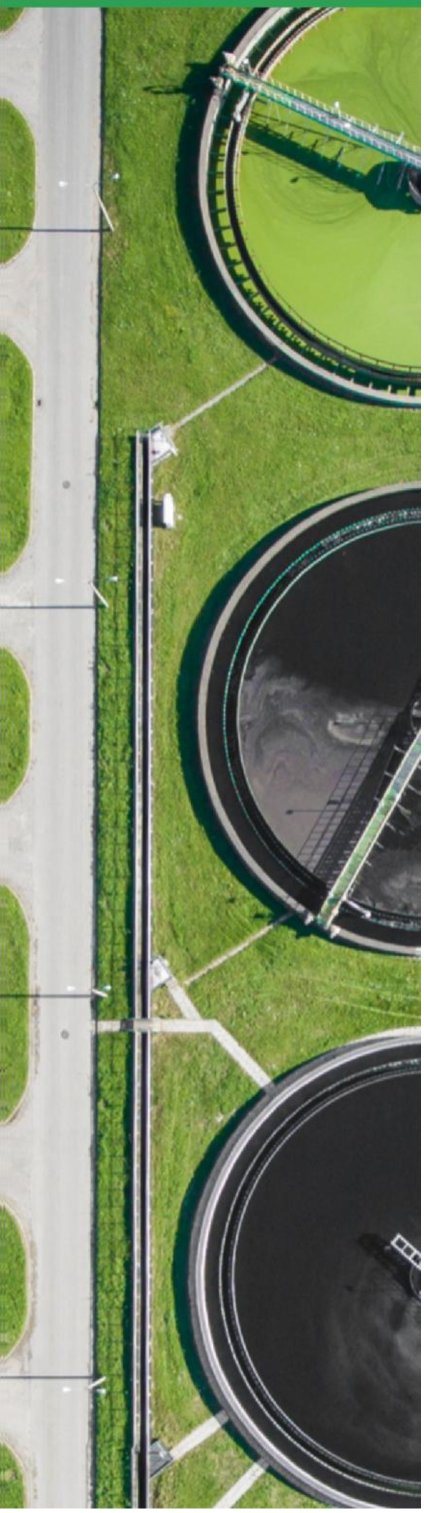

Transforming Biosolids

Life Cycle Assessment of Biosolids

Harmonised literature results and Australian-specific modelling

J.Luo, S. Aryampa, R. Fisher, T. Wiedmann, R. Stuetz, December 2025

A report of a study funded by the ARC Training Centre for the Transformation of Australia's Biosolids Resource

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About the report

The ARC Training Centre for the Transformation of Australia's Biosolids Resource has a primary goal of delivering world-class and innovative technological solutions and knowledge, to train the next generation of biosolids practitioners in cutting-edge, transformational approaches, and to guide best practice in the biosolids sector. A key project delivered by the Centre was ensuring sustainability in biosolids management by exploring the role of Biosolids Management in preserving Earth's resilience (Project 3B). The project used tailored sustainability assessment frameworks to quantify the environmental, economic and social impacts of key biosolids treatment alternatives. The assessments included carbon, water, energy and nutrient management, life cycle assessments. Carbon, energy, flows of nutrients, variability in sludge and biosolids composition, and emissions were studied and modelled using Life Cycle Analysis (LCA) and Material Flow Analysis (MFA). This report presents the results of that research. For further information visit: www.transformingbiosolids.com.au

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Contents

Executive summary

In Australia, increasing public concern over emerging contaminants, ongoing regulatory changes, and capacity constraints have driven the water sector to place increased emphasis on the optimisation and upgrade of biosolids processing systems. In this context of substantial infrastructure investment, robust sustainability assessment is essential to minimise the potential risk of environmental trade-offs and ensure long-term sustainability.

This report presents findings from research conducted as a part of the project ***The role of Biosolids Management in preserving Earth's resilience*** undertaken with the ARC Training Centre for the Transformation of Australia's Biosolids Resource. The primary aim of the project is to provide a generic and flexible environmental sustainability framework for assessing existing and emerging biosolids treatment technologies.

The aim of this report is to deliver a screening-level understanding of the environmental performance of various biosolids processing systems. Two sets of results are presented: harmonised LCA outcomes derived from a developed harmonisation framework applied to published literature, and modelling results from an Australia-specific LCA. These findings offer water utilities practical insights to benchmark technologies, assess environmental trade-offs, and support more sustainable decision-making.

Key findings and recommendations:

- **Environmental advantages of conventional anaerobic digestion systems:** Both harmonised literature results and Australian-specific LCA demonstrated lower global warming impact associated with anaerobic digestion and land application systems compared to other technologies.
- **No single best option**: No single biosolids processing technology consistently outperforms others across all environmental indicators considered. The full range of impact categories should be included when selecting and comparing options to ensure balanced and sustainable outcomes.
- **Local context matters**: The environmental performance of each technology shifts across Australian states and territories, driven primarily by differences in electricity grid carbon intensity. No single solution is best for all sites.
- **Caution with site-specific decisions**: Facility-level LCA is recommended for detailed planning due to variability in sludge characteristics and operational parameters.
- **Ongoing data improvements**: The reliability of LCA will continue to improve as industry partners contribute more site-specific operational data and as uncertainty and sensitivity analyses are further developed in future work.

