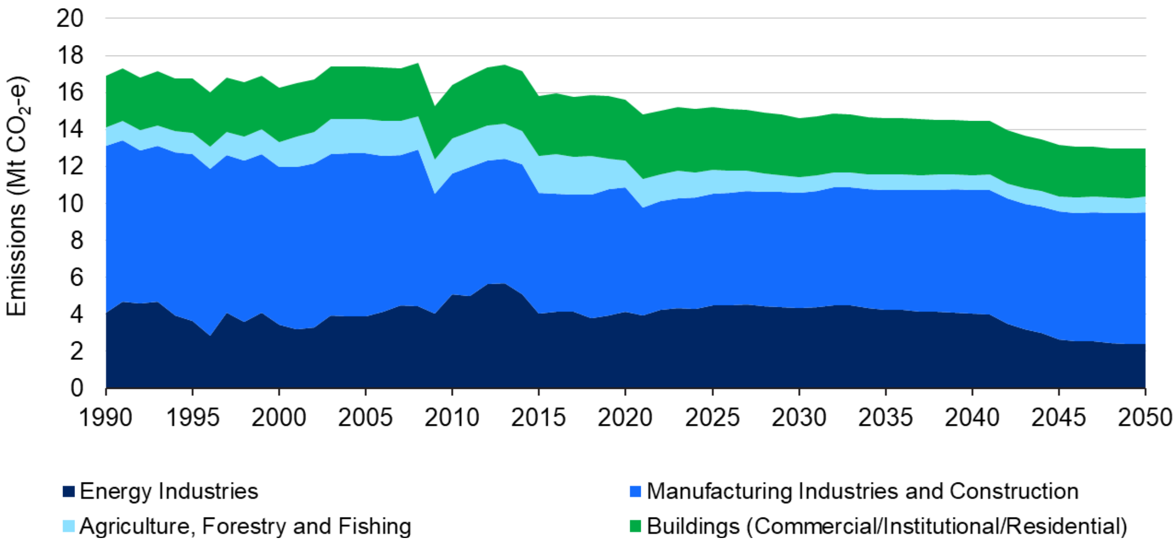

Figure 3 Stationary energy emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

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%).

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 the Net Zero Industry and Innovation Program (DPIE 2021c), 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 (DPIE 2021a).

The Safeguard Acceleration Program aims to support 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 Energy Savings Scheme.

The Accelerating Net Zero Buildings initiative contributes to emissions reduction forecasts for the commercial and institutional sectors through projected gas savings through energy efficiency improvements.

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.

The integrated abatement in the stationary energy sector modelled to be achieved as a result of these programs is shown in Figure 4, with resultant current policy projections for this sector compared to base case projections in Figure 5.

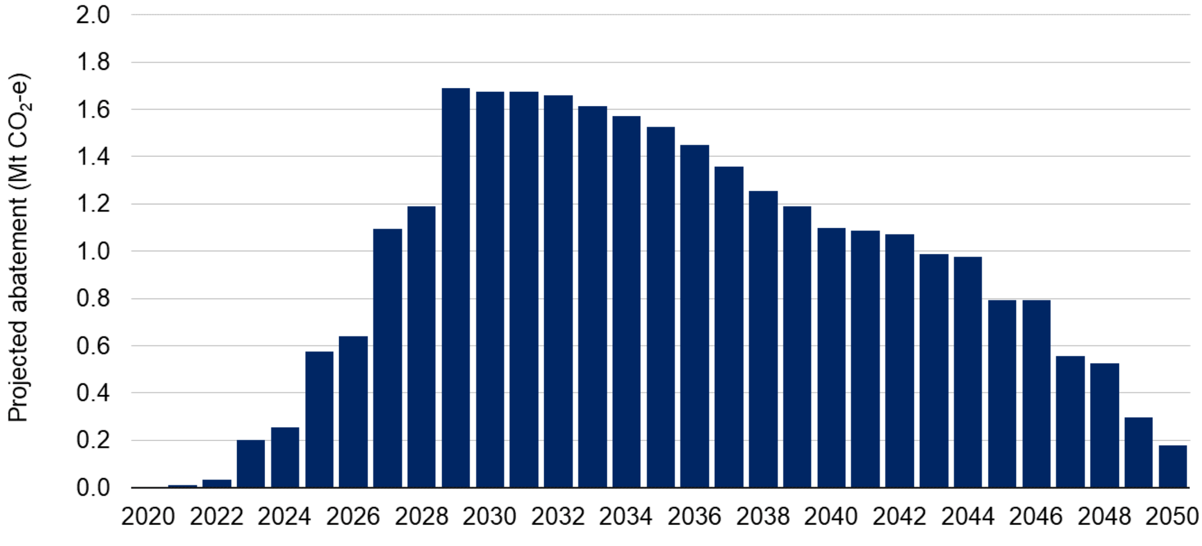

Figure 4 Abatement of stationary energy (excluding electricity generation) emissions projected to be achieved by Net Zero Plan Stage 1 programs

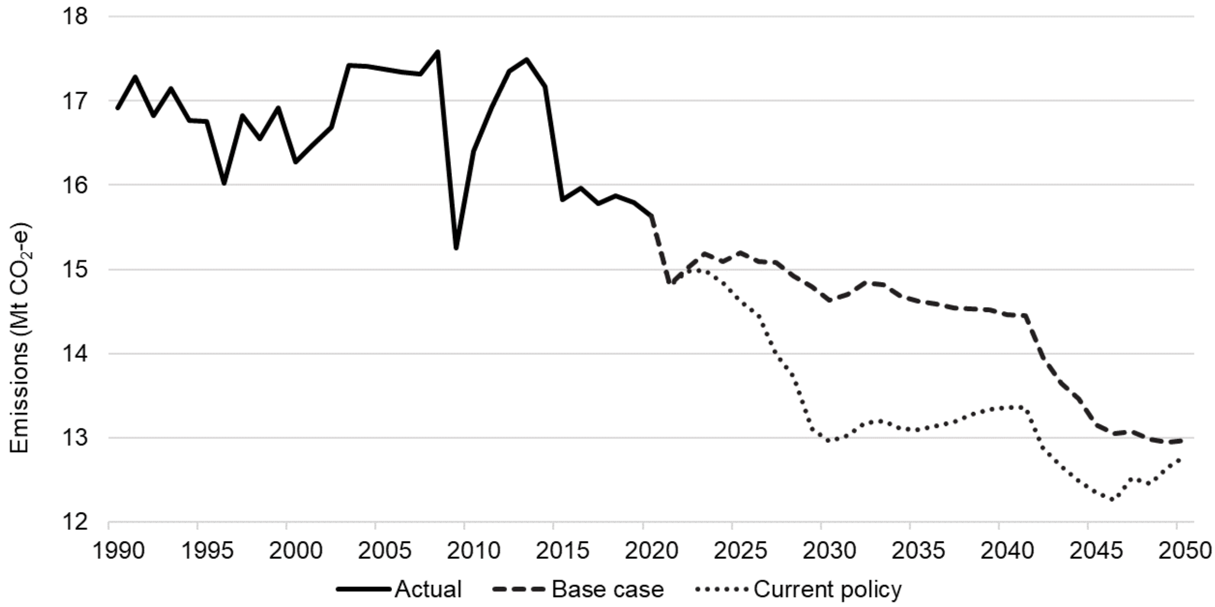

Figure 5 NSW stationary energy (excluding electricity generation) emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)

Future projections

Future projection updates will consider:

- the latest NGERS data, EIS information for new projects and commodity forecasts
- changes in building codes at federal and state levels that may impact gas consumption
- productivity rather than revenue forecasts for use in the emissions projections for manufacturing industries
- incorporating sectoral efficiency and productivity improvements (in place of assuming the emission intensity of future production will remain constant)
- potential market variance, fuel switching or demand/supply changes that may impact long-term 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 'other sectors'.

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, light commercial vehicles (LCVs) and motorbikes, contributed 74% of road transport emissions in 2019, with the remaining 26% due to heavy duty vehicles (mainly trucks).

Light duty vehicles

The NSW fleet and emissions models applied for LDVs 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 (as at June 2021).

Fleet and emissions modelling

The fleet model projects the future fleet profile and vehicle kilometres travelled (VKT) by estimating fleet growth, vehicle sales and vehicle attrition from a base year of NSW registration data.

LDV numbers for NSW for the base year of 2012 were taken from the Australian Bureau of Statistics (ABS) Motor Vehicle Census (MVC) (ABS 2019). Within each light vehicle type (e.g. passenger cars, sport utility vehicles (SUVs), LCVs) the MVC data was apportioned into vehicle sizes based on a detailed analysis of the entire Transport for NSW (TfNSW) registration database. The age profile was calculated to match the TfNSW registration data.

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

Projected growth in the vehicle fleet was estimated by fitting saturating curves to the trend of PVs and LCVs per capita and applying these relationships to NSW department 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.

The annual vehicle sales by vehicle type were divided into fuel types (motive power) by applying a percentage of sales figure. The base case (business-as-usual) uptakes of battery electric vehicles (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.

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 Survey of Motor Vehicle Use (SMVU) (ABS 2020b). Total fleet VKT was estimated for each vehicle and fuel type category by multiplying the number of vehicles of each year of manufacture (YOM) by the corresponding annual VKT and summing over the YOMs.

The emissions model estimates the fleet aggregate emission factors (grams of emission per kilometre, 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 emissions factors and fuel consumption based on limited Australian test data and the guidebook/COPERT data.

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

New petrol and diesel vehicles entering the NSW fleet were assumed to be certified to Euro 5 (ADR79/04) and Euro 6 was not assumed to be introduced before the end of the NSW Electric Vehicle Strategy funding period. Hybrid vehicles and PHEVs were assumed to consume 22–31% and 53–58% less fuel than equivalent internal combustion engine (ICE) 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 2020d, 2021c).

Model validation

Modelled EV sales and stock numbers derived for 2019 were found to be in good agreement with TfNSW registration data sales (new registrations) and stock numbers for 2020 (Table 3). The combined fleet and emissions model was validated for the base year of 2018 by comparing the total calculated fuel consumption with the NSW fuel sales statistics from the APS (DISER 2020c) and with the 2018 release of the SMVU (ABS 2020b) (Table 4).

Table 3 Comparison of the department modelled EV sales and stock with actual sales and stock from the TfNSW database for calendar year 2019

	Total EV sales (BEVs and PHEVs)	Total EV stock (BEVs)
Department model for 2020	1,788	5,388
TfNSW data for 2020	1,786	5,287

Table 4 Comparison of the department motor vehicle emission model fuel consumption with AFS and ABS SMVU, for calendar year 2018

	Department model fuel consumption (ML)				APS		SMVU 2018 Cars + LCVs
	Cars & SUVs	LCVs	Allowance for non-road[2]	Total	Total	Retail	
Petrol (incl. hybrids)	4,954	506	364	5,824	5,770	4,368	5,425
Diesel	744	1,105	N/A	1,849	N/A	N/A	2,057

The department model estimates 1% higher total petrol compared to the total NSW petrol sales and estimates light duty motor vehicle petrol consumption 1% higher than the SMVU (Table 4). Light duty diesel fuel consumption is unable to be meaningfully compared to the APS due to the very large non-road diesel use and lack of disaggregation in the APS.

The department model estimates 11% lower LDV diesel consumption than the SMVU. It is noted that the SMVU diesel (and petrol) fuel consumption rates vary moderately over SMVU issues and the light duty diesel fuel consumption in the 2018 release was considerably higher than the 2012–2016 SMVU releases. The department model was thus calibrated based on the relatively stable light duty fuel consumption rates of the 2012–2016 SMVU releases.

Modelled CO_2-e emissions were compared to emissions from the NSW Greenhouse Gas Inventory and found to be within 1.5% of inventoried emissions for 2019.

Base case EV uptake rates are consistent with the moderate–high EV stock forecasts underpinning the projections for the electricity sector.

COVID-19 impacts

Light vehicle transport activity and emissions reduced due to the impact of COVID-19. In NSW, petrol use decreased by 10% in 2020 and 8% in 2021 compared to 2019 petrol consumption. PV sales reduced by 49% in 2020. The reduction in road transport emissions was evidenced by the reduction in traffic air pollution concentrations recorded by the NSW Air Quality Monitoring Network.

The impact of COVID-19 was accounted for in the fleet and emissions modelling for 2020–2022, after which it was assumed road transport would return to pre-COVID trends with base case emissions due to light vehicles projected to rise slightly through to 2026. Emissions are

[2] An allowance for non-road use such as recreational boats, small garden and commercial petrol equipment is made from the ratio of all non-road petrol use to on-road petrol use from the 2013 EPA NSW GMR Air Emission Inventory (EPA 2019).

then projected to reduce as a result of improved fuel efficiencies of ICE vehicles and base case uptake of EVs (Figure 6).

A limitation of the modelling is that COVID-19 impacts due to increased work from home patterns compared to pre-COVID and potential ongoing changes to transport mode were not accounted for.

Heavy duty vehicles

Emissions projections for truck and bus movements were based on detailed modelling of the NSW fleet for a 2018 base case year (TER 2021), and projected changes in emissions accounting for increased activity and reduced emission intensities due to fuel efficiency improvements and fleet technology changes[3] (Figure 6).

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, excluding military aviation.

Activity data

Data used in the projection of NSW domestic aviation emissions are listed in Table 5.

Table 5 Data referenced for projection of aviation emissions

Dataset	Description	Source
NSW population	NSW population data to 2060–61; growing 1.3% p.a. to 2041 2041: 10.6 million; 2061: 12.3 million	DPIE 2019a
NSW population	Historical national, state and territory population	ABS 2021a
BITRE airport traffic data	Domestic and international passengers and aircraft movements by airport (1985–2020)	BITRE 2021
APS	Sale of domestic and international aviation fuel in NSW (2010–11 to 2020–21)	DISER 2021b
NSW Greenhouse Gas Inventory	NSW domestic aviation emissions (1990–2019)	DISER 2021f

Projection approach

Domestic aviation emissions were projected based on NSW population projections to 2050 accounting for trends in:

- domestic and regional passenger movements relative to state population numbers over 1990–2019

[3] CSIRO (2018) modelling of road transport emissions for NSW to 2050 using the Adoption, Demand and Aus-TIMES models, unpublished data.

- GHG emission intensity of domestic and regional passenger movements over 1990–2014[4], calculated based on emission estimates from the NSW Greenhouse Gas Inventory.

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). This increase is assumed to continue with a projected movement/population ratio of 5.1 in 2050 representing a 33% increase over 2018–2050.

The impact of COVID-19 was accounted for based on:

- domestic and regional passenger movements recorded in 2020 relative to 2019 movements (27% reduction)
- domestic aviation fuel consumption in 2021 compared to 2019 consumption rates (55% reduction both for NSW and nationally) (no passenger movement data was available for 2021 at the time of the calculations)
- the assumption that the impact on domestic aviation experienced in 2022 would be of a similar order to that experienced in 2020 (27% reduction).

The impact of COVID-19 was assumed to be transient with domestic and regional passenger movements returning to the same trajectory post-2022.

