the international water association

CLIMATE SMART UTILITIES

A SHORT IWA GUIDE TO

Greenhouse Gas Emissions and Water Resource Recovery Facilities

Acknowledgments

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Abbreviations

ECAM	Energy Performance and Carbon Emissions Assessment and Monitoring
EPA	Environmental Protection Agency
EPU	Environmental Product Declaration
EU	European Union
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IWA	International Water Association
LCA	Life Cycle Assessment
OEF	Organisational Environmental Footprint
OFWAT	UK Water Services Regulation Authority
PEF	Product Environmental Footprint
SDGs	Sustainable Development Goals
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WRRF	Water Resource Recovery Facility (also referred to as WWTP)
WWTP	Wastewater Treatment Plant
WRI	World Resources Institute

Introduction

As humanity faces the looming challenges of global heating and irreversible tipping points such as increasingly frequent and record-breaking heatwaves and flooding, it is crucial for the water sector to accurately establish baselines and effectively reduce its greenhouse gas emissions (GHG). These actions are integral to global efforts aimed at achieving the critical objective of limiting global warming to within 1.5 degrees Celsius above pre-industrial levels. To date, there is limited guidance available for the water sector to support utilities in comprehensively accounting for and reporting emissions at water resource recovery facilities (WRRFs), which includes both upstream and downstream emissions from wastewater management.

This white paper has been produced by the IWA Climate Smart Utilities GHG sub-group with the aim of providing a concise overview of GHG emissions for utilities and practitioners. It draws upon recent research and publications on the subject, highlighting the relevance of life cycle carbon accounting and wider life cycle assessment (LCA). This paper serves as the first instalment in a series focusing on GHG emissions, monitoring, and mitigation in wastewater treatment.

Emissions of GHG from wastewater management

Accurate reporting of GHG emissions in wastewater management is crucial for global protocols and practices in water treatment plants, including water resource recovery facilities (WRRFs) and residuals management. These protocols consider sectoral, geographical and company boundaries. With progressive water utilities, sectors, and cities aiming for science-based net zero targets, accounting for emissions of GHG emissions from wastewater management is critical.

This concise guide aims to provide an inclusive list of major GHG emissions from WRRFs and wastewater management. Additionally, we outline some of the most effective and emerging practices for quantifying and reporting these emissions. Future papers will focus on monitoring and mitigation strategies that exemplify best practices for addressing these emissions. Further papers will delve into the accounting of GHG benefits, which should be reported independently from GHG emissions.

Accepted definitions of emissions commonly encompass both direct and indirect emissions within categorised as Scope 1, 2, and 3 emissions. These categories are aligned with the global framework for GHG emissions provided by the GHG Protocol, developed by the World Business Council for Sustainable Development and the World Resources Institute. The Protocol collaborates with various stakeholders, including governments, industry associations, NGOs, and businesses, to establish emission measurement and management guidelines. While primarily targeting the private sector, the GHG protocol offers extensive guidance relevant to various sectors, including wastewater management. It provides resources such as calculation tools for Scope 1, 2, and 3 emissions. However, specific guidance tailored to the water sector is currently lacking. Figure 1 provides an overview of these emissions within the same framework, specifically for key WRRF emissions.