1 Introduction

Biosolids processing and utilisation present a critical component of the Australian water sector, with far-reaching implications for environmental sustainability, regulatory compliance, and resource recovery. In recent years, growing public concern about emerging contaminants, ongoing regulatory updates and capacity constraints have driven the sector to place increased emphasis on optimising and updating biosolids processing systems1. This shift presents a valuable opportunity for water utilities to enhance environmental performance, explore new market opportunities, and improve community acceptance of biosolids. However, significant challenges remain, particularly in balancing diverse needs such as addressing emerging contaminants, reducing carbon emissions, enhancing resource recovery, and ensuring long-term sustainability. Without a comprehensive assessment of alternative options, there is a risk of unintended outcomes, including increased financial burdens and environmental trade-offs.

Life cycle assessment (LCA) has emerged as a valuable tool for addressing the complexity of environmental trade-offs and for incorporating a comprehensive perspective on environmental sustainability into decision-making processes[2]. However, past applications of LCA to biosolids systems have exhibited substantial variations, which have compromised the reliability and comparability of results, making it difficult to draw clear conclusions on the relative environmental performance of different processing options[3].

However, despite variations in outcomes, past efforts in biosolids LCA still provide valuable information and can serve as useful benchmarks or offer a high-level understanding of different processing systems. Nevertheless, their value for direct comparison is limited, as variability among studies has hindered effective benchmarking and reduced confidence in reported results. This limitation highlights the need for a standardised approach to synthesise and interpret existing LCA studies.

Additionally, existing LCAs of biosolids processing systems in the Australian context are either outdated[4] or focused on only a limited set of processing options[5], resulting in a lack of a comprehensive, up-to-date understanding of the life cycle environmental performance of different technological options. This gap limits the ability of utilities and industry partners to make informed decisions and to compare the trade-offs associated with alternative processing options on a consistent and standardised basis.

1.1 Aim of this report

The aim of this report is to provide a screening-level understanding of the environmental performance of different biosolids processing systems, offering utilities valuable insights into the relative impacts and trade-offs associated with each option. The report presents two levels of results: harmonised outcomes based on existing LCA studies, and an Australia-specific LCA modelling of various biosolids processing systems.

The key components of this study include:

- Establish a harmonisation framework to align and synthesise results from previous LCAs, enabling a consistent and comparable understanding of the environmental performance of different biosolids processing systems.
- Conduct LCA modelling of various biosolids processing technologies within the Australian context, providing screening-level insights into their relative environmental performance.
- Demonstrate the practical application of best-practice guidelines for biosolids LCA in Australia.

2 Our approach

2.1 Harmonisation framework for synthesising literature LCA outcome

High-quality published LCA studies were selected from literature gathered through a systematic review, following the methodology detailed in Luo et al[3]. A harmonisation framework was developed for these selected studies to facilitate meaningful comparisons across different LCA studies of biosolids processing systems. The framework focused on standardising system boundaries and background data to minimise methodological discrepancies and variations originating from supply chain assumptions. System boundary harmonisation involved systematically including or excluding specific processes to achieve consistency across studies. Background datasets were harmonised using Australian average data sourced from the AusLCI (for electricity mix and transportation impacts) and Ecoinvent databases (for other background processes), and standardised assumptions were applied for avoided impacts from electricity and mineral fertiliser substitution.

The harmonisation analysis focused solely on Global Warming Potential (GWP), given its relevance for decision-makers and suitability for cross-study comparisons. All harmonised results were recalculated to a standardised functional unit of one dry tonne of sewage sludge processed. Studies that could not be reliably reproduced were excluded. A sensitivity analysis was conducted using electricity grid mixes specific to different Australian states and territories to assess the influence of geographical variability.

2.2 LCA of Biosolids Processing in the Australian Context

An LCA was conducted for biosolids processing systems in the Australian context, in accordance with the best practice guidelines outlined in the industry report, ***Life Cycle Assessment of Biosolids Processing Systems: Investigating Variation and a Best Practice Guide***. The study adopts a design-level objective, aiming to assess and compare the environmental performance of various biosolids processing systems identified across Australia. It provides industry partners with insights into the relative environmental advantages and trade-offs among different systems and demonstrates the application of the best practice guide for biosolids LCA. The functional unit defined for this study is **one tonne of dry solids of thickened mixed sludge** entering the processing system, with detailed characteristics of the input sludge provided in Appendix A. The analysis encompasses eight biosolids processing systems, selected based on prevalent technologies reported in the ANZBP 2023 survey[6]. A process flow diagram for these systems is illustrated in Figure 1.

System boundaries were defined in line with recommendations from the best practice guide and available data. Process-level boundaries are detailed in Appendix B, while plant-level boundaries are shown in Figure 1. For the industry-level boundary, background data were sourced from AusLCI and Ecoinvent 3.10 databases, with detailed selections provided in Appendix D. For downstream boundaries, the treatment of reject water utilised data from Ecoinvent, with the boundary ending at treated effluent discharge. Recovered electricity was assumed to be fully utilised within the plant, and avoided impacts related to the transportation, application, and post-application emissions of mineral fertilisers were included.

Primary data from industry partners was prioritised in compiling the inventory data, supplemented by literature sources to address any gaps. Detailed information on data sources, documentation, and quality assessments is included in Appendix B. The environmental impacts of the biosolids processing systems were quantified using the EASETECH V3.6.0 LCA model, employing the recommended impact assessment methods from the Australian Life Cycle Assessment Society[7]. Impact categories evaluated include GWP, eutrophication potential, acidification potential, human toxicity potential and ecotoxicity potential (see box 1 for more information).