On the basis of population projections and forecasts passenger movements per capita, total domestic and regional passenger movements were projected to increase from about 31 million in 2019 to about 58 million in 2050. 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 emission intensity was calculated to have reduced from 10.5 movements/t CO_2-e in 1990 to 15.2 in 2014 (~45% improvement over 24 years; 1.9% per year). This was likely due to increased seats/seats filled per aircraft movement and increased fuel efficiency (Department of Infrastructure and Transport 2010). Further improvements in the emission intensity were projected, constrained to a 34% improvement being achieved by 2050 relative to recent levels (23.3 movements/t CO_2-e). This is in line with average improvements in fuel savings reported by the International Air Transport Association (IATA) for future aircraft, conservatively taking only impending technologies (e.g. turbofan engines) with no new configurations assumed (IATA 2021). Projected improvements in movements/t CO_2-e for 2020–2050 (1.1% per year) were relatively modest, lower than calculated for 1990–2014 (1.9% per year).

IATA has adopted targets to mitigate CO_2 emissions from air transport:

- an average improvement in fuel efficiency of 1.5% per year from 2009–2020
- a cap on net aviation CO_2 emissions from 2020 (carbon-neutral growth)
- a reduction in net aviation CO_2 emissions of 50% by 2050, relative to 2005 levels.

Although these targets have been referenced by major airlines operating in NSW, as at June 2021 when projections were being completed, there were no committed public plans in place to demonstrate how these targets will be met.

---

[4] Trends in inventoried NSW GHG emissions for 2015–2019 were identified as anomalous and likely due to distinct changes in the AES domestic aviation fuel consumption for NSW for these years. The National Greenhouse Accounts use AES fuel consumption to confirm allocation of emissions by state/territory. The lower than expected fuel consumption in NSW over 2015–2019 may have been due to airlines purchasing their fuel in other jurisdictions for logistical or cost reasons.

In addition to fuel efficiency improvements associated with newer aircraft, IATA projects significant reductions in emissions can be achieved through the introduction of radically new technologies over the longer term (2035 onwards) (IATA 2021). For example, hybrid electric aircraft are indicated to be able to achieve CO_2 emissions reductions of up to 40%, with fully electric aircraft completely eliminating emissions during operation.

Base case domestic aviation emissions projections do not account for the potential uptake of revolutionary aircraft technologies, nor do they account for measures that may be implemented by airlines to meet the IATA targets (Figure 6).

Railways, navigation and other transport

Railway transport includes freight and passenger rail. Domestic navigation refers to emissions from fuels used by vessels that depart and arrive in the state, including emissions from fuels used to propel waterborne vessels excluding fishing and military vessels. 'Other transport' includes pipeline transport and off-road recreational vehicles.

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 (Figure 6) (DISER 2020d, 2021c).

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 6. Transport emissions have increased by 1.4% year-on-year since 1990, with 2019 emissions about 50% higher than in 1990.

Road transport 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.

Given business-as-usual, transport emissions are projected to peak in 2025–2030 and then reduce primarily due to market-driven take-up of EVs within the light vehicle fleet. By 2050, based case transport emissions are projected to be of a similar order to 1995 levels with the percentage share of light vehicle emissions projected to halve as freight and aviation emissions continue to increase in the 2030s and 2040s.

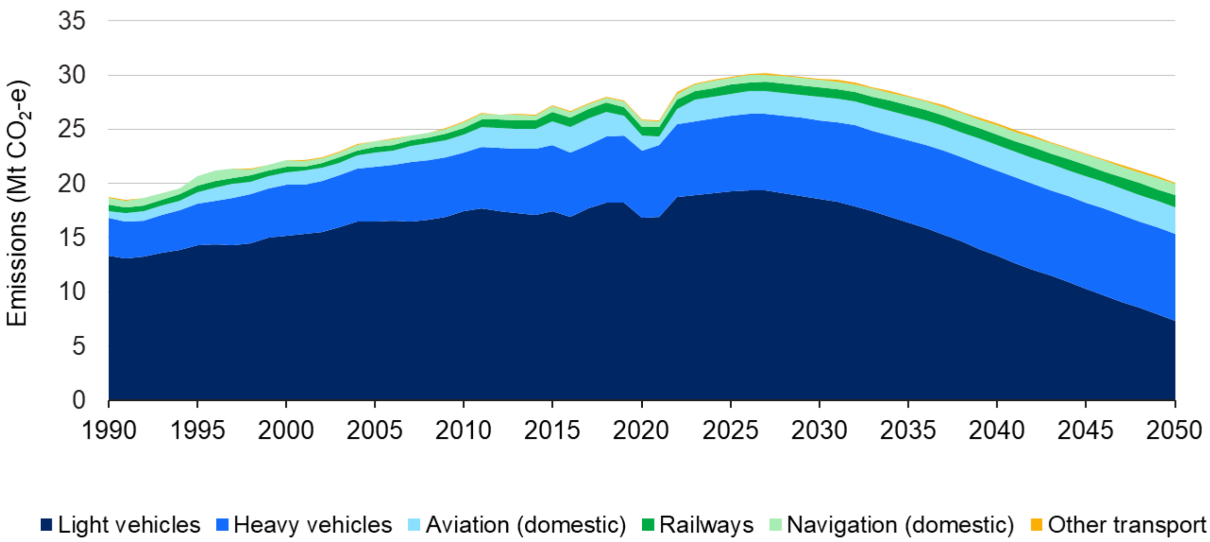

Figure 6 Transport emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

Current policy emissions projections

Programs under the Net Zero Plan that address transport (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
- 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
- Hydrogen Hubs[5] – initially proposed to provide competitive grants to help overcome barriers and commercialise hydrogen supply chains in NSW; it included limited potential pilot projects for hydrogen-fuelled buses and trucks.

Emissions reduction 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.

The NSW fleet and emission models were applied to projected changes in emissions due to major programs. BEV uptake rates were adopted from modelling by Veitch Lister Consulting as referenced in the NSW Electric Vehicle Strategy (NSW Government 2021) and extended out to 2050. Under the NSW Electric Vehicle Strategy, BEVs are projected to make up 52% of new car sales in 2030–31.

Annual abatement of direct emissions due specifically to the NSW Electric Vehicle Strategy is projected to increase from 0.72 Mt CO_2-e in 2030 to 2.3 Mt CO_2-e in 2040, to 3.1 Mt CO_2-e in 2050. With the increasing decarbonisation of the grid, accelerated by the NSW Electricity Infrastructure Roadmap and the broader shift towards renewables, indirect (scope 2) emissions from grid electricity consumption are projected to be about 0.1 CO_2-e by 2030. Indirect emissions are forecast to reduce significantly from 2036 onwards despite increased EV numbers due to 4 of the 5 coal-fired power stations in NSW having retired.

The NSW fleet and emissions model provided a preliminary estimate of the abatement to be achieved by the Zero Emission Buses Transition Strategy being led by TfNSW. Electric buses were assumed to replace ICE buses linearly over the 2020–2030 period after the initial 120 electric buses assumed to be implemented in 2021. Metro buses contracted through TfNSW were estimated to travel on average about 35,000 km/year. Fleet average emission factors, accounting for travel by road type and speed, were estimated using the emissions model to range from 1295–1275 g CO_2-e/km over the period. The preliminary emissions reduction projections undertaken by the department will be updated when further information becomes available from TfNSW.

The integrated abatements in the road transport sector modelled to be achieved as a result of these programs are shown in Figure 7, with resultant current policy projections for this sector compared to base case projections in Figure 8. Emissions reductions continue to increase as the fleet turns over and the share of EVs and zero emission buses in the stock increases.

[5] Expanded Hydrogen Hubs as a key action under the NSW Hydrogen Strategy funded as part of the New Low Carbon Industry Foundation Fund Extension as announced in February 2022 post-dates the 2021 projection modelling (NSW Government 2022a).

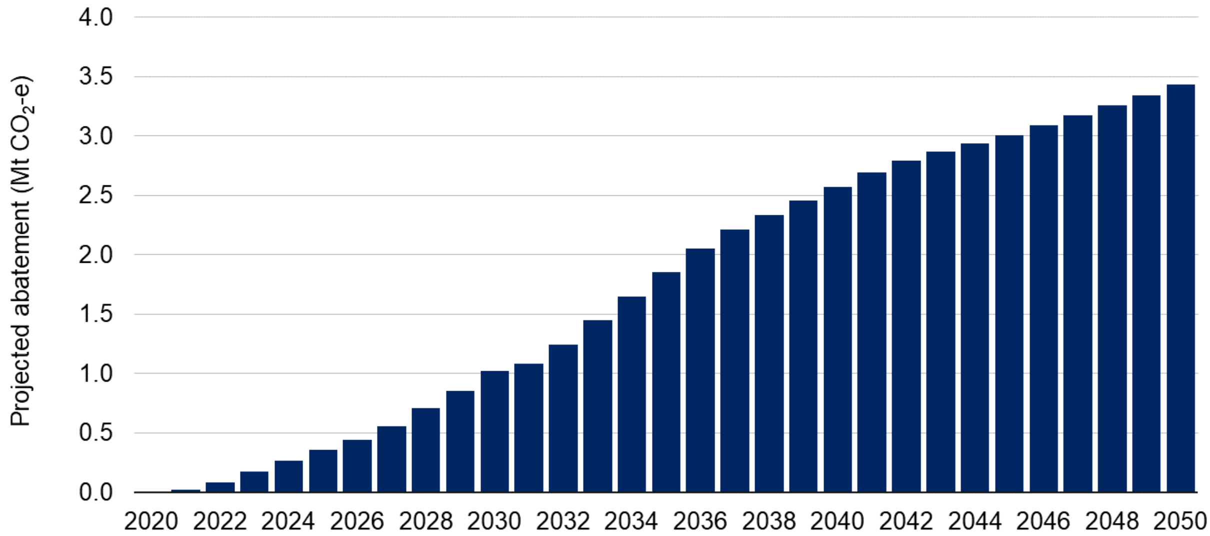

Figure 7 Abatement of road transport emissions projected to be achieved by Net Zero Plan Stage 1 programs

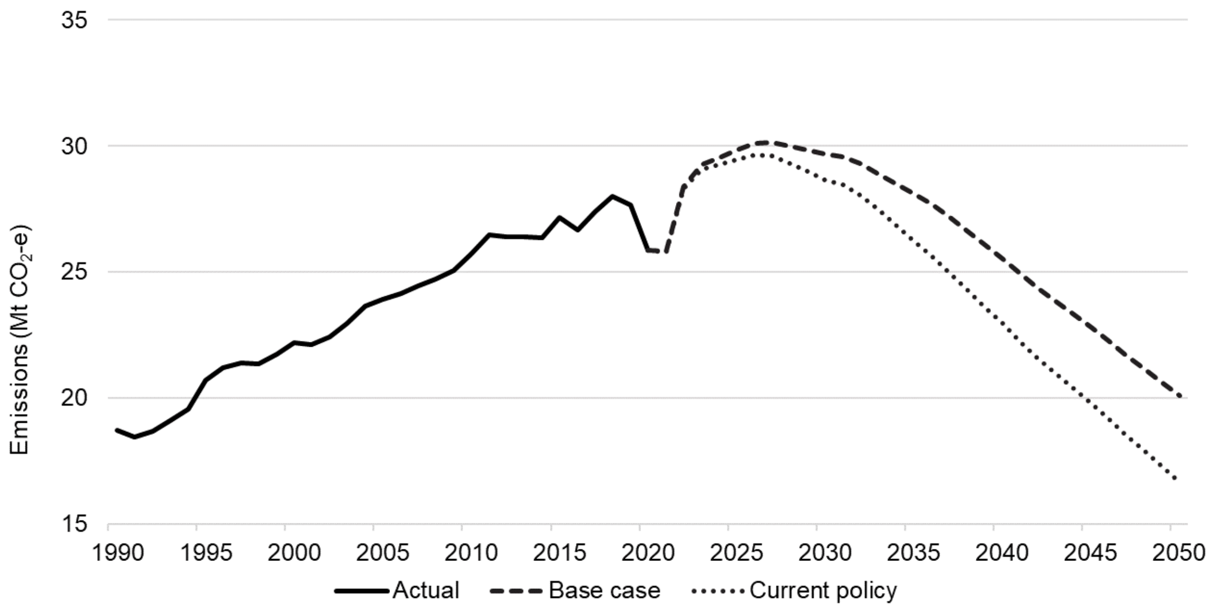

Figure 8 NSW transport emissions as inventoried (1990–2020), with base case and current policy emissions projections (2021–2050)

Inventoried emissions (1990–2020) and current policy emissions projections (2021–2050) for the NSW transport sector are shown in Figure 9. Light vehicles are projected to reduce significantly in terms of absolute emissions and percentage share of transport sector emissions due to the implementation of the NSW Electric Vehicle Strategy. Heavy duty vehicles are projected to become the dominant source of transport emissions in the 2040s with aviation emissions growing to be about 15% of transport emissions by 2050.

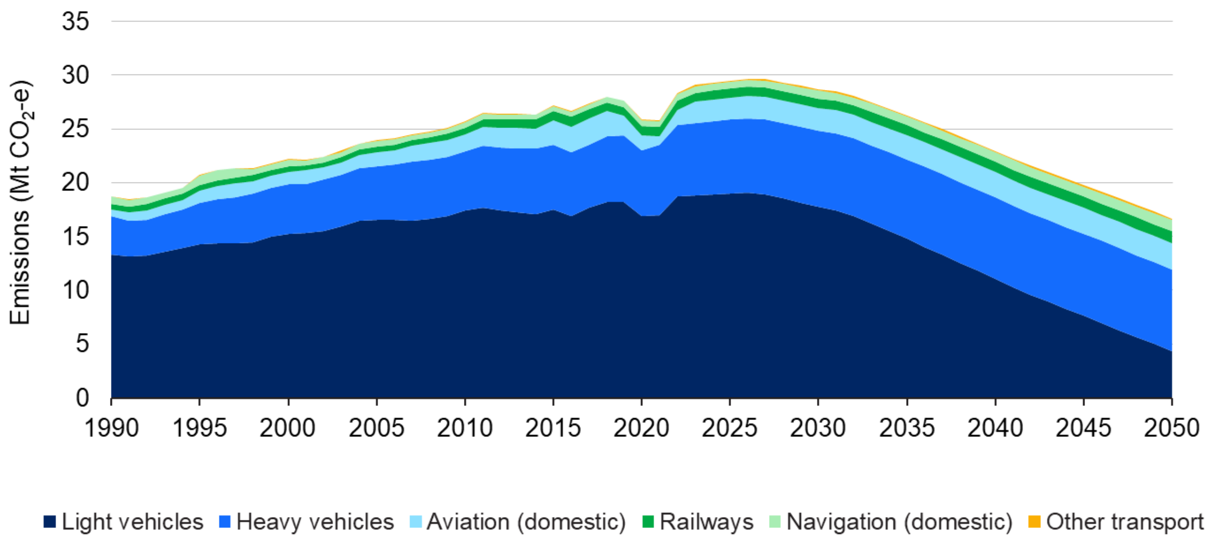

Figure 9 Transport emissions by subsector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)

Future projections

Future projection updates will consider:

- further updates to the NSW fleet and emissions models and application of these models for both light vehicle and freight emissions using as input:
  - population projections released by the department in March 2022
  - the latest available road transport projections from TfNSW, which account for ongoing impacts of COVID-19 such as changes in travel zone demographics and ongoing 'work from home' practices
- more detailed analysis of the pace of transition within the aviation industry accounting for recent industry commitments and technological advances
- potential ongoing impacts of COVID-19 on domestic aviation
- impacts of policies and programs not included in the 2021 projections, including actions under NSW Future Transport 2061
- more resolved modelling of bus types and the timing of the transition based on information from TfNSW on implementation plans for the NSW Zero Emission Bus Transition Strategy
- modelling of rail, domestic navigation, pipeline and off-road recreational vehicles based on NSW-specific data.