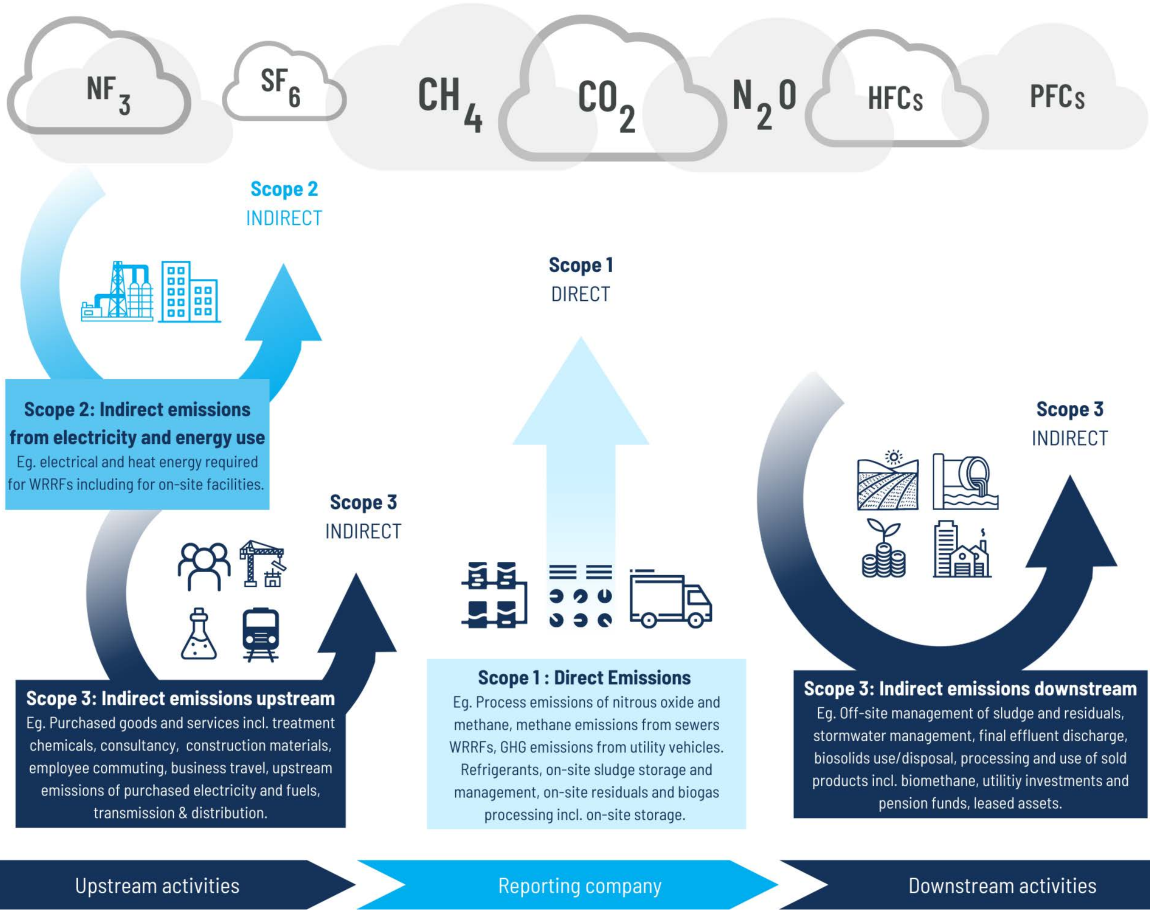


Figure 1 – Examples of activities that fit under Scope 1, 2, and 3 emissions categories under the Greenhouse Gas Protocol.

In light of the risks associated with surpassing irreversible planetary tipping points and the mounting evidence of climate breakdown, it is imperative for utilities and practitioners to report GHG emissions in the most comprehensive manner possible. Historically, the focus has primarily been on Scope 1 and 2 emissions as shown above. However, it is now widely acknowledged that effective climate action based on scientific evidence necessitates collaborative efforts from the water sector to address Scope 1, 2, and 3 emissions, with a strong emphasis on mitigation, as well as adaptation and wider planetary boundaries.

Table 1 below presents the sources for emissions factors (which quantify the amount of pollutant released into the environment resulting from a specific activity or process) and calculations for each key GHG emissions category. A growing number of water and wastewater utilities have aligned their GHG reduction commitments with a specific subset of these categories, such as Scope 1 and 2 emissions only, or Scope 1, 2, and major Scope 3 emissions – such as in accordance with the requirements set out by industry standards like the Science Based Targets Initiative (SBTi™). Key challenges remain in identifying and quantifying major Scope 3 emissions – with closer collaboration within the water sector necessary to demonstrate the leadership required to understand and collectively reduce these emissions.

Table 1 Key GHG emissions with relevance to WRRFs, scopes and useful references for calculation and reporting.

Emissions Category	No.	WRRF area	Examples and remarks	Key references
Direct	1	Sewerage Network	Methane emissions from degradation in network	Excluded from IPCC Guidelines[1].
		WWTPs Sewage Treatment	Direct emissions of nitrous oxide, methane and carbon dioxide[2] from treatment of wastewater including its constituents (grit, screenings, fats, oils and grease). Given variability, these emissions should be measured at WRRF level; global or national EFs are not likely to provide accurate accounting.	IPCC Guidelines[3] for Waste sector provide guidance. Work at country level – for example in France[4], Denmark[5] and Switzerland[6] provides some leading examples of EFs which have been derived using science-based WRRF level monitoring and considerations for GHG reporting.
		Sludge and residuals management	Methane, nitrous oxide, and carbon dioxide emissions due to sludge storage and treatment including biogas use on site and upgrading, tank, valve leaks. On site [7]composting or drying and incineration.	For sludge storage: IPCC guidelines (2019 Refinement, v5, chapter 6) do not provide specific guidance and suggest N_2O emissions should be low and CH_4 can be estimated between 0-10% of production with no literature cited and an estimate of 5% recommended in absence of other information. Limited individual studies to date have quantified EFs of N_2O for sludge management (e.g. Post Aerobic Digestion, biosolids stockpiling) but provide no sector level guidance, similarly for non-biogenic CO_2 from sludge treatment. For biogas handling: Work across multiple WRRFs in Denmark showed 7-8% of biogas production may be emitted in leaks[8]. For other emissions relating to biosolids management, use the references mentioned under Scope 3 below.
		Direct emissions from stationary and mobile sources	Carbon dioxide emissions from sludge, water, and inbound tankers. On site combined heat and power engines, generators using fossil fuels etc. Site Operator vehicle use	2019 Refinement to 2006 IPCC Guidelines Volume 2 – Energy