Due to limited primary data availability, the study presents preliminary results only; uncertainty and sensitivity analyses were not conducted. Consequently, these results should be interpreted with caution, acknowledging the inherent limitations of single-point data, which do not capture variability or the range of potential operational scenarios. The presented findings reflect aggregated conditions across Australia and therefore may not directly represent specific facility conditions. Facility-level assessments are recommended for more precise decision-making. Future work will focus on enhancing data completeness and performing uncertainty and sensitivity analyses to provide a more comprehensive understanding of variability and reliability in LCA results.

Box 1 Impact indicators

Impact categories in LCA are used to quantify and compare the potential environmental effects of assessed systems across a range of key areas, include:

- **Global Warming potential (GWP)**: Measures life cycle greenhouse gas emissions contributing to climate change, expressed as carbon dioxide equivalents (CO_2-eq).
- **Eutrophication potential**: Assesses the risk of nutrient pollution (mainly nitrogen and phosphorus) leading to excessive growth of algae in water bodies.
- **Acidification potential**: assesses emissions that can lead to acid rain and soil acidification, affecting ecosystems and infrastructure.
- **Human toxicity potential**: Indicates the potential harm of chemical emissions to human health, considering both cancer and non-cancer effects.
- **Ecotoxicity potential**: Reflects the possible toxic effects of chemical emissions on aquatic and terrestrial ecosystems.

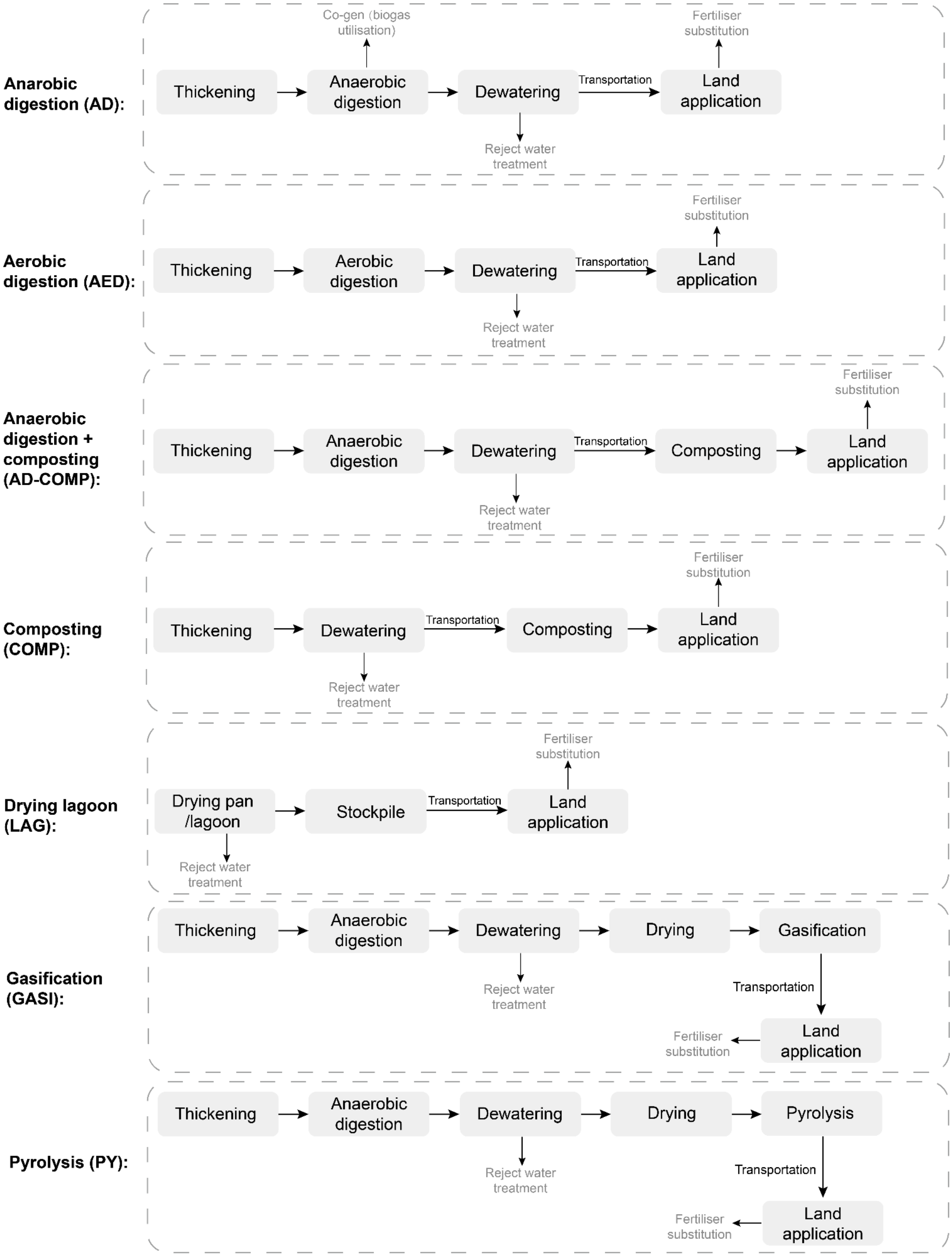

Fig. 1 Process flow diagrams of included biosolids processing systems

3 Outcomes

3.1 Harmonised LCA results: a clearer benchmark for industry

By aligning boundaries and background processes across studies, the harmonisation process has reduced variability in GWP results, offering clearer and more consistent insights based on literature outcomes.