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 projections for each mine are modelled using run-of-mine (ROM) coal production forecasts provided by the Department of Regional NSW's Minerals, Exploration and Geoscience group.

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

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 methane 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 Investigated (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. 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. methane content) of the seams being worked.

Modelling approach

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

$$EF_{j,T} = E_{j,T}/Q_{j,T}$$

where:

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

$E_{j,T}$ is 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

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

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:

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

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

$EF_{j,T}$ is 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.

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, then 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 emission 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:

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

where:

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

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

EF_{dm} is the emission factor for the mine

F_{dm} is 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 is 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} is 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} is the mine void volume in cubic metres

T is 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} .

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 methane 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 methane 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 2021 projections, the average of the 5 years of NGERS fugitive emissions data (2015–16 to 2019–20) 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 5 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 also based on the AEMO GSOO Central Case (scenario 1) (AEMO 2021). 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 2019b), 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 10. 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 13.7 Mt CO_2-e in 2030, representing 12% of NSW emissions at that time.

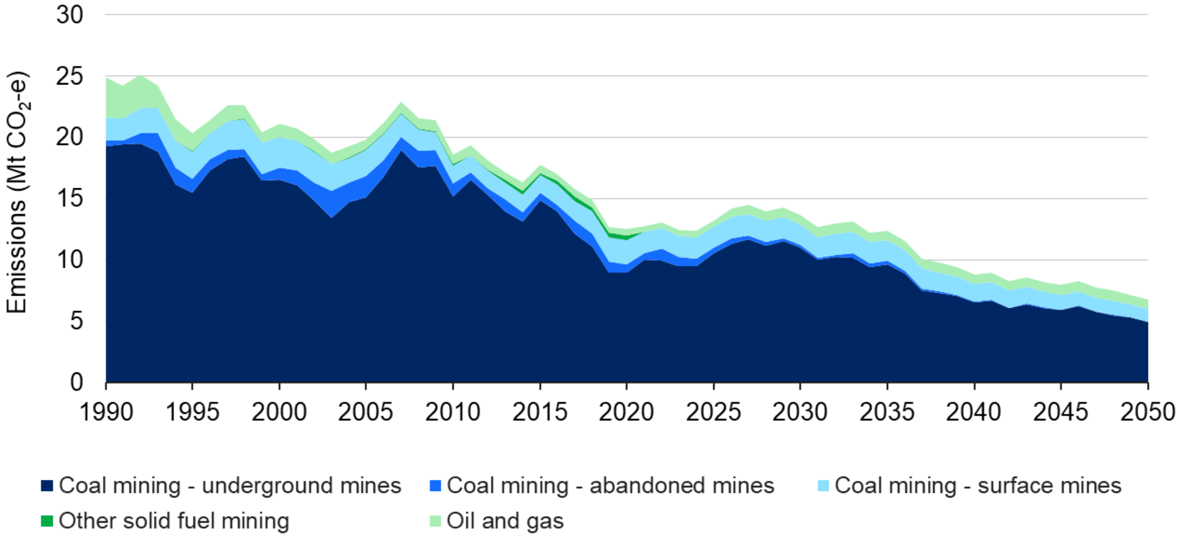

Figure 10 Fugitive emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

Current policy emissions projections

Abatement from the fugitive emissions sector was projected to occur as a result of actions under the Net Zero Industry and Innovation Program, and particularly the High Emitting Industry focus area (Table 2).

Modelling and analysis was undertaken to assess potential fugitive emissions reductions from gassy underground coal mines based on mine-specific assessments and technology abatement cost estimates ($/t CO_2-e abated) (Figure 11), with resultant current policy projections for this sector compared to base case projections in Figure 12.

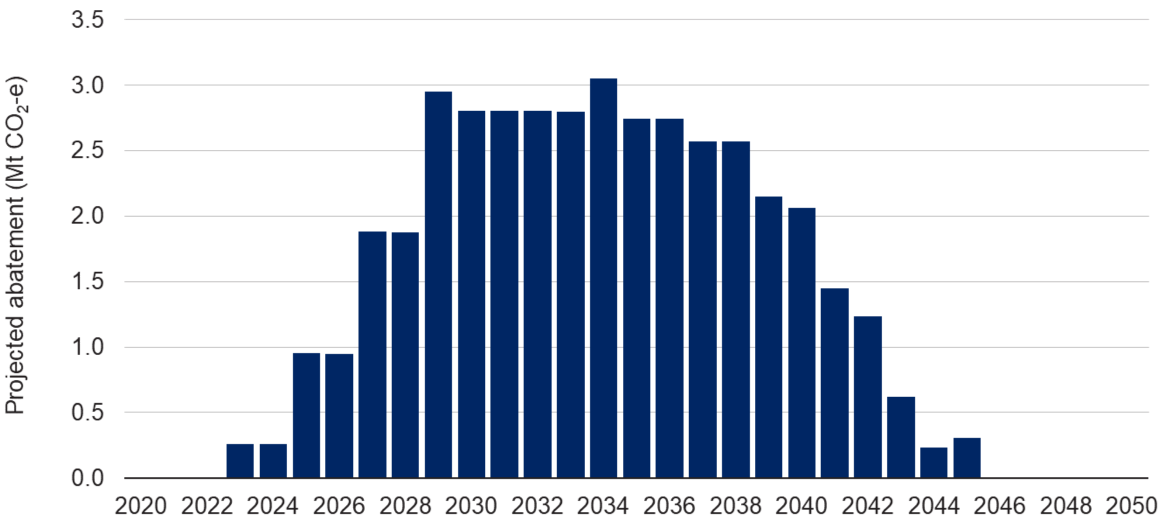

Figure 11 Abatement of fugitive emissions from underground coal mining projected to be achieved by Net Zero Plan Stage 1 programs

Inventoried emissions (1990–2020) and current policy projections (2021–2050) for the NSW fugitive emissions sector by subsector are shown in Figure 13. Fugitive emissions from underground coal mining are projected to be reduced by 2.5–3 Mt CO_2-e per year by 2030 as a result of abatement projects. The potential broader market impact of these projects in terms of accelerating uptake of abatement measures by other mining operations is not included in the emissions reduction projections.

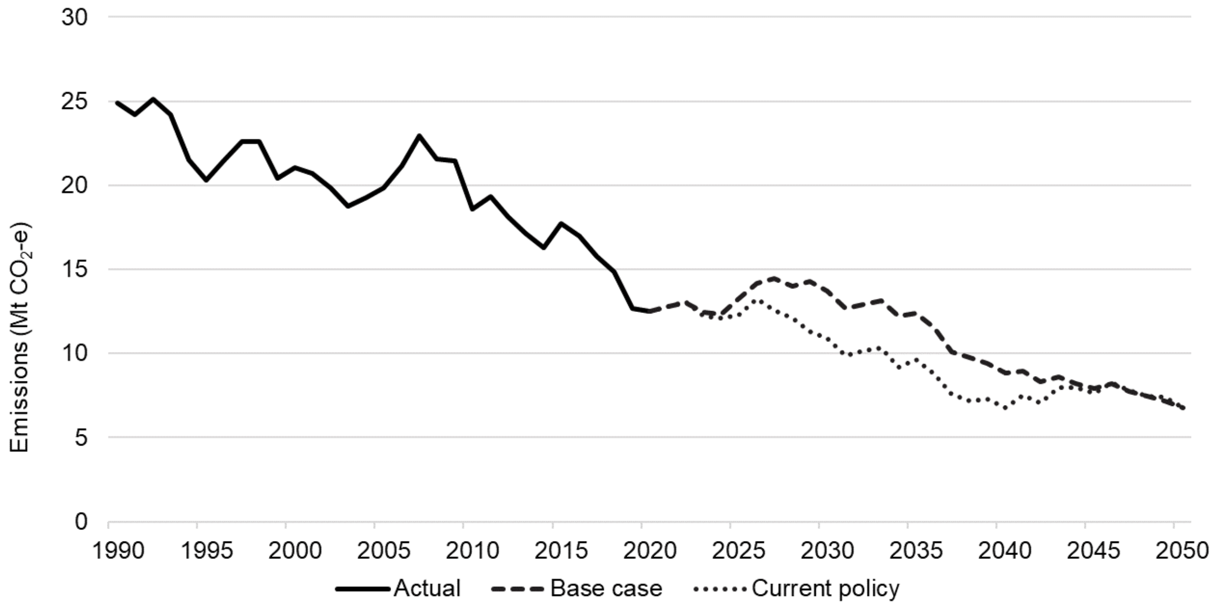

Figure 12 NSW fugitive emissions (including coal and oil and gas) as inventoried (1990–2020), with base case and current policy emissions projections (2021–2050)

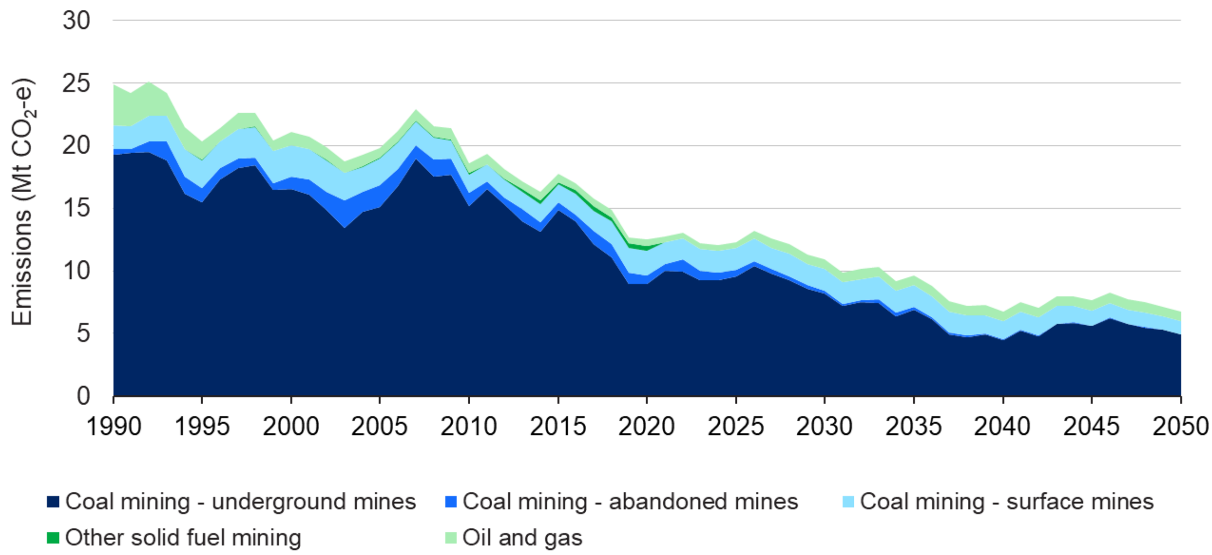

Figure 13 Fugitive emissions by subsector showing inventory estimates (1990–2020) and current policy emissions projections including Net Zero Plan Stage 1 programs (2021–2050)

Future projections

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)
- ensure all mines likely to be decommissioned over the period to 2050 are accounted for in the modelling
- revisit assumptions regarding the likely uptake of incentives to abate coal mining fugitives under the NSW Net Zero Industry and Innovation Program, and the potential for further abatement as a result of market impacts
- address fugitive emissions reductions to be achieved from the full-scale ventilation air methane (VAM) abatement project at South32’s Illawarra coal mine, co-funded by Coal Innovation NSW (Department of Regional NSW 2022)
- consider the impact of new corporate commitments announced and potential changes to the Commonwealth Government’s Safeguard Mechanism on the emission intensity projections for coal and gas fugitives.

Industrial processes and product use

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

Base case emissions projections

The general approach is as per stationary energy related emissions.

Chemicals industry

This includes natural gas consumption in the production of ammonia and ammonium nitrate fertiliser and nitric acid production.

Industrial process and product use emissions were collated from NGERS for the facilities in this sector and the sector was assumed to experience annual growth according to the revenue projections from IBISWorld (IBISWorld 2022).

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Chemicals	–3.25%	2.34%	1.83%	1.43%	0.88%	1.26%

The emissions out to 2025 are calculated according to the formula:

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

where:

$\mathrm{E_t}$ = annual emissions in year t (tonnes CO_2-e)

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

$\Delta production$ = percentage change in production between year t and year t–1 up to 2025–26.

From 2025–26 to 2050 a linear projection was used based on 2019–20 to 2025–26 emissions changes.

For acetylene gas production, there is no specific facility emissions data under NGERS; therefore, data from the STGGI for carbide processing was the basis for the calculation. The data is scaled by the annual percentage change in NSW population as per DISER projections methods.

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

where:

$\mathrm{E_t}$ = annual emissions in year t (Mt CO_2-e)

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

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

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 described above and NGERS facility emissions data aggregated for each subsector. The various subsectors are forecast to experience the following revenue/production growth rates according to IBISWorld (except for iron and steel production, which is taken from the OCE):

	2020–21	2021–22	2022–23	2023–24	2024–25	2025–26
Clinker use, lime production	–7.5%	6.7%	1.4%	1.2%	–0.8%	1.4%
Glass production and soda ash use	–10.3%	–0.8%	1.5%	2.9%	2.5%	2.2%
Iron and steel	3.00%	3.70%	0.01%	–	–	–
Ceramics	–7.3%	8.0%	5.7%	1.5%	0.2%	2.5%

The exceptions to the above are magnesium production and unspecified use of carbonates. 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 DISER). Only 2 relatively small facilities in NSW contribute to emissions from unspecified carbonate use so these are also held fixed over time.

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 ferro-alloys.

In the near term to 2022–23, the OCE in its June 2021 Resources and Energy Quarterly forecast predicts modest growth in the production of steel and aluminium in Australia as shown in the table below.

	2020–21	2021–22	2022–23	2023–24	2024–25
Iron and steel	3.00%	3.70%	0.01%	–	–
Aluminium	0.67%	–0.52%	0.08%	–	–

Iron and steel and aluminium IPPU emissions are forecast as per chemical industry emissions above.

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 2019 National Inventory Report (NIR) (DISER 2021c) section 4.8.

Historical emissions of halocarbon substances are estimated based on the STGGI data.

To project emissions from this sector, the base year for emissions is 2019. Based on the Cold Hard Facts report (DAWE 2020, 2021) the Commonwealth Government is phasing-down the importation of equipment with halocarbon refrigerants. The target is to reduce emissions to 15% of the 2019 baseline level by 2036.

This translates to a growth rate of –10.5% per year to 2036. This negative growth rate is extended to 2050. As the halocarbon phase-down program commenced in 2018 it is considered base case for the sector.

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 DISER. Emissions are calculated using the relevant energy content and emission factors. For projections to 2050, 2019 emissions are adjusted for annual percentage changes in NSW population.

Other product manufacture and use

The subsector covers sulfur hexafluoride leaks from electrical switchgear, emissions of nitrous oxide 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 DISER. Projections to 2050 used 2019 as the base year and future emissions were calculated by adjusting for annual percentage changes in NSW population.

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 14.