[1] Methane from sewers is recognised as significant – see the IWA publication and hear from experts in the 2022 IWA Process Emissions Masterclass on methane.
[2] See previous comments on biogenic and non-biogenic carbon.
[3] IPCC Guidelines Chapter 6 provides Waste sector emissions which provides guidance. For constructed treatment wetlands for wastewater treatment, the 2013 Wetlands Supplement provides emission factors.
[4] Filali et al., (2022) Évaluation des émissions de N2O lors du traitement biologique de l'azote en station de traitement des eaux usées (New methods for calculating N2O emissions).
[5] MUDP (2021) Paris model reporting for the water sector in Denmark which includes reference to National N_2O EF and Fredeslund et al., (2022) The Danish National Effort to minimise methane emission from biogas plants.
[6] Gruber et al., (2021) Estimation of countrywide N2O emissions from wastewater treatment in Switzerland using long-term monitoring data
[7] Note that the biosolids management activities that occur outside the boundaries of the utility have to be reported under Scope 3. Therefore depending on the specificity of the utility, the emissions related to composting, drying and incineration, or even land application could be considered Scope 1 or Scope 3
[8] Total methane emission rates and loses from 23 biogas plants is reported here by Scheutz & Fredenslund (2019).

Emissions Category	No.	WRRF area	Examples and remarks	Key references
		Refrigerant use	Leaks from use of refrigerants and coolants	Refinement to 2006 IPCC Guidelines Volume 3 – Industrial Processes and Product Use, Chapter 7 – Emissions of Fluorinated Substitutes for Ozone Depleting Substances.
Indirect	2	Emissions from electricity and energy use	Emissions related to electricity, heat and steam consumption, if this energy source is produced from fossil fuels.	2019 Refinement to 2006 IPCC Guidelines Volume 2 - Energy.
Other – indirect emissions*	3	Materials – operational GHG emissions related	Production and distribution of chemicals used for treatment and other materials (e.g. fuels for transport not in Scope 1)	IPCC Guidelines Volume 3 – Industrial Processes and Product Use, Chapter 2 Mineral Industry Emissions (not amended in 2019 Refinement)
		Materials – capital carbon GHG emissions related	Construction of new assets - construction materials	2006 IPCC Guidelines Volume 3 – Industrial Processes and Product Use, Chapter 2 Mineral Industry Emissions (not amended in 2019 Refinement)
		Services	Purchase of goods and services - including financial flows (e.g. pension funds, retirement accounts) and financed emissions	GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard provides references for multiple value chain emissions and the GHG Protocol Product Life Cycle Accounting and Reporting Standard.
		Employees	Employee business travel and personal commuting	2019 Refinement to 2006 IPCC Guidelines Volume 2 – Energy
		Discharge to waterbody	Final effluent (treated or untreated) discharge to receiving waters. It includes N_2O and CH_4 emissions but, to date does not account for dissolved N_2O and CH_4[9]. . Includes stormwater discharge to receiving waters from the wastewater treatment infrastructure.	Final effluent discharge may be Scope 1 or 3 depending upon boundaries of assessment and whether city-based GHG accounting or utility. IPCC 2019 Refinement to 2006 Guidelines Volume 5 Chapter 6 – Wastewater Treatment and Discharge for final effluent (e.g. Tables 6.3 and 6.8a).
		Off site management of residuals	Includes application of biosolids to land off-site, off-site incineration etc. Off-site waste management and disposal including packaging, electronics, wastewater screenings, grit, ash, chemicals etc.	For application of biosolids to land, refer to IPCC 2019 Refinement to 2006 Guidelines Volume 4 – Chapter 11 (N_2O emissions from managed soils…). For incineration, refer IPCC 2019 Refinement, Volume 5, Chapter 5 (Solid Waste). For all other solid waste disposal (including composting), refer IPCC 2019 Refinement, Volume 5, Chapter 3 (Solid Waste).