The harmonised results show more distinct trends between technologies (Fig. 2). AD generally achieves the lowest average greenhouse gas emissions, reaching net-negative outcomes in many cases, largely due to credits from energy recovery and fertiliser substitution. COMP and INC tend to have similar ranges, with COMP showing a slightly lower average impact. PY, while presenting a large reduction in the results variation between studies, still shows a wide spread of results, reflecting ongoing uncertainties and operational diversity. Despite these uncertainties, PY typically performs better than composting or incineration in terms of average GWP outcomes, largely due to credits achieved from carbon sequestration.

A high-level review on factors driving GWP performance of different technologies and how these drivers shift after harmonisation has identified environmental hotspots and opportunities for improvement. For example, the environmental impact of AD is strongly affected by direct greenhouse gas emissions from land application and the cogeneration unit, while incineration results are influenced by whether all energy consumption steps are accounted for. Composting's impacts are mainly tied to direct emissions during the composting process, and for pyrolysis, the overall GWP performance is closely related to the balance between credits from biochar land application and emissions from drying energy consumption.

For water utilities, harmonised LCA outcomes provide a more reliable comparison across different biosolids processing options and with previous LCA results, supporting better-informed decision-making and benchmarking for biosolids processing systems. Despite the improved consistency in LCA outcomes following harmonisation, some variability remains due to differences in process parameters originating from variations in system configurations and operating conditions specific to each facility. As a result, while harmonised LCA results offer a stronger basis for benchmarking and screening-level assessments, they should be complemented by detailed, site-specific analysis.

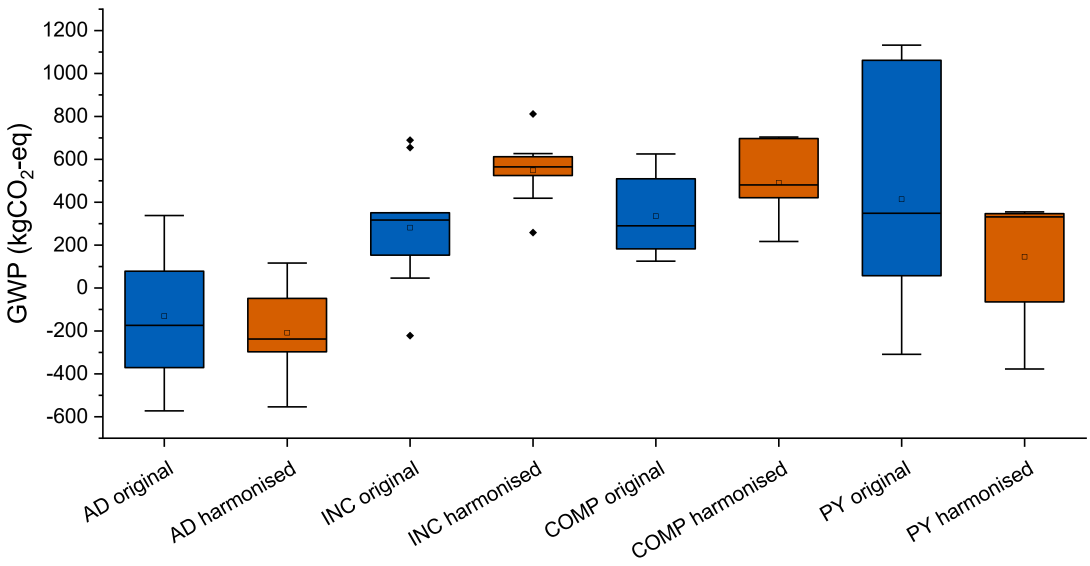

Fig. 2 Comparison of results before and after harmonisation for different systems: Anaerobic Digestion (AD), Composting (COMP), Incineration (INC), Pyrolysis (PY)