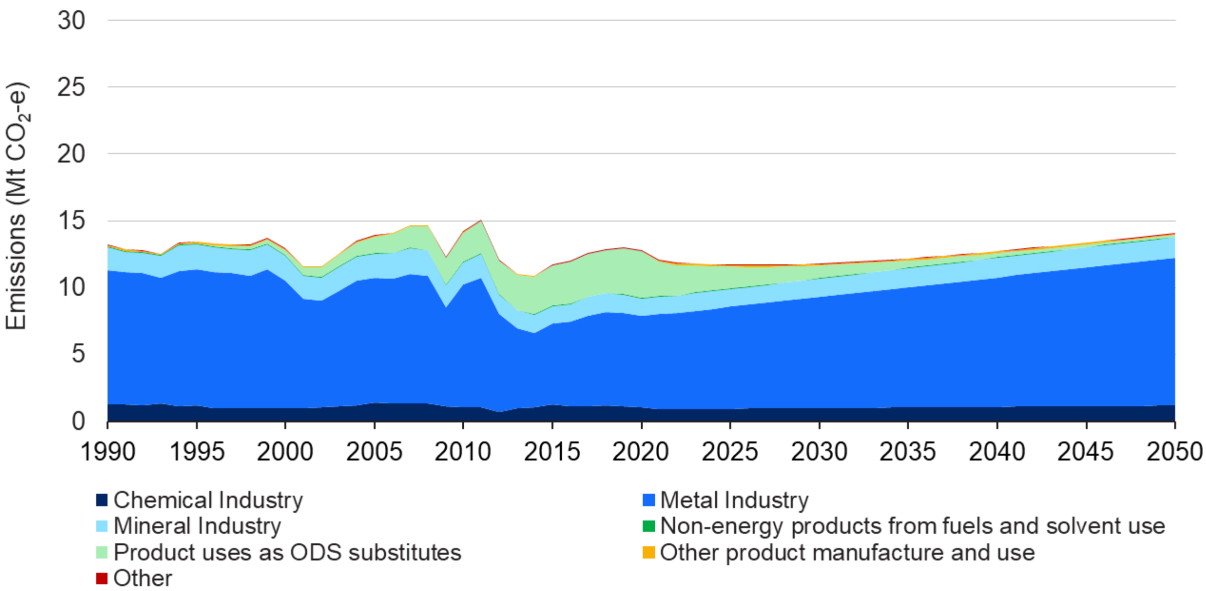

Figure 14 IPPU emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

Emissions from this sector currently produce 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.

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 Commonwealth Government has a program to phase-down the import of goods containing halocarbons with high global-warming potential. The target is to reduce emissions to 15% of the 2019 baseline level by 2036 (DAWE 2021).

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 the Net Zero Industry and Innovation Program, 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.

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.

The abatement in the IPPU sector modelled to be achieved as a result of these programs is shown in Figure 15, with resultant current policy projections for this sector compared to base case projections in Figure 16. Due to conservative assumptions regarding the potential ongoing market impact on industrial process emissions to be delivered under Stage 1 of the Net Zero Plan, IPPU emission are projected to start increasing post-2035 in line with production forecasts. These assumptions will be revisited within projection updates.

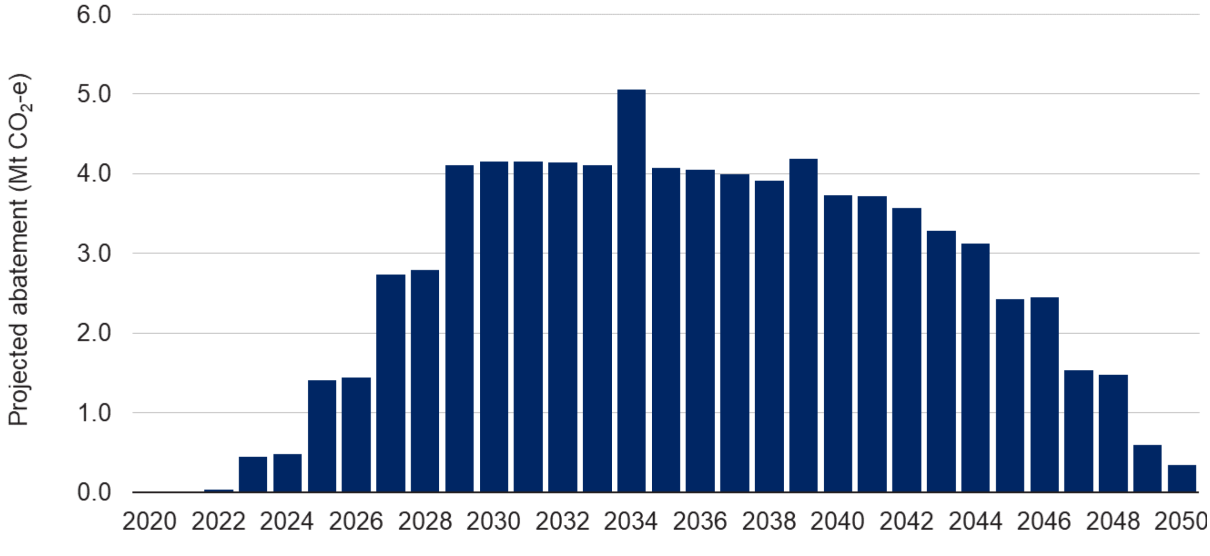

Figure 15 Abatement of IPPU emissions projected to be achieved by Net Zero Plan Stage 1 programs

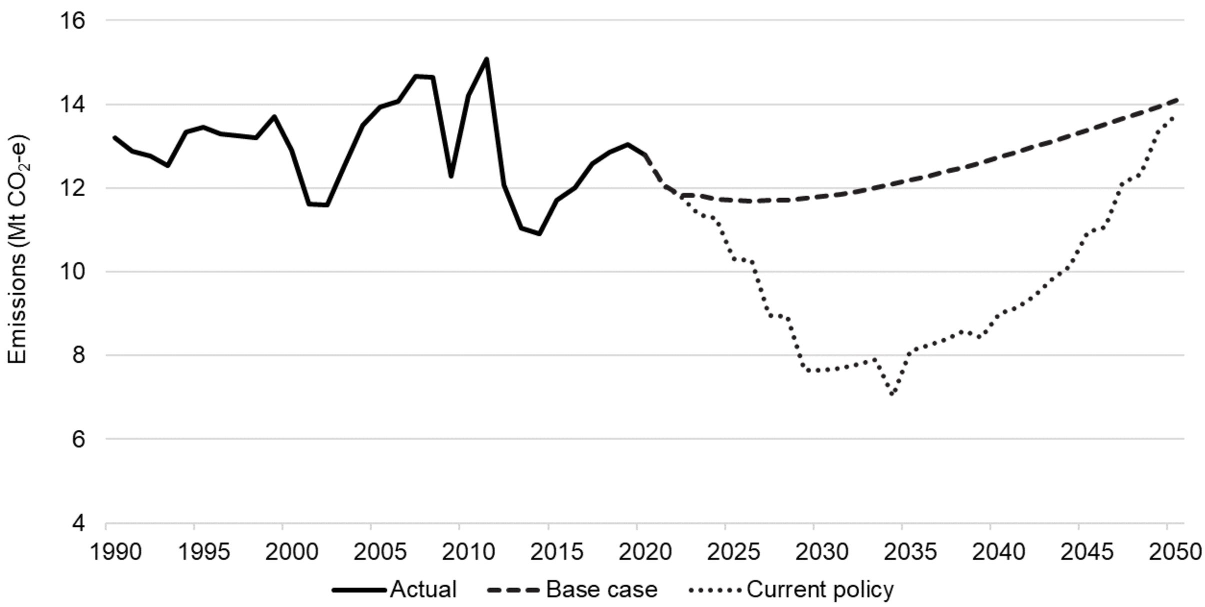

Figure 16 NSW IPPU sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)

Future projections

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.

Agriculture

Emissions from agriculture comprise emissions from livestock and crop production. It includes emissions from enteric fermentation, manure management and agricultural soils. These emissions are predominantly nitrous oxide and methane.

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 2020d) for the years where outlook data is available from ABARES and OECD-FAO. The emission commodity/sectors and subsectors covered in the NIR are included in this agricultural projection (Table 6).

Table 6 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 7. NSW activity was projected using predominantly the commodities outlook data from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (ABARES 2021a, b). The outlook data from ABARES provided crop and livestock forecasts to 2026. This was supplemented with outlook data from OECD-FAO (OECD 2020), which provided selected crop outlooks to 2029. Historical activity data was based on NIR 2019 (DISER 2021c).

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

National outlook activity was apportioned to NSW by applying a 2019 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 7 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 (2021a) for 2020–2022 ABARES (2021b) for 2023–2026	Regression to the long-term (2010–2019) mean
Pig	ABARES (2021b) for 2020–2026	
Beef cattle – feedlot	ABARES (2021b) for 2020–2026	Wood et al. (2021) growth rates
Rice, sugar cane, oilseeds, maize	OECD-FAO (2020) to 2029	Regression to the long-term (2010–2019) 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 (2010–2019) mean	

Post-outlook years, a linear regression to the long-term average (2010–2019) 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 2020d). For feedlot cattle, we applied Wood et al. (2021) beef cattle growth rates for 2027–2050.

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 2019. The emission intensity of each subsector is assumed to remain constant for the projected period; 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 2019

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

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[6]

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

[6] 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 2019.

For urea application and inorganic fertiliser applied to irrigated and non-irrigated crop, 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 73–84% 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 is 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 (2010–2019) 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 2010–2019. 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 1990–2019; 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 2026 but highlighted it as an area for further analysis when preparing updated projections.

Results from this study were 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 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 (Figure 17). Emissions are projected to be 21.5 Mt CO_2-e in 2050, compared to 20.6 Mt CO_2-e based on the LUTO base case.

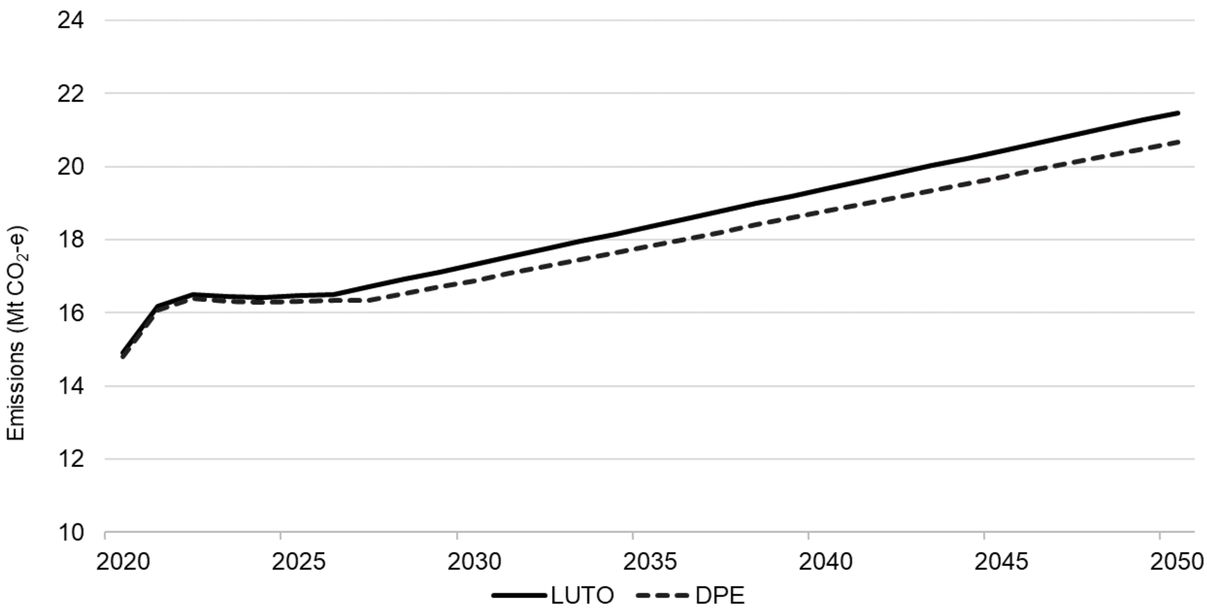

Figure 17 Comparison of total NSW agriculture sector emissions based on the LUTO model base case with long-term base case emissions projections in this study (the department)

Base case agriculture emissions projections

Inventoried emissions (1990–2020) and base case emissions projections (2021–2050) for the NSW agriculture sector are shown in Figure 18 by commodity, and in Figure 19 by emission subsector.

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 over three-quarters of NSW agriculture emissions in 2019, mainly due to the methane 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.

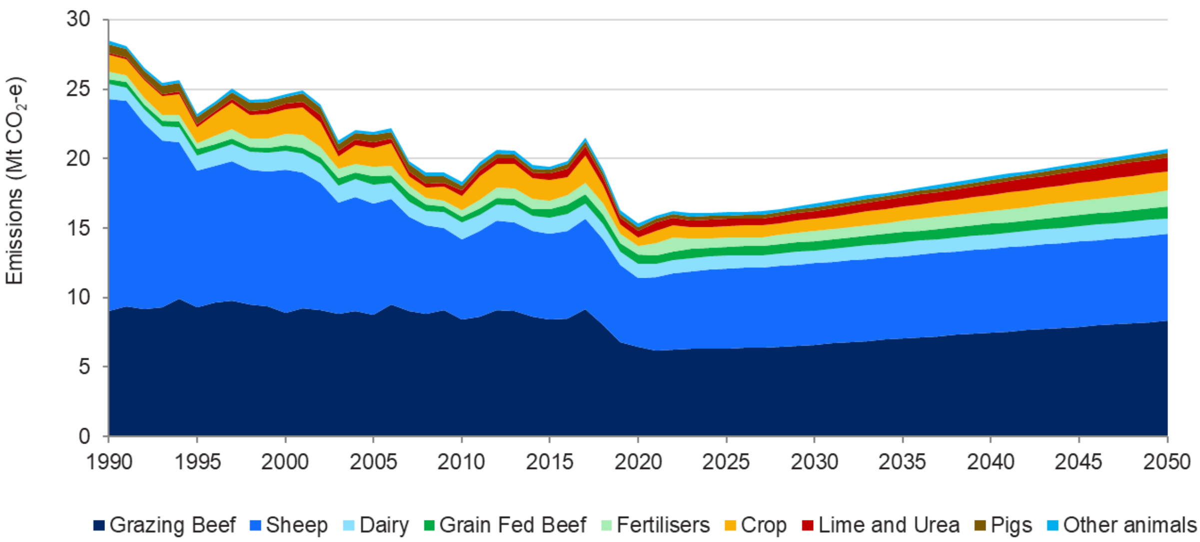

Figure 18 Agriculture emissions by commodity showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

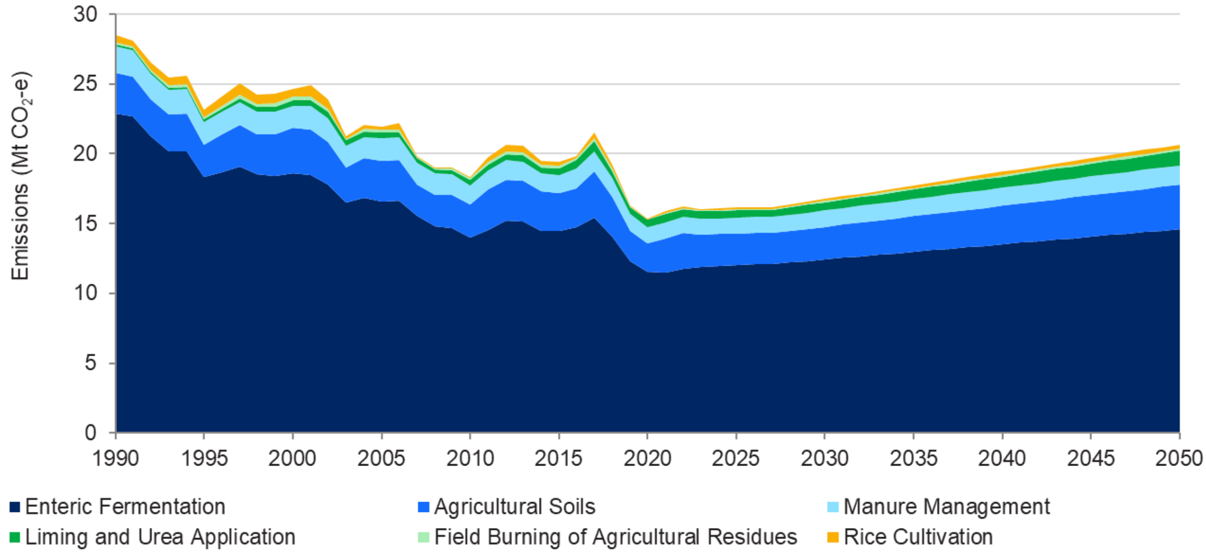

Figure 19 Agriculture emissions by emission subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

Current policy emissions projections

Preliminary modelling was undertaken to estimate emissions reduction and carbon sequestration for the agriculture and LULUCF sectors potentially achievable under the Primary Industries Productivity and Abatement Program (PIPAP). This modelling was undertaken based on the draft program design as at June 2021, noting that this design was subsequently revised prior to the official launch of the program in May 2022.