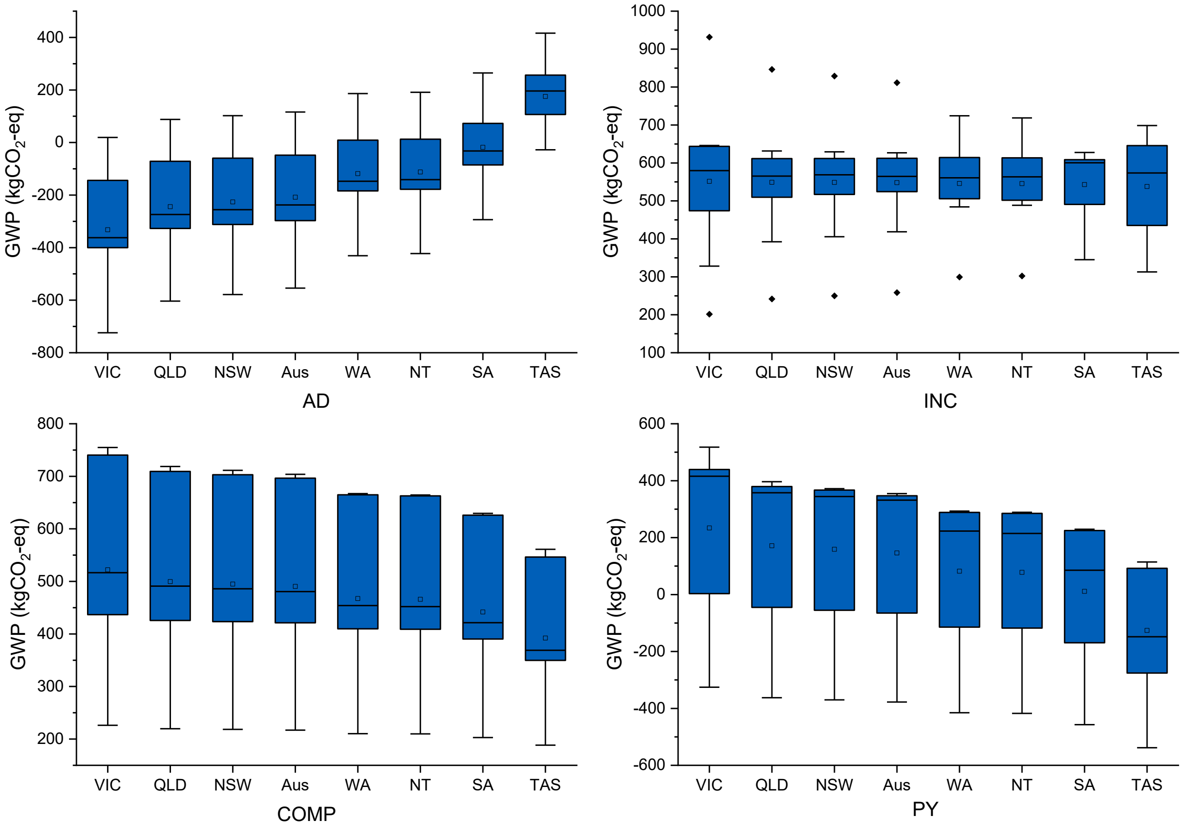

Fig. 3 Harmonised results for different systems based on the electricity mix in different states and territories in Australia: Anaerobic Digestion (AD), Composting (COMP), Incineration (INC), Pyrolysis (PY)

	AD	INC	COMP	PY
VIC	-332	552	522	234
QLD	-244	549	500	171
NSW	-226	549	495	159
Aus	-208	548	490	146
WA	-118	546	467	82
NT	-112	546	466	78
SA	-18	543	442	11
TAS	175	538	392	-126

Min Max

Fig. 4 Comparison of average harmonised global warming potential of different technologies based on the electricity mix in different states and territories in Australia; Anaerobic Digestion (AD), Composting (COMP), Incineration (INC), Pyrolysis (PY)

3.2 Shifting technology performance across states and territories

The environmental performance of biosolids processing technologies is not the same across the country; it changes depending on the local electricity supply in each Australian state and territory. Our analysis shows that the ranking of different systems can shift across regions as a result of differences in electricity carbon intensity.

For most states and territories, AD generally delivers the lowest GWP, largely due to the benefits of electricity recovery. However, as electricity grids become cleaner, the carbon credits from energy recovery decrease, which can reduce the relative advantage of AD. This effect is especially clear in Tasmania, where the grid is already very low in carbon emissions, and PY outperforms other options. In contrast, technologies like COMP and PY show an opposite trend: their performance improves as the electricity grid becomes cleaner, because these systems are net users of electricity, and using cleaner power reduces their overall emissions.

INC presents a more complex picture, with its environmental performance varying due to differences in plant configurations and electricity balances. Some incineration systems generate excess electricity, while others consume more than they produce, leading to mixed outcomes that are strongly influenced by site-specific factors.

These regional differences mean that there is no single best biosolids processing technology for Australia as a whole; local conditions can also shift the relative advantages. It's also important to note that other local factors, such as sludge characteristics, climate conditions and regulatory requirements, can also influence environmental outcomes, which are not fully captured by harmonisation due to their complex indirect influence on LCA outcomes. These regional variations highlight the importance of considering local conditions when selecting and investing in biosolids management technologies. Tailoring LCA assessment to the specific context of each state or territory can help ensure the best environmental outcomes.

3.3 Environmental performance of biosolids processing systems: Australian LCA Insights

3.3.1 Global warming potential

The results from Australian-specific LCA based on primary industry data are illustrated in Fig.5. All systems except AD resulted in a net increase in GWP, indicating net greenhouse gas (GHG) emissions. While fugitive emissions of GHG during land application, biogas leakage, and the thickening process contribute to the impact of AD, these are effectively offset by the credits from electricity substitution, and to a lesser extent, mineral fertiliser substitutions. AED showed the highest GWP, driven by high electricity consumption during operation. High GWP impacts were also observed for COMP and LAG, with impacts largely attributed to direct emissions from composting and dewatering in lagoon systems. Integrating composting with AD effectively reduced GWP impacts by combining energy recovery with stabilisation prior to composting. Thermochemical technologies demonstrated advantages in GWP compared to AED, COMP and LAG, with PY showing the second lowest GWP, mainly due to the carbon sequestration potential of biochar when applied to land. GAS, despite better energy efficiency, resulted in slightly higher emissions than PY due to its lower biochar carbon content and hence reduced sequestration potential.