The abatement in the agriculture sector modelled to be achieved within the 2021 projections is shown in Figure 20, with resultant current policy projections for this sector compared to base case projections in Figure 21.

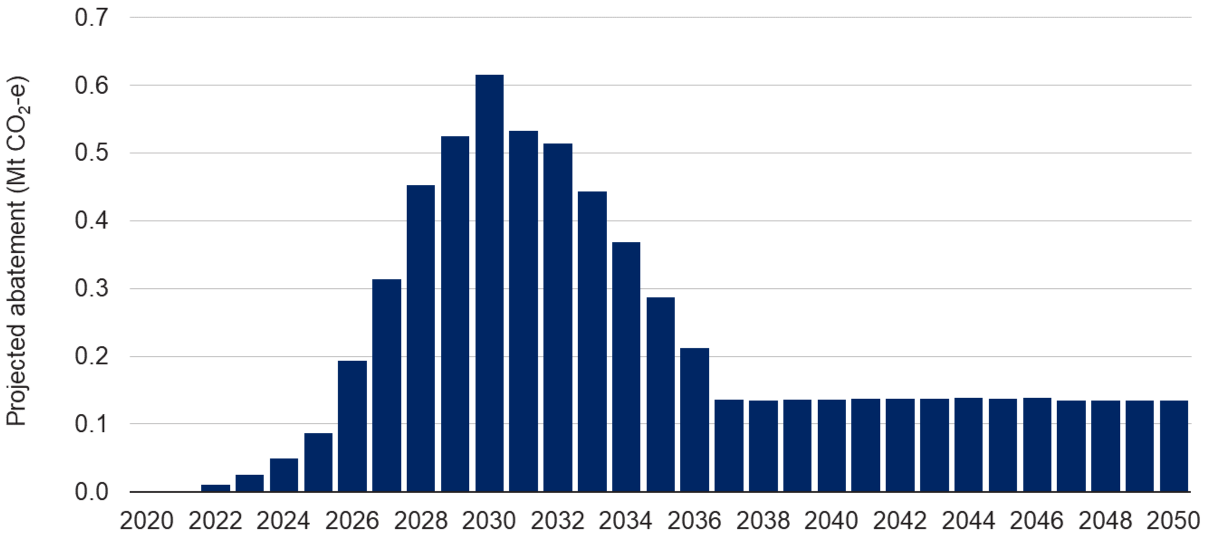

Figure 20 Abatement of agriculture sector emissions projected to be achieved by Net Zero Plan Stage 1 programs

Relatively conservative assumptions were applied in the abatement modelling when considering the commercial readiness and costs of abatement and consequently likely uptake rates of measures. Actions were also assumed to have a very modest market impact in terms of influencing emission intensities of agricultural commodity production more broadly. For these reasons, a very modest reduction in agriculture sector emissions was projected to be achieved under Stage 1 of the Net Zero Plan. These assumptions will be revisited within future projection updates accounting for new information on the commercial readiness of abatement measures, and with the impact of the NSW Government's Sustainable Farming Program announced in June 2022 also considered.

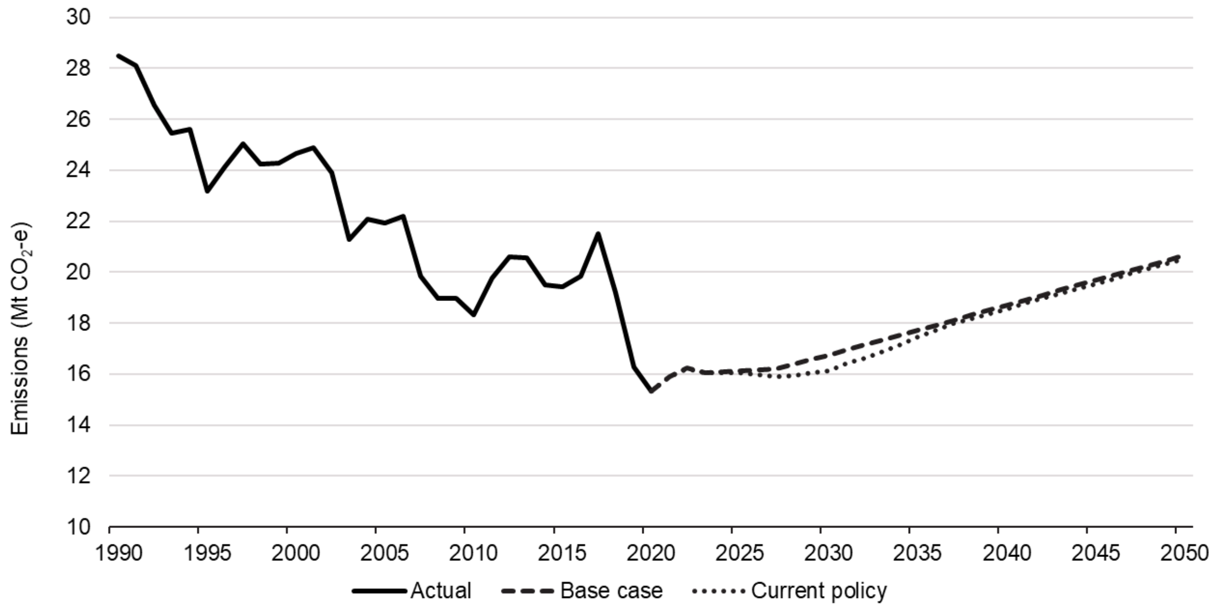

Figure 21 NSW agriculture sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)

Future projections

Future projection updates will consider:

- the latest outlook data for agricultural commodities and improved projections for post-2026 considering holding capacities, arable land limitations and climate impacts
- sensitivity testing related to changed global warming potentials published within the IPCC's Sixth Assessment Report
- potential implications of growing corporate carbon reduction commitments
- revised abatement modelling considering changes in the design of the PIPAP as launched in May 2022, the latest information on the commercial readiness of abatement measures, and the impact of the NSW Sustainable Farming Program announced in June 2022.

Land use, land-use change and forestry

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

Base case emissions projections

Emissions from the LULUCF sector were projected using a mix of bottom-up and top-down modelling. The results presented in NSW State of the Environment 2021 are largely based on projections developed by DISER (DISER 2020d) and reported in Australia's emissions projections 2020 (DISER 2020a) at aggregated national level, updated to reflect the release of the NIR 2019 (DISER 2021d). The methods are briefly summarised in this section.

Activity data

The harvesting activity in native forests, including multiple use forests and private native forests, is a key driver of carbon flux in native forests. Over recent years, harvesting in the native forest sector has reached historically low levels (Gavran 2020) (Figure 22). The log harvest volumes were assumed to linearly regress to the longer-term average (2010–2019) by 2030 and remain stable at 2030 levels to 2050. In the previous projections (DISER 2020a, pp.54–57) released in December 2020, the log harvest volumes were derived from ABARES outlook scenarios for Australia's forestry sector (ABARES 2015). 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, this projection assumed that log harvest volumes will linearly regress to the longer-term average (2010–2019) by 2030.

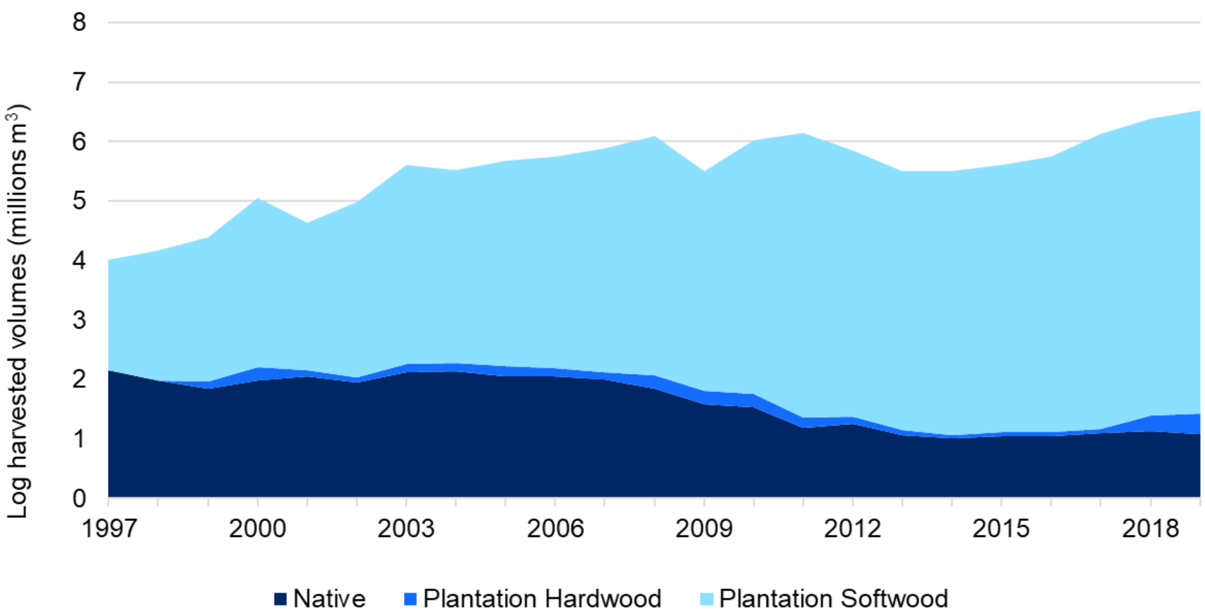

Figure 22 Historical log harvested volumes from native forestry and plantations (1997–2019)

Plantations included within forestland include softwood and hardwood plantations. The log harvest volumes from plantations have increased over the past 30 years (Figure 22). The maximum estate size of plantation was reached in 2016 at 394,400 ha (Gavran 2020). The plantation projection was developed on the basis that yield remains at around current levels (2010–2019) over the long term. As such, the planted area remains relatively stable with areas of loss due to fire being recovered through replanting.

Based on analysis by DISER (DISER 2020a), most forest conversion activity in Australia is for the purpose of maintaining pastures for grazing activities. Some forest conversion does occur 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. Most clearing activity in Australia is associated with the re-clearing of regrown forest vegetation (DISER 2021d). Land clearing restrictions have seen primary forest conversion stabilise at low levels over the past decade compared to the historic record (Figure 23).

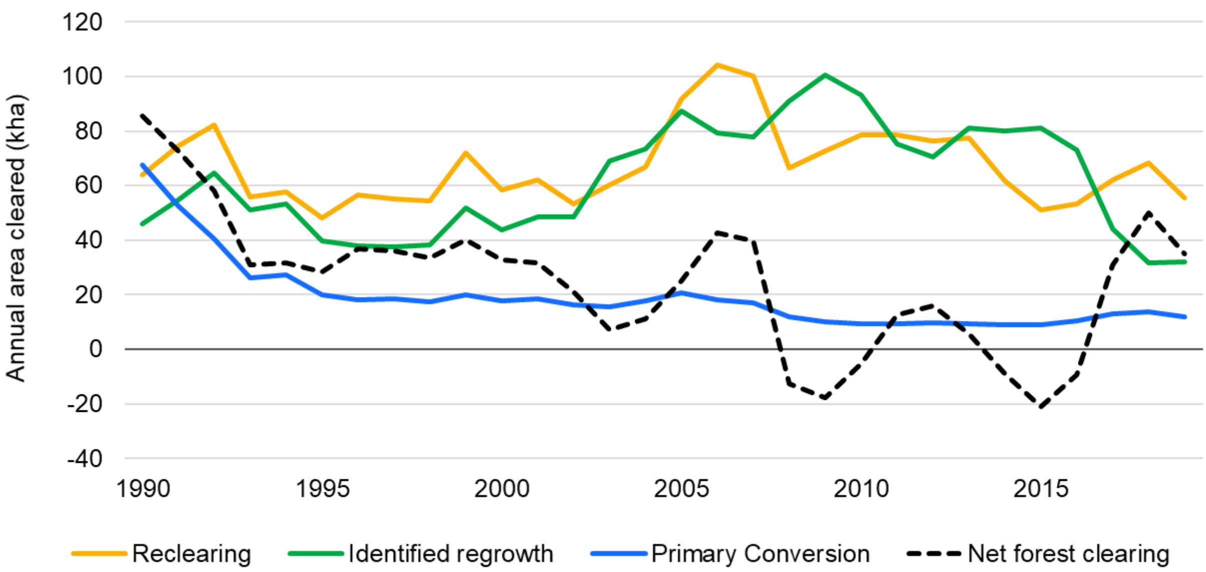

Figure 23 Historical primary conversion, re-clearing and regrowth (1990–2019)

Primary forest conversion is assumed to remain at low levels compared to 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. 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 2021d).

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 (2010–2019) over the projection period.

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

Harvested wood products are estimated as the production plus imported materials minus exported materials (DISER 2021d, p.156). Activity from harvested wood products is projected based on forecast wood production and recycling rates[7].

[7] DISER internal analysis.

Emissions projections

Land clearing

The emission intensity for first time clearing and re-clearing is based on the average emission intensity recorded in the NIR for NSW over the period 2010–2019. The emissions from first time clearing and re-clearing are calculated as the emission intensity of clearing multiplied by the projected area of first time clearing and re-clearing.

Sequestration associated with regrowing forests is estimated using the Full Carbon Accounting Model (FullCAM) which is used in Australia's National Greenhouse Accounts. It is calibrated to the average historical rate of regrowth observed in NSW over the period since 1990. The calibrated growth curve is initialised to calculate sequestration based on the projected area of forest regrowth.

Forests

Emissions from harvested native forests (HNF) and plantations were also simulated using FullCAM. Emissions from HNF and plantations were simulated using FullCAM Research (2021)[8] and FullCAM PR [9](2020) respectively. FullCAM was configured to operate in a 'Tier 3 approach 2 mode', known as the 'Estate' module, as spatially explicit data were unavailable for future harvests. The model parameterisation for harvested native forests and plantations, including harvest intensities and recoveries, were similar to the parameters used in the spatially-explicit FullCAM model for harvested native forests for NSW in NIR 2019 (DISER 2021d). Details of the model are provided in NIR 2019.

Agriculture and other land

Emissions from agricultural land and other land were estimated by applying the emission intensity calibrated to the average historical rate from 2010–2019 to the projected activity.

Emissions from harvested wood products were calculated using the national inventory harvest wood product model using the projected activity data.

Fires

Australia's National Greenhouse Gas Inventory includes all anthropogenic fires. Approaches have been developed to identify non-anthropogenic natural disturbances, and carbon stock loss and subsequent recovery from non-anthropogenic natural disturbances are modelled to average out over time, leaving GHG emissions and removals from anthropogenic fires as the dominant result. Bushfires release significant amounts of CO_2, but generally recover over time, generating a significant carbon sink in the years following the fire. This means, for example, that the 2019–20 bushfires will have a negligible impact on Australia's progress towards its national 2020 and 2030 targets.

Consistent with this method, the emissions projections include emissions from prescribed burning and anthropogenic wildfires. Wildfires are projected by identifying a historical period of high activity and applying the emissions associated with that level of activity annually for the projected period. Fire management practices, such as prescribed burns, are projected by applying long-term average fire activity to FullCAM Tier 3 approach 2 mode using the parameters for prescribed burns in the NIR.

---

[8] V7.21.04 – Dianella, DISER

[9] Public release 2020, DISER

Base case LULUCF emissions projections

Base case emissions projections for the LULUCF sector are shown in Figure 24, 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. 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 (DISER 2021a).

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 2016, 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 net emissions. Under the base case scenario the emissions sink is projected to decline. In the current decade this is projected to be due to the impact of current La Ninã conditions on soil carbon stocks (DISER 2021a).

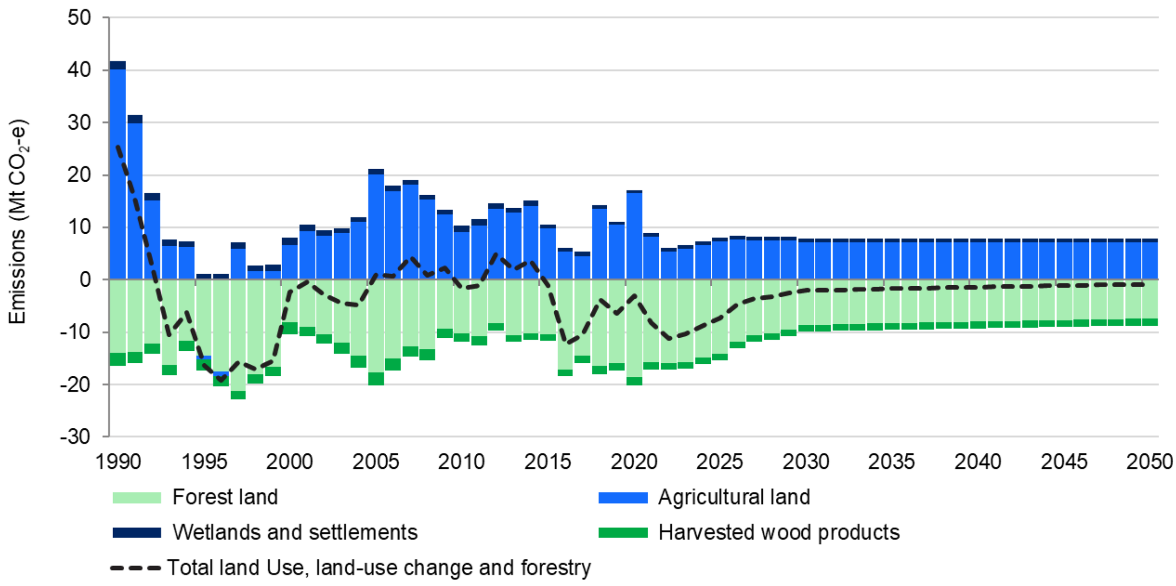

Figure 24 LULUCF emissions and sequestration showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

Gaps and limitations

Addressing emissions from land clearing associated with grazing was a focus in this study due to it being considered the dominant forest conversion activity. Land clearing for settlements, infrastructure and cropland were not accounted for in the current projections.

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 extreme temperature and rainfall extremes than the preceding decade (BOM and CSIRO 2020) and included an agricultural drought period.

Current policy emissions projections

Preliminary modelling was undertaken to estimate emissions reductions and enhance carbon sequestration within the agriculture and LULUCF sectors potentially achievable under the PIPAP. This modelling was based on the draft program design as at June 2021, noting the program design was subsequently revised prior to the launch of the program in May 2022. Sequestration opportunities were considered across all land tenures in NSW, including private farmland, public lands and Aboriginal-managed lands.

The abatement in the LULUCF sector modelled to be achieved within the 2021 projections is shown in Figure 25, with resultant current policy projections for this sector compared to base case projections in Figure 26. Policies under the Net Zero Plan were modelled to enhance carbon sequestration by the land sector with the potential of increasing the net LULUCF sink to 7 Mt CO_2-e by 2030 to help offset emissions from other sectors. This was due to sequestration in soil and vegetation.

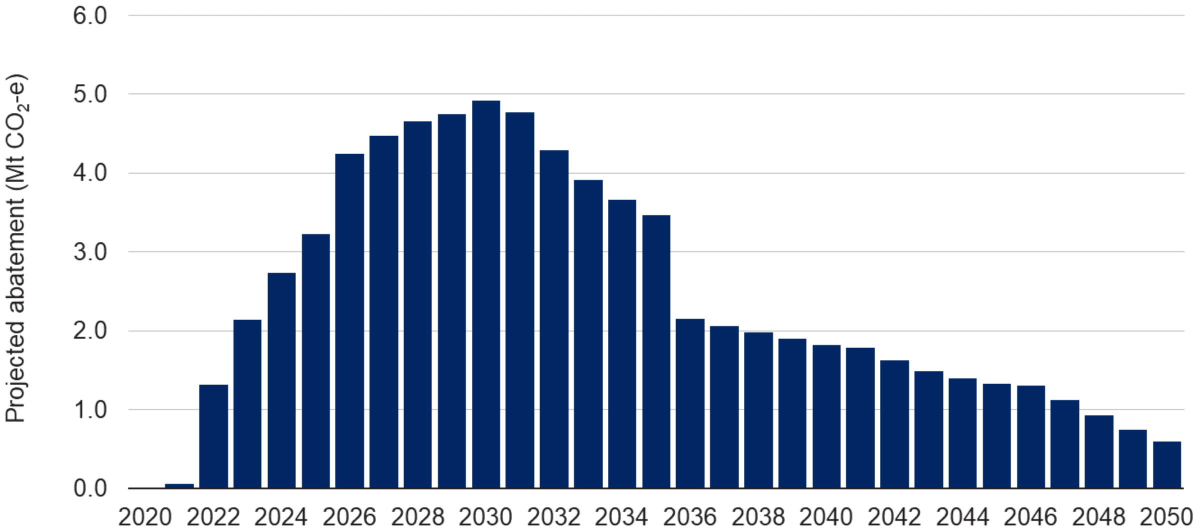

Figure 25 Enhancement of LULUCF sector carbon sequestration projected to be achieved by Net Zero Plan Stage 1 programs

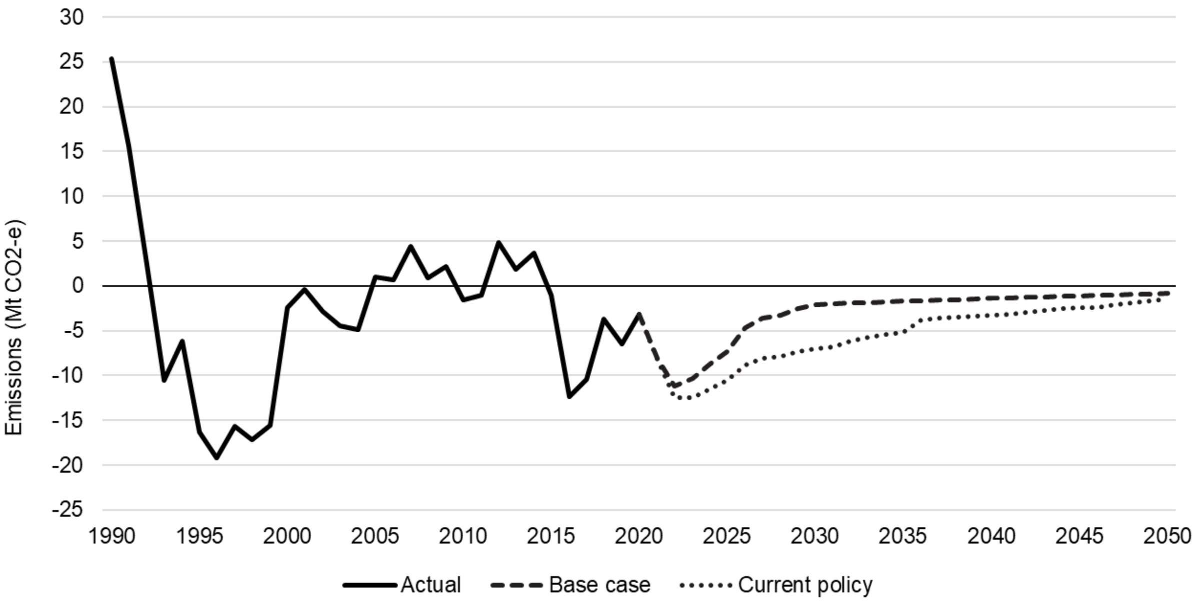

Figure 26 NSW LULUCF sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)

Future projections

Future projection updates will consider:

- the latest data and model improvements, including options to account for land clearing for cropping areas
- revised carbon sequestration modelling considering changes in the design of the PIPAP as launched in May 2022 and opportunities for enhanced sequestration under the NSW Sustainable Farming Program announced in June 2022.

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 2019, and detailed emissions projections have been undertaken for this sector.

Domestic wastewater treatment is the next largest source contributing a further 17% of waste emissions in 2019. Industrial wastewater treatment accounted for about 7% with biological treatment and incineration being minor sources (<2% 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 methane, 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 business-as-usual 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:

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

where:

E_{SW} = solid waste emissions

i = emissions from solid waste incineration

b = emissions from biological treatment

$CH_4(g)$ = solid waste methane generated

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

According to NSW STGGI data over the period 2015–2019, emissions from incineration and biological treatment of waste accounted for 0.1% and 3% 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 DISER and more contemporary data from the NSW EPA Waste and Resource Reporting Portal (WARRP)

(EPA 2022).[10] It also relies on DISER's estimates of gas capture (i.e. transfer of landfill gas offsite for power generation, landfill gas flaring or landfill gas captured on-site) at each landfill site.

DISER has gathered waste disposal data for 27 specific landfills in NSW, most of which are currently in operation. Some of these landfills are closed but continue to emit methane. 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 27 large landfills are responsible for 65% and 62% of waste disposed in NSW in 2018–19 and 2019–20, respectively. The modelling assumes no new landfills, and that the 27 landfills listed will continue to operate out to 2050.

For the remaining smaller landfills (about 270 landfills according to recent NSW EPA WARRP data), DISER'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. DISER has provided an estimate of landfill gas captured for 'residual NSW'; in 2019–20 the capture efficiency was 14%.

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 carbon pricing scheme. Thus DISER does not have access to recent council landfill disposal data and hence their GHG estimates are unknown.
- DISER 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 DISER and the NSW EPA WARRP. Over FYs 2015–2019, the DISER 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 27 specific landfills in the DISER dataset cannot be verified due to lack of historical record keeping and data availability.

[10] Detailed individual landfill data is strictly confidential.

Activity data inputs for GHG emissions projections

- DISER historical (FYs 1940–2014) waste stream data (i.e. tonnes of MSW, C&I, and C&D) are from the DISER solid waste spreadsheet model. FYs 2015–19 use the NSW EPA WARRP data.
- Waste disposal projection data beyond 2019–20, use assumptions outlined in the department Research and Insight Team's Waste Generation Model (summarised below).
- DISER historical gas capture data (FYs 1940–2018) are from the DISER solid waste spreadsheet model.
- Gas capture beyond 2019–20, uses a similar methodology to that outlined in the Blue Environment Report[11] that escalates the annual methane capture efficiency per landfill (i.e. methane captured (t CO_2-e)/methane generated (t CO_2-e)) using the formula:

  $$\textit{methane capture efficiency}_{t} = \textit{methane capture efficiency}_{(t-1)}{}^{(1 + \text{growth rate})}$$

  where the growth rate = 0.25% p.a.

  The methane capture efficiency in 2018–19 (obtained from DISER's dataset) is the initial value for gas capture; that is, the (t–1) value.

- Given the complexity in forecasting the change in waste stream mixes at each landfill, they are held constant at 2017–18 values (provided by DISER); 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.
- Years 2020–21 out to 2049–50 project the WARRP waste data according to the department Research and Insight Team's Waste Projection Model assumptions:
  - For MSW, this means a 0.8–1.5% (average 1.0%) increase p.a. in waste mass in line with projected growth in the NSW population to 2041 (DPE 2022c). To 2050, the rate of increase is held constant at the 2041 value.
  - For C&I waste, the rate of increase is in line with the projected increases in Gross State Product[12] (GSP; average 2.5% p.a. from 2021–2050).
  - For C&D waste, the rate of increase is in line with projected increases in building activity, approximately 2.0% 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 2024. A linear trend of the above historical data was used to development total construction forecasts to 2041. The rate was then 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 2020–2050. Modest improvements in gas capture rates as per DISER projections are assumed, based on the Blue Environment[11] methodology.

the department's version of the CER's Solid Waste Calculator is used to model methane 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 27 individual landfills. All landfills are

[11] Blue Environment, Emissions Projections from the Waste Sector, 24 October 2019, prepared for the Department of the Environment and Energy (the report is confidential).

[12] Provided by NSW Treasury, Economic.Forecasting@treasury.nsw.gov.au

considered to be in temperate (dry) regions except for one landfill in the Wollongong local government area and ‘residual NSW’, which were assumed by DISER to be temperate (wet).

To calculate the ‘residual NSW’ waste disposal for 2015–16 to 2018–19 WARRP data were used, with all waste disposal summed across the approximately 300 landfills in NSW and the waste disposed of at the 27 landfills that are individually modelled subtracted. DISER waste mix percentages as at 2017–18 are adopted and held constant to 2050.

The annual methane captured, flared or transferred (units t CO_2-e) at each landfill was deducted from the annual methane generated. The net methane emissions at each landfill are then summed to produce p.a. net methane emissions for NSW.

Domestic wastewater

Domestic wastewater emissions were projected based on NSW population projections (DPIE 2019a) and average emission intensity (kg CO_2-e/person) based on historical NSW population (ABS 2020a) and emissions inventory data for the sector (DISER 2021c).

Other waste sources

As a first approximation, industrial wastewater treatment, 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 (2019), with the 2021–2030 trend continued to 2050 (DISER 2020d, 2021c).

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 27.