However, caution is needed when applying or comparing these results in a site-specific context. The analysis was based on the Australian average electricity mix for 2022, which may not reflect local conditions. As shown above, variations in grid carbon intensity can significantly influence the environmental performance and relative ranking of technologies. For instance, under Tasmania's electricity mix, the GWP of AD increases to 224 kg CO_2-eq/tds, while PY achieves a net credit of –111 kg CO_2-eq/tds. To ensure accurate and meaningful results, facility-specific LCAs should use locally relevant, and where appropriate, time-specific, background data.

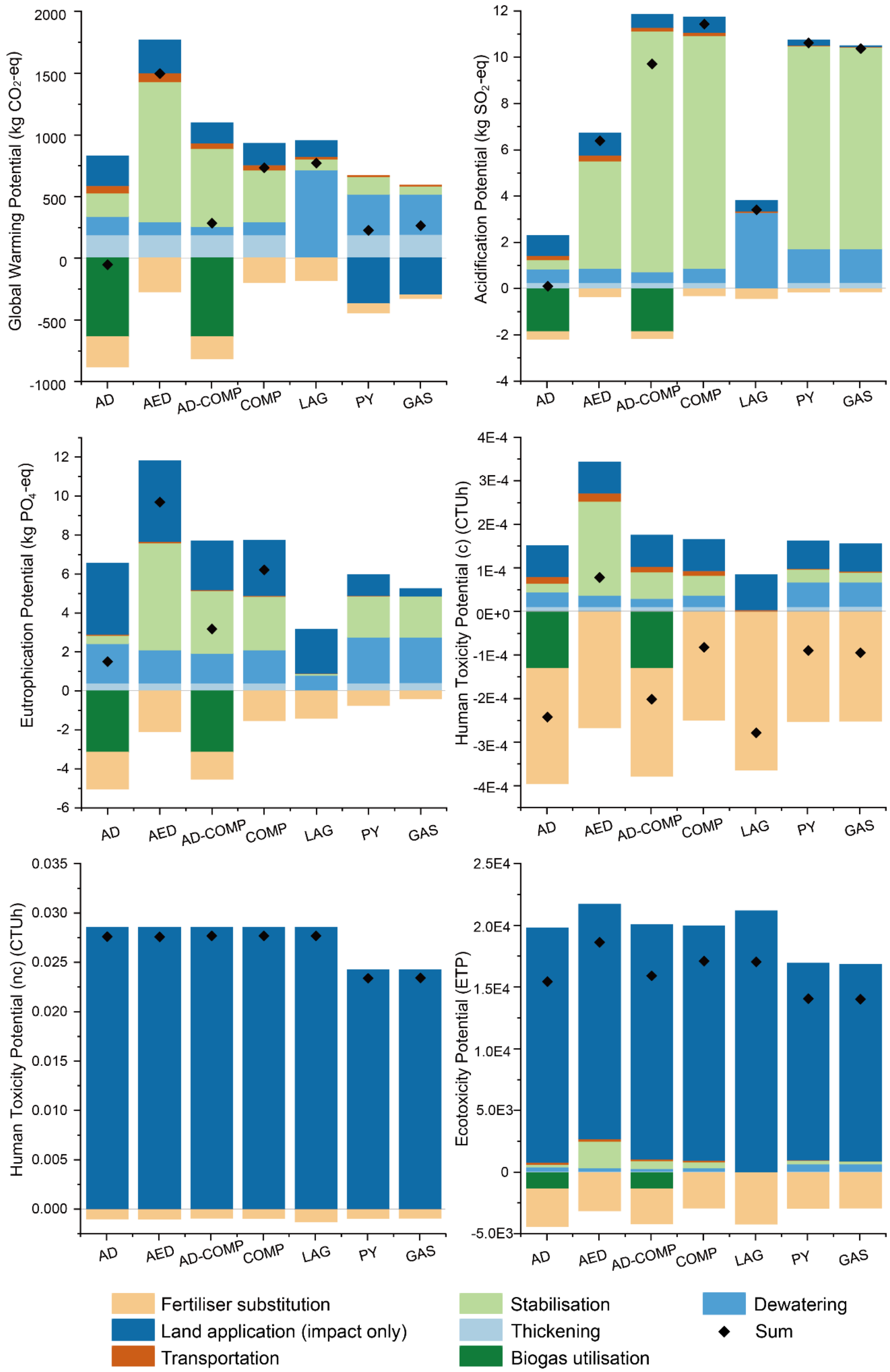
Global Warming Potential (kg CO_2-eq)
Acidification Potential (kg SO_2-eq)
Eutrophication Potential (kg PO_4-eq)
Human Toxicity Potential (c) (CTUh)
Human Toxicity Potential (nc) (CTUh)
Ecotoxicity Potential (ETP)
AD
AED
AD-COMP
COMP
LAG
PY
GAS
Fertiliser substitution
Land application (impact only)
Transportation
Stabilisation
Thickening
Biogas utilisation
Dewatering
Sum

Fig. 5 Life cycle assessment modelling and contribution analysis outcomes; Anaerobic Digestion (AD), Composting (COMP), Incineration (INC), Pyrolysis (PY)

3.3.2 Acidification potential and eutrophication potential

Acidification potential is primarily driven by electricity consumption and direct emissions of ammonia and nitrogen oxides. For AED, high impacts were linked to the intensive electricity demand during operation. In AD-COMP and COMP systems, fugitive ammonia emissions were the dominant contributors, while nitrogen oxide emissions were more significant for PY and GAS. It is important to note that these emissions were estimated based on literature data, which introduces uncertainty due to limited representativeness and variability. For example, a

fixed value of 10.27 kg NO_x per tonne dry solid treated was used for pyrolysis, despite reported emission factors in the literature ranging from 0.03 to 34 kg.

Similar to acidification potential, eutrophication potential is mainly influenced by electricity use and nitrogen-based emissions. However, fertiliser substitution played a more prominent role in offsetting impacts. As a result, land application of biosolids and compost offered greater eutrophication offset compared to biochar from PY and GAS, where nitrogen losses during treatment reduced the benefits from fertiliser substitution.

3.3.3 Human toxicity and ecotoxicity potentials

Results for human toxicity potential (cancer effect) showed distinct patterns compared to human toxicity potential (non-cancer effect) and ecotoxicity potential. For the cancer effect, all systems except AED achieved net credits, demonstrating the net reduction of potential human toxicity related to the cancer effect. These benefits are primarily related to fertiliser substitution and, to a lesser extent, electricity substitution. In the case of AED, the credits from fertiliser substitution were insufficient to offset the impacts associated with high electricity consumption.

In contrast, the non-cancer and ecotoxicity categories were dominated by heavy metal emissions, despite receiving some credits from fertiliser substitution. The divergence in trends between cancer and non-cancer effects is mainly due to differences in the toxicity potential of specific heavy metals for different impact categories. For non-cancer and ecotoxicity potentials, zinc emissions, which are identified as a priority contaminant in biosolids, were the primary contributors. For the cancer effect, the dominant impact was linked to substituted chromium.

3.3.4 Limitations

Inventory data used in the assessment represents average values across multiple facilities and utilities, as well as a wide range of literature. These values may not reflect the specific performance of individual plants, particularly where process configurations, biosolids characteristics, or operational practices differ.

In addition, uncertainty and sensitivity analyses were not undertaken due to gaps in Australian-specific primary data and information. As a result, the results are presented as single-point estimates, which provide indicative trends but do not capture variability in key parameters such as biogas leakage, electricity use, or emissions during land application. We are currently working to improve data coverage and plan to develop more detailed, location-specific assessments in future updates.

Another key constraint is the reliance on literature-based or international sources for several foreground parameters. This lack of high-quality Australian-specific data for some key parameters, such as electricity use in aerobic digestion, fugitive emissions during land application, and biogas leakage from digesters, could potentially introduce uncertainty that cannot yet be resolved without further local monitoring.

Table 1 List of data sources used in the analysis

Thickening	Electricity consumption	Primary data	Australian specific
	Dryness achieved	Primary data	Australian specific
	Emissions	Literature	Non-Australian specific
Anaerobic digestion	Electricity consumption	Primary data	Australian specific
	Biogas generation	Primary data	Australian specific
	Electricity recovery	Primary data	Australian specific
	Emissions	Literature	Non-Australian specific
Composting	Energy consumption	Literature	Non-Australian specific
	Emissions	Literature	Non-Australian specific
Aerobic digestion	Electricity consumption	Literature	Non-Australian specific
	Emissions	Literature	Non-Australian specific
Lagoon	Emissions	Literature	Australian specific
Dewatering	Electricity consumption	Primary data	Australian specific
	Polymer consumption	Primary data	Australian specific
Stockpile	Emissions	Literature	Australian specific
Land application	Energy consumption	Literature	Non-Australian specific
	Emissions	Literature	Non-Australian specific
Pyrolysis/gasification	Energy consumptions	BTTAS	Non-Australian specific
	Chemical consumptions	BTTAS	Non-Australian specific
	Emissions	BTTAS	Non-Australian specific

4 Conclusion and future outlook

This report provides a screening-level assessment of the environmental performance of different biosolids processing systems based on the Australian context, based on both harmonised literature results and Australia-specific LCA modelling. The findings highlight the value of a standardised, comprehensive approach to comparing technologies and offer practical insights for water utilities on the relative environmental performance and trade-offs of different systems.

Key findings include the superior performance of conventional anaerobic digestion with land application for global warming potential and several other impact categories, as well as the identification of significant trade-offs between different technologies across various environmental indicators. These trade-offs reinforce the need for utilities to adopt a holistic assessment framework when making investment and operational decisions, taking into account local conditions and the full range of environmental impacts.

Despite advances in data harmonisation and modelling, some limitations remain, particularly in the availability of high-quality, facility-specific data and in the lack of uncertainty and sensitivity analysis in this initial assessment. As the industry moves forward, addressing these gaps will be crucial for further improving the reliability and relevance of LCA results.

Future work should focus on:

- Updating the assessment model with primary data collected from Australian facilities to improve accuracy and representativeness.
- Integrating uncertainty and sensitivity analyses to better capture the variability and robustness of results.
- Tailoring LCA studies to specific local contexts, including facility configurations, sludge characteristics, and regional electricity mixes.
- Exploring emerging technologies, regulatory updates and alternative end-use scenarios in future LCA modelling.