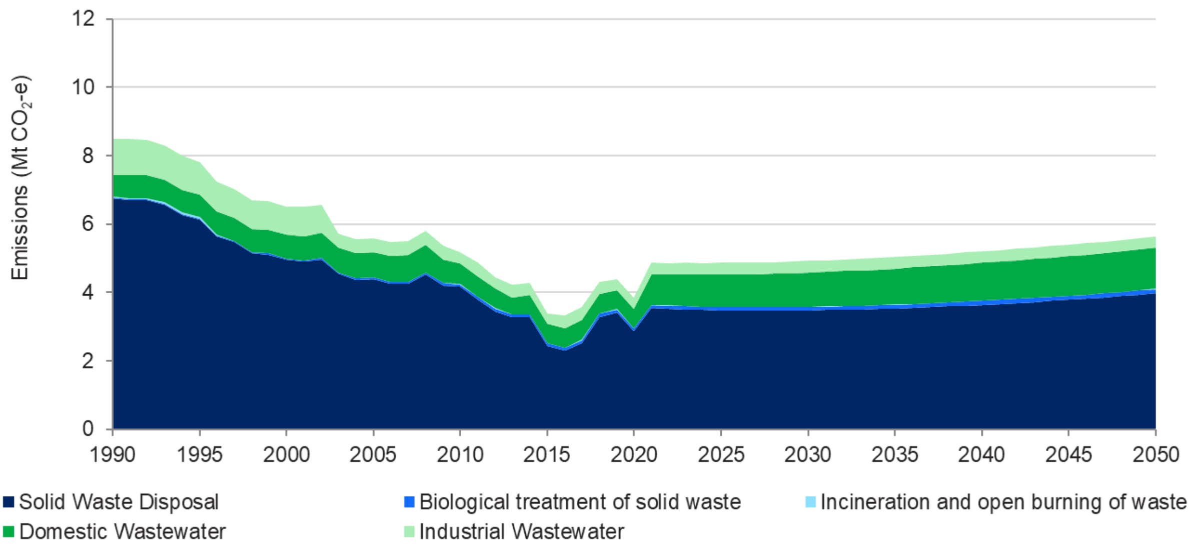

Figure 27 Waste emissions by subsector showing inventory estimates (1990–2020) and base case emissions projections (2021–2050)

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 methane 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.

Current policy emissions projections

A target of net zero emissions from organic waste by 2030 has been set under the Net Zero Plan. 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:

- a 10% reduction in waste generated per person by 2030
- a 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 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 2021 projections addressing the specific targets noted above but not yet capturing the actions related to further landfill gas capture nor the future net zero requirements for landfills subject to an environment protection licence due to information on these actions not being available at the time the projections were being done.

The following assumptions were 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 abatement in the waste sector modelled to be achieved within the 2021 projections is shown in Figure 28, with resultant current policy projections for this sector compared to base case projections in Figure 29.

Inventoried emissions (1990–2020) and current policy emissions projections (2021–2050) for the NSW waste sector by subsector are shown in Figure 30. 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. Actions 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.

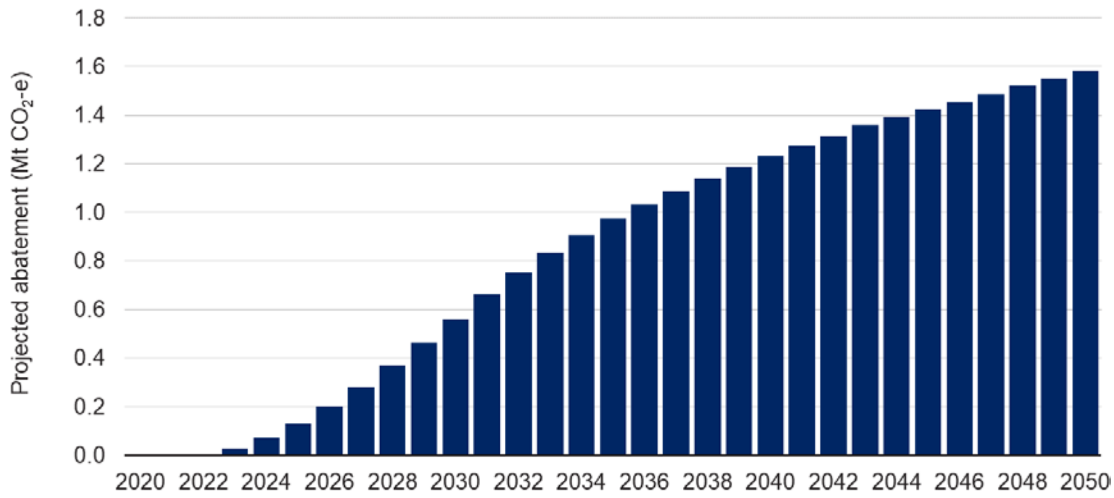

Figure 28 Abatement of waste sector emissions projected to be achieved by Net Zero Plan Stage 1 programs

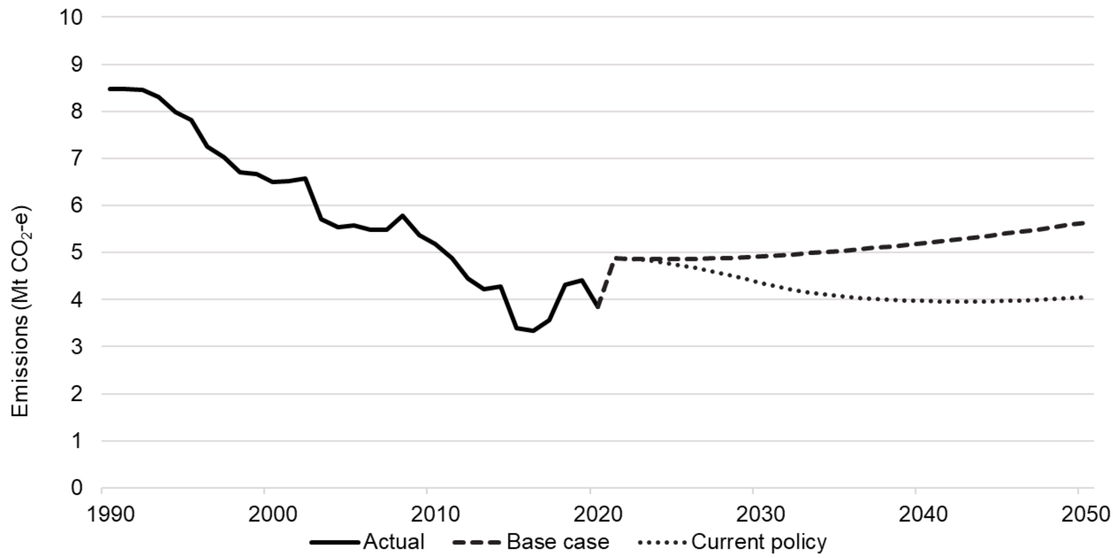

Figure 29 NSW waste sector emissions as inventoried (1990–2020), with base case and current policy projections (2021–2050)

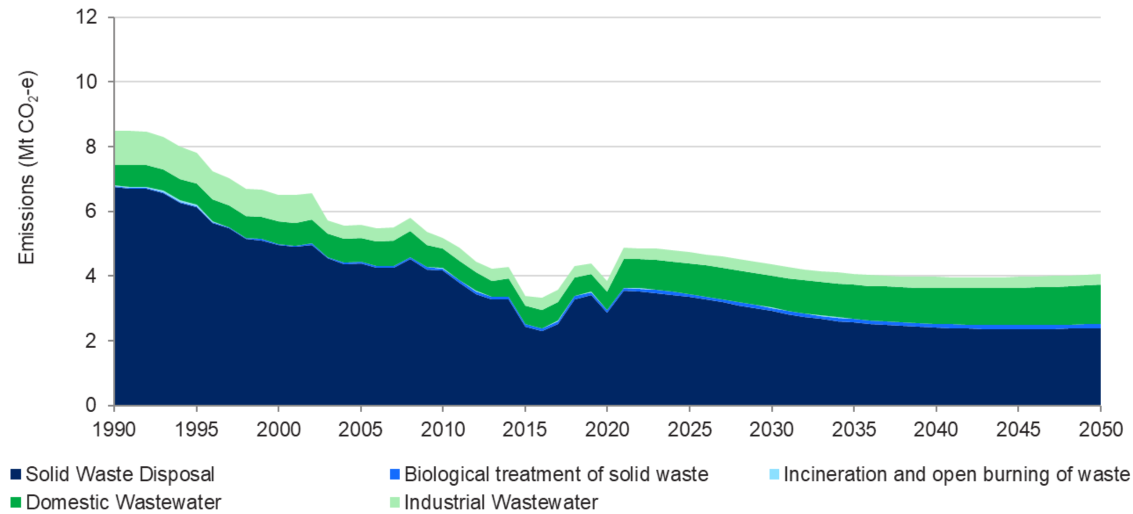

Figure 30 Waste emissions by subsector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)

Future projections

Future projection updates will consider:

- improved modelling of domestic/commercial and industrial wastewater emissions
- 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 announced in 2022 on waste sector emissions.

Summary of sector emissions and abatement

The abatement modelled to be achieved by programs under the Net Zero Plan Stage 1 is shown by sector in Figure 31, with resultant current policy projections for NSW emissions across all sectors compared to the base case in Figure 32. 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).

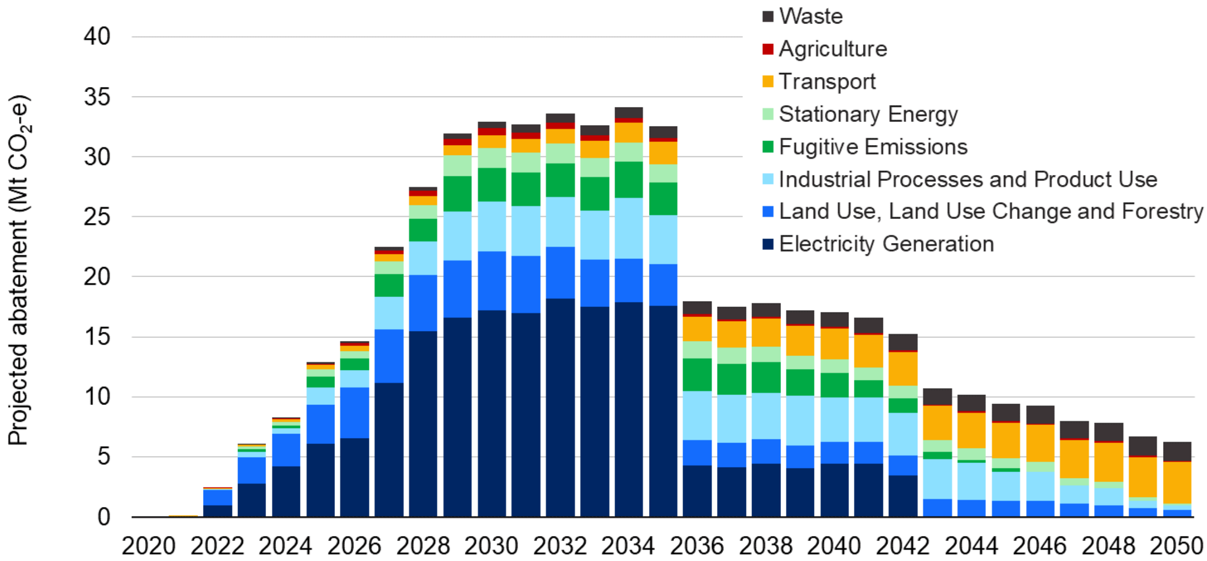

Figure 31 Abatement of emissions by sector projected to be achieved by Net Zero Plan Stage 1 programs

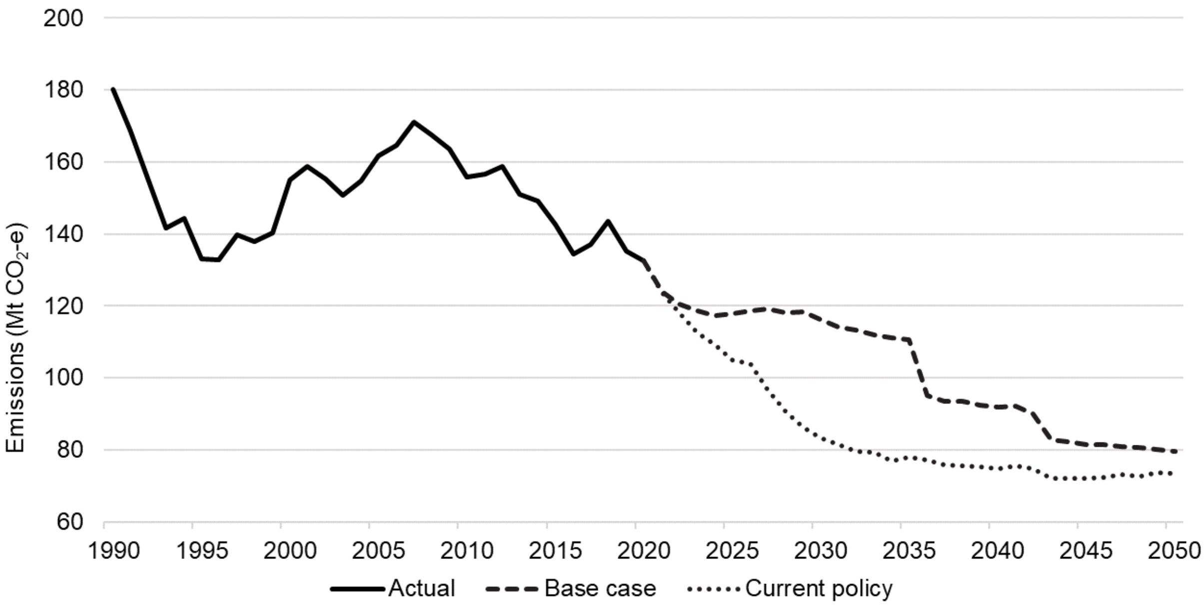

Figure 32 NSW emissions across all sectors as inventoried (1990–2020), with base case and current policy projections (2021–2050)

The abatement modelled to be achieved by sector can also be represented relative to the base case as illustrated in Figure 33 for emissions reductions to 2030.

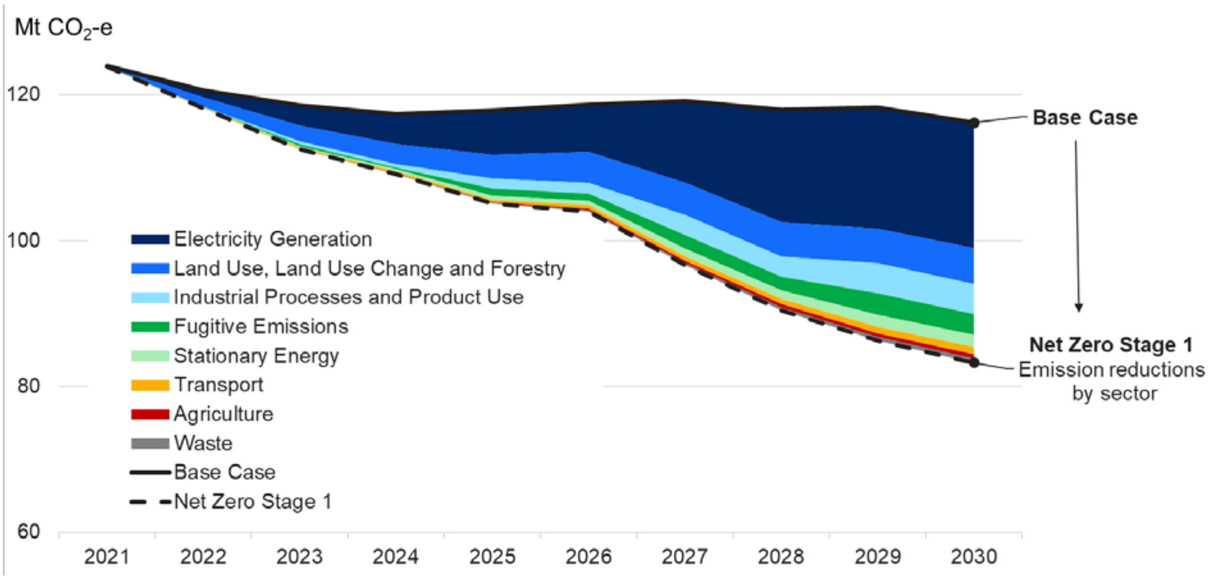

Figure 33 Projected abatement by sector to 2030 due to Net Zero Plan Stage 1 programs (central estimate)

Inventoried NSW emissions (1990–2020) and current policy emissions projections (2021–2050) are shown in Figure 34. The current policy projections provide an upper bound estimate of emissions out to 2050 as Net Zero Plan Stage 1 actions are not fully accounted for. The projections also do not capture increased actions by local government and the private sector, nor the impact of policies to be implemented under Stages 2 and 3 of the Net Zero Plan.