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Appendix-A Sludge characteristics

Table. A. 1 Sludge characteristics adopted in this study

Category	Sludge	Unit
Water	99	%
TS	1	%
VS	70	%TS
Ash	30	%
C	40	%TS
N	4	%TS
P	2	%TS
Zn	0.0677	%TS
Cu	0.0206	%TS
Pb	0.00381	%TS
Cd	0.0001	%TS
Cr	0.0024	%TS
Hg	4.69E-05	%TS
Ni	0.00263	%TS

Appendix-B Inventory data

Table. A. 2 Inventory data and process-level system boundary adopted

Inventory	Unit	Value	DQI	Data source
Thickening				
Electricity input	kWh	83.17	2, 3, 2, 2, 2	Australian specific primary data
Polymer input	kg	3.33	2, 5, 2, 5, 2	Australian specific primary data
Nitrous oxide emission	kg	0.57	5, 5, 3, 5, 5	Literature data based on mass balance
Methane emission	kg	1.99	5, 5, 3, 5, 5	Literature data based on mass balance
Dryness achieved	%	4.33	2, 3, 1, 2, 2	Australian specific primary data
Anaerobic digestion and cogeneration				
Electricity input	kWh	104.11	2, 5, 2, 5, 2	Australian-specific primary data
Heat	MJ	72.57	1, 3, 1, 2, 1	Australian-specific primary data
Biogas generation	M^3	315.64	2, 3, 1, 2, 2	Australian-specific primary data
Methane content	%	60.81	2, 3, 1, 2, 2	Australian-specific primary data
Electricity output	kWh	865.79	2, 3, 1, 2, 2	Australian-specific primary data
Biogas leakage rate	%	2.31	NA	Literature average
Ammonia emission	kg	1.81E-01	NA	Literature average
Nitrous oxide emission	kg	1.10E-02	NA	Literature average
Nitrogen oxide emissions	kg	5.45E-01	NA	Literature average
NMVOC emission	kg	5.60E-02	NA	Literature average
Sulphur dioxide emission	Kg	3.15E-01	NA	Literature average
Particles emission	kg	8.00E-02	NA	Literature average
Methane emission	kg	3.17	NA	Literature average
Hydrogen sulphide emission	kg	0.02	NA	Literature average
VS reduction	%	50.36	NA	Australian-specific primary data
Aerobic digestion				
Electricity input	kWh	1440	4, 5, 5, 5, 2	From the BEAM tool
VS reduction	%	46.5	NA	Literature average
Dewatering				
Electricity input	kWh	127.22	2, 5, 2, 5, 2	Australian-specific primary data
Polymer input	Kg	12.5	2, 5, 2, 5, 2	Australian-specific primary data
Dryness achieved	%	21.67	2, 5, 2, 5, 2	Australian-specific primary data
Composting				
Electricity input	kWh	124.03	NA	Literature average

Fuel consumption	Kg	11.18	NA	Literature average
Bulking material	Kg	1438.52	NA	Literature average
VS reduction	%	37.59	NA	Literature average
Ammonia emission	Kg	5.75	NA	Literature average
Methane emission	Kg	5.50	NA	Literature average
Nitrous oxide emission	kg	0.37	NA	Literature average
Drying pan and lagoon				
Methane emission	%C	6.69	4,4,1,2,4	Literature, Australian specific
Nitrous oxide emission	%TN	0.45	4,4,1,2,4	Literature, Australian specific
Ammonia emission	%TN	4.24	4,4,1,2,4	Literature, non-Australian specific
Stockpile				
Methane emission	Kg	0.09	NA	Literature, Australian specific
Nitrous oxide emission	Kg	0.32	NA	Literature, Australian specific
Ammonia emission	Kg	1.42	NA	Literature, non-Australian specific
Pyrolysis				
Electricity consumption	kWh	209	4, 5, 4, 5, 2	BATTAS tool
Heat recovery	MJ	509	4, 5, 4, 5, 2	BATTAS tool
Biochar yield	%	45.5	4, 5, 4, 5, 2	BATTAS tool
Nitrous oxide emission	kg	0.003	NA	Literature average
Nitrogen oxide emissions	Kg	10.27	NA	Literature average
Carbon monoxide emission	Kg	1.53	NA	Literature average
Sulphur dioxide emission	kg	2.47	NA	Literature average
Gasification				
Electricity consumption	kWh	497	2, 4, 4, 5, 2	Literature, Australian specific
Heat recovery	MJ	2570	4, 5, 4, 5, 2	BATTAS tool
Biochar yield	%	29	4, 5, 4, 5, 2	BATTAS tool
Nitrous oxide emission	kg	0.003	NA	Literature average
Nitrogen oxide emissions	Kg	10.27	NA	Literature average
Carbon monoxide emission	Kg	1.53	NA	Literature average
Sulphur dioxide emission	kg	2.47	NA	Literature average

Appendix-C: Background data selected

Table A. 3 Background data selected

Electricity	electricity, low voltage, Australian/AU U	AusLCI
Polymer	market for polyacrylamide	Ecoinvent 3.11
Transportation	market for transport, freight, lorry, unspecified, RoW	Ecoinvent 3.11
Phosphorus fertiliser	nutrient supply from monoammonium phosphate, RoW	Ecoinvent 3.10
Nitrogen fertiliser	Inorganic nitrogen fertiliser, as N, nutrient supply from urea, RER	Ecoinvent 3.10
Wastewater treatment	wastewater, average, treatment of wastewater, average, wastewater treatment, RoW	Ecoinvent 3.11