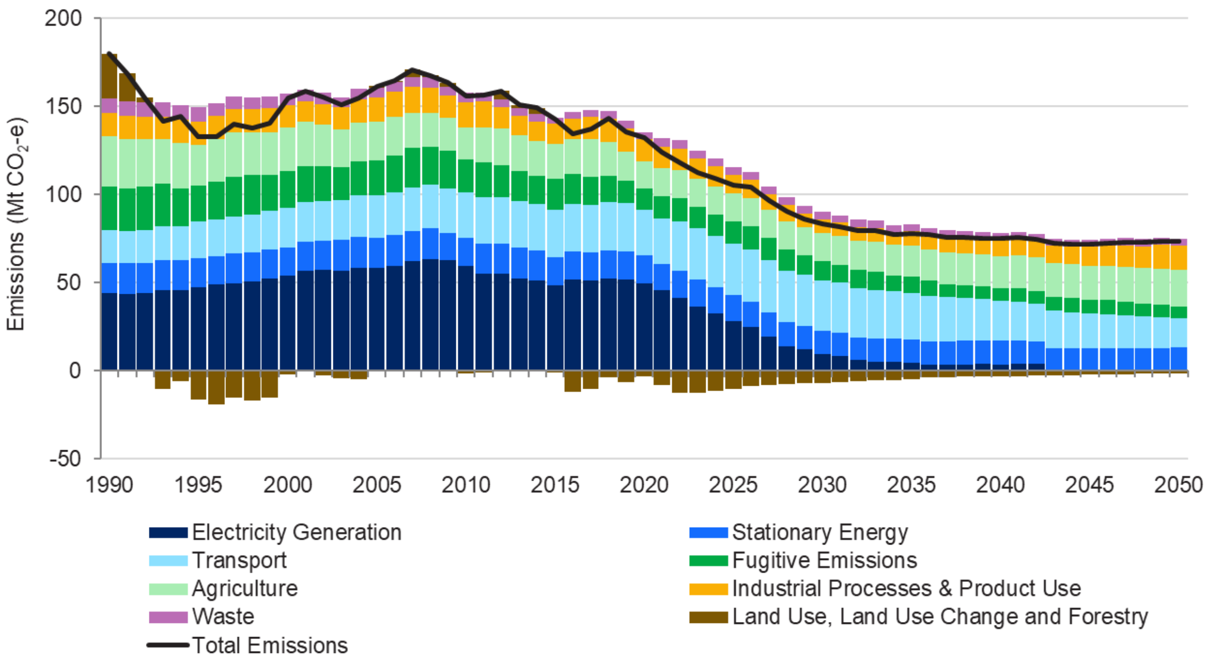

Figure 34 NSW emissions by sector showing inventory estimates (1990–2020) and current policy emissions projections (2021–2050)

Uncertainties in projections

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 8).

Table 8 Criteria for assessing the level of confidence in the NSW emissions projections

Projection inputs	High	Medium	Low
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 9.

Table 9 Level of confidence in base case NSW emissions projections

Sector / subsector	Projections to 2030	Projections 2030–50
Electricity generation	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
Industrial processes and product use	Medium	Low
Agriculture	Medium	Low
LULUCF	Medium	Low
Waste	High	Medium

Future projections

NSW 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. Specific factors to be considered in the modelling and model improvements anticipated for each sector are listed in the future projections section of each sector chapter. More generally these include:

- integration of the latest available data, information and forecasts
- improvements to modelling, such as the use of the department's NSW fleet and emission models together with TfNSW's updated transport projections for light and heavy vehicles, accounting for ongoing COVID-19 impacts and recent updates to population projections
- more resolved modelling for subsectors with more minor contributions to NSW emissions
- addressing recent NSW Government major strategies, policies and programs not yet accounted for within the 2021 emissions projections
- taking a less conservative approach to future NSW emissions by considering recent federal, local government and corporate commitments. The inclusion of emissions reductions due to such commitments will however depend on whether related actions are published, timebound and subject to monitoring and reporting.

Future projections will also include more detailed sensitivity testing to address areas with the greatest uncertainty, particularly in regard to emissions projections for future decades.

References

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) (2015) *Outlook scenarios for Australia's forestry sector: key drivers and opportunities*, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

ABARES (2021a) Agricultural commodities: June quarter 2021, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

ABARES (2021b) Agricultural commodities: March quarter 2021, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

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

ABS (2019) *9309.0 – Motor Vehicle Census, Australia, 31 Jan 2019*, Australian Bureau of Statistics, July 2019.

ABS (2020a) *3101.0 National, state and territory population*, accessed July 2021, www.abs.gov.au/statistics/people/population/national-state-and-territory-population/dec-2020

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

ABS (2021) Australian National Accounts: State Accounts, Australian Bureau of Statistics.

AEMO (2019) 2019 WA Gas Statement of Opportunities, Australian Energy Market Operator.

AEMO (2020a) *2020 Electricity Statement of Opportunities*, Australian Energy Market Operator, aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf [PDF 4.2MB]

AEMO (2020b) 2020 Gas Statement of Opportunities, Australian Energy Market Operator.

AEMO (2020c) *Integrated System Plan*, Australian Energy Market Operator, aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf [PDF 4.0MB

AEMO (2021) 2021 Gas Statement of Opportunities, Australian Energy Market Operator.

AER (Australian Energy Regulator) (2021) *State of the Energy Market 2021, Market Overview*, Australian Energy Regulator.

BITRE (Bureau of Infrastructure and Transport Research Economics) (2021) *Australian Domestic Airline Activity, Domestic Totals and Top Routes July 2014-June 2021*, Australian Government Department of Infrastructure, Transport, Regional Development and Communities, accessed July 2021, www.bitre.gov.au/publications/ongoing/domestic_airline_activity-time_series

BOM and CSIRO (2020) *State of the Climate 2020*, Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, 24pp.

CER (Clean Energy Regulator) (2020a) *Large-scale Renewable Energy Target supply data* (version available August 2020), Australian Government Clean Energy Regulator, www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/Large-scale-Renewable-Energy-Target-market-data/large-scale-renewable-energy-target-supply-data

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

CER (2020c) *Quarterly Carbon Market Report: September Quarter 2020*, Australian Government Clean Energy Regulator, https://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/Quarterly%20Carbon%20Market%20Report%20-%20September%20Quarter%202020.pdf [PDF 2.3MB]

Coal Services (2022) NSW coal industry statistics, Coal Services Pty Ltd.

Commonwealth of Australia (2019) Climate Solutions Package [PDF 1.2MB], Australian Government Department of the Environment and Energy.

DAWE (Department of Agriculture, Water and Environment) (2020) *Cold Hard Facts 2020*, Australian Department of Agriculture, Water and Environment, www.dcceew.gov.au/sites/default/files/documents/cold-hard-facts-2020.pdf [PDF 1.1MB]

DAWE (2021) *Australia's HFC Phase-down*, Australian Department of Agriculture, Water and Environment, www.dcceew.gov.au/environment/protection/ozone/publications/hfc-phase-down-factsheet

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

DCCEEW (2022b) National Greenhouse Accounts 2019, Australian Government Department of Climate Change, Energy, the Environment and Water.

DCCEEW (2022c) Resources and Energy Quarterly, Australian Government Department of Climate Change, Energy, the Environment and Water.

Deloitte (2017) *Western Sydney Airport Aviation Fuel Supply Corridor Options Report*, prepared by Deloitte Financial Advisory Pty Ltd for the Department of Infrastructure, Regional Development and Cities, www.westernsydneyairport.gov.au/sites/default/files/Fuel_Supply_Corridor_Options_Report_Feb2018.pdf [PDF 2.8MB]

Department of Infrastructure and Transport (2010) *Joint Study on Aviation Capacity in the Sydney Region*, Australian Department of Infrastructure and Transport, Canberra ACT, www.westernsydneyairport.gov.au/sites/default/files/sydney_aviation_capacity.pdf [PDF 56MB]

Department of Regional NSW (2022) Fugitive methane emissions from coal mines, Department of Regional NSW.

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

DISER (Department of Industry, Science, Energy and Resources) (2020a) *Australia's emissions projections 2020, December 2020*, Australian Department of Industry, Science, Energy and Resources, www.industry.gov.au/sites/default/files/2020-12/australias-emissions-projections-2020.pdf [PDF 2.9MB]

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

DISER (2020c) *Australian Petroleum Statistics 2020*, Australian Government Department of Industry, Science, Energy and Resources, www.energy.gov.au/publications/australian-petroleum-statistics-2020

DISER (2020d) *Methodology for the 2020 Projections*, December 2020, www.industry.gov.au/sites/default/files/2020-12/australias-emissions-projections-2020-report-methodology.pdf [PDF 1.1MB]

DISER (2021a) Australia's emissions projections 2021, Australian Department of Industry, Science, Energy and Resources, October 2021.

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

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

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

DISER (2021e) Resources and Energy Quarterly: June 2021, Australian Department of Industry, Science, Energy and Resources.

DISER (2021f) *State and Territory greenhouse gas inventories: 2019 emissions*, released April 2021, https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-2019/state-and-territory-greenhouse-gas-inventories-2019-emissions

DPE (2022a) Major Projects, NSW Department of Planning and Environment, Parramatta.

DPE (2022b) NSW Net Zero Emissions Dashboard, NSW Department of Planning and Environment, Parramatta.

DPE (2022c) Population Projections, NSW Department of Planning and Environment, Parramatta.

DPIE (Department of Planning, Industry and Environment) (2019a) *2019 NSW Population Projections*, NSW Department of Planning, Industry and Environment, Parramatta.

DPIE (2019b) Queensland-Hunter Gas Pipeline, NSW Department of Planning, Industry and Environment, Parramatta.

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

DPIE (2021a), *Business Decarbonisation Support*, www.energysaver.nsw.gov.au/reducing-emissions-nsw/business-decarbonisation-support

DPIE (2021b) Fire extent and severity mapping, NSW Department of Planning, Industry and Environment, Parramatta, www.environment.nsw.gov.au/research-and-publications/publications-search/fire-extent-and-severity-mapping-annual-report-2019-20

DPIE (2021c), *Net Zero Industry and Innovation Program,* NSW Department of Planning, Industry and Environment, Parramatta, www.energysaver.nsw.gov.au/reducing-emissions-nsw/net-zero-industry-and-innovation

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

DPIE (2021e) *NSW Net Zero Buildings Initiative*, NSW Department of Planning, Industry and Environment, Parramatta, www.environment.nsw.gov.au/news/nsw-to-lead-the-way-on-net-zero-buildings

DPIE 2022a, *Growing NSW's primary industrial and land sector in a low carbon world, Primary Industries Productivity and Abatement Program*, NSW Department of Planning, Industry and Environment, Parramatta, www.energysaver.nsw.gov.au/reducing-emissions-nsw/primary-industries-productivity-and-abatement

DPIE (2022b) NSW Waste and Sustainable Materials Strategy 2041, Stage 1: 2021−2027, NSW Department of Planning, Industry and Environment, Parramatta.

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

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

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

EPA (2022) The Waste and Resource Reporting Portal, NSW Environment Protection Authority.

FCAI (Federal Chamber of Automotive Industries) (2019) Get VFACTS, Federal Chamber of Automotive Industries, Kingston ACT.

Gavran M (2020) *Australian forest and wood products statistics datasets 2020*, ABARES technical report, Canberra, November 2020, doi:10.25814/8vah-r089

Graham PW, Havas L, Brinsmead T and Reedman L (2019) *Projections for small scale embedded energy technologies*, report to AEMO, CSIRO, Australia.

IATA (International Air Transport Association) (2021) *Aircraft Technology Roadmap to 2050*, International Air Transport Association, July 2021, www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/Technology-roadmap-2050.pdf [PDF 2.8MB]

IBISWorld (2022) Expert Industry Research You Can Trust, IBISWorld, Melbourne.

ICCT (International Council on Clean Transportation) (2017) *Too low to be true? How to measure fuel consumption and CO_2 emissions of plug-in hybrid vehicles, today and in the future*, International Council on Clean Transportation, July 2017, theicct.org/publications/too-low-be-true-how-measure-fuel-consumption-and-co2-emissions-plug-hybrid-vehicles

ICCT (2019) *From Laboratory to Road,* International Council on Clean Transportation, January 2019, theicct.org/publications/laboratory-road-2018-update

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

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

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

NSW Government (2020b) NSW Energy Security Safeguard, NSW Government.

NSW Government (2021) *NSW Electric Vehicle Strategy*, NSW Government, www.environment.nsw.gov.au/topics/climate-change/net-zero-plan/electric-vehicle-strategy

NSW Government (2022a) Developing hydrogen hubs for NSW: Helping create a thriving hydrogen industry, NSW Government.

NSW Government (2022b) SEED: The Central Resource for Sharing and Enabling Environmental Data in NSW, NSW Government.

OECD (Organisation for Economic Co-operation and Development) (2020) *OECD-FAO Agricultural Outlook 2020-2029*, accessed 9 April 2021, https://stats.oecd.org/viewhtml.aspx?datasetcode=HIGH_AGLINK_2020&lang=en

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

Sydney Airport (2019) Sydney Airport Master Plan 2039, Sydney Airport Corporation Ltd.

TER (2021) 'Estimation of total travel and total emissions for the NSW on-road fleet with the Australian Fleet Model (AFM) and COPERT Australia', Transport Emission/Energy Research, unpublished report.

TfNSW 2022, *NSW Government Zero Emission Bus Transition Strategy*, Transport for New South Wales, www.transport.nsw.gov.au/projects/current-projects/zero-emission-buses

TNO (2018), *Real world fuel consumption of passenger cars based on monitoring of Dutch fuel pass data 2017,* May 2018.

Wood N, Beauman M and Adams P (2021) *An indicative assessment of the four key areas of climate risk for the 2021 NSW Intergenerational Report*, Treasury Technical Research Paper Series, NSW Treasury, TTRP 21-05, April 2021, www.treasury.nsw.gov.au/sites/default/files/2021-04/2021_igr_ttrp_-_an_indicative_assessment_of_four_key_areas_of_climate_risk_for_the_2021_nsw_intergenerational_report.pdf [PDF 575KB]