[9] *Other indirect emissions from wastewater treatment but occurring from outside control or ownership of company/city boundary These are divided into reported upstream and downstream Scope 3 emissions in reporting protocols. However, recent work by Filali et al. (2022) for the French water sector highlight the significance of dissolved fractions and need to further consider these.

Considerations on Biogenic Carbon

It is worth noting that carbon dioxide emissions from WRRFs, which include both upstream and downstream emissions from wastewater management, have predominantly been classified as biogenic and thus not mandatorily reported. However, it is crucial to consider the inclusion of fossil-based carbon associated with biological nutrient removal and the presence of fossil-based carbon in personal care products that are flushed into sewers. These factors contribute to the production of non-biogenic carbon dioxide during wastewater treatment and should be given due consideration. The 2019 Refinement to the IPCC 2006 Guidelines acknowledges the emerging evidence indicating that wastewater contains a notable but highly fluctuating proportion of non-biogenic carbon derived from fossil fuel sources. The IPCC references indicate a range of 4-14%, although some measurements have reported even higher percentages (refer to 2019 Refinement Appendix 6A.1).

This non-biogenic carbon is believed to originate from the usage of petroleum-based products such as cosmetics, pharmaceuticals, surfactants, detergents, and food additives. As a result, when reporting GHG, it is important to consider a site-specific percentage representing the contribution of total carbon dioxide emitted during treatment that is derived from non-biogenic sources. In the current GHG accounting practices adopted by utilities, the biogenic fraction of carbon dioxide generated in WRRFs is typically not included. However, it is worth noting that this predominantly biogenic carbon dioxide can still be considered for carbon capture, storage, utilisation, or sequestration purposes. Utilities can account for the captured CO_2 from point source emissions such as biogas upgrading, combustion, or biosolids incineration to support projects that yield carbon-related benefits (e.g., through emission avoidance or sequestration). Several important factors should be taken into account, including the ultimate use and long-term viability of CO_2 capture and storage, as well as ensuring consistency in accounting methodologies across different projects and utilities.

Reporting GHG emissions

Reporting of different GHG emissions is required at both utility and country levels. The United Nations Framework Convention on Climate Change (UNFCCC) provides reporting guidelines for Parties, which are outlined in Annex I of the Paris Convention. These guidelines require Parties (countries)to report their annual GHG emissions and removals across five sectors: Energy; Industrial Processes & Product Use; Agriculture; Land Use, Land-use changes, and Forestry; Waste. Emissions related to municipal wastewater management are reported within these sectors. For instance, process emissions of nitrous oxide and methane, categorised as Scope 1 emissions, are reported in Section 5D (Waste) emissions. The reporting follows standardised formats in line with UNFCCC guidelines.

In line with global best practice and the framework set by the Paris Agreement, the quantification of GHG emissions from wastewater management should follow inventory methods outlined in the Intergovernmental Panel on Climate Change (IPCC) Guidance. Specifically the 2006 IPCC Guidelines and the 2019 Refinement to these guidelines, as highlighted in Table 1, should be used. As noted, key GHG reporting guidance has been developed over the past two decades by the GHG Protocol. This protocol establishes comprehensive and standardised global frameworks to measure and manage GHG emissions across private and public sector operations, value chains and mitigation actions. However, specific guidance tailored to the water sector remains limited. For more background on Scope

1, 2 and 3 emissions from the urban water cycle, refer to another 2022 IWA publication, "Reducing the Greenhouse Gas Emissions of Water and Sanitation Services: Overview of emissions and their potential reduction illustrated by utility know-how". The recent Nordic Principles publication "The road towards a Nordic climate neutral water sector" published by Danish, Finnish, Swedish and Norwegian water industry organisations, also provides a comparative basis for current GHG accounting methods across countries, including both emissions and avoided emissions or emissions that may be substituted in other value chains. It identifies principles for collaboration and sharing.

The Energy Performance and Carbon Emissions Assessment and Monitoring tool (ECAM) is an open-source tool based on IPCC and the emerging science-base. It empowers water and wastewater utility operators to assess their Scope 1, 2 and some Scope 3 greenhouse gas emissions. Among other applications, ECAM can be used as a decision-making tool for planning urban wastewater systems, especially in smaller municipalities. With the opportunity to incorporate country-specific emissions considerations (e.g. energy mix), ECAM can calculate GHG emissions for different scenarios, allowing comparisons across the urban water cycle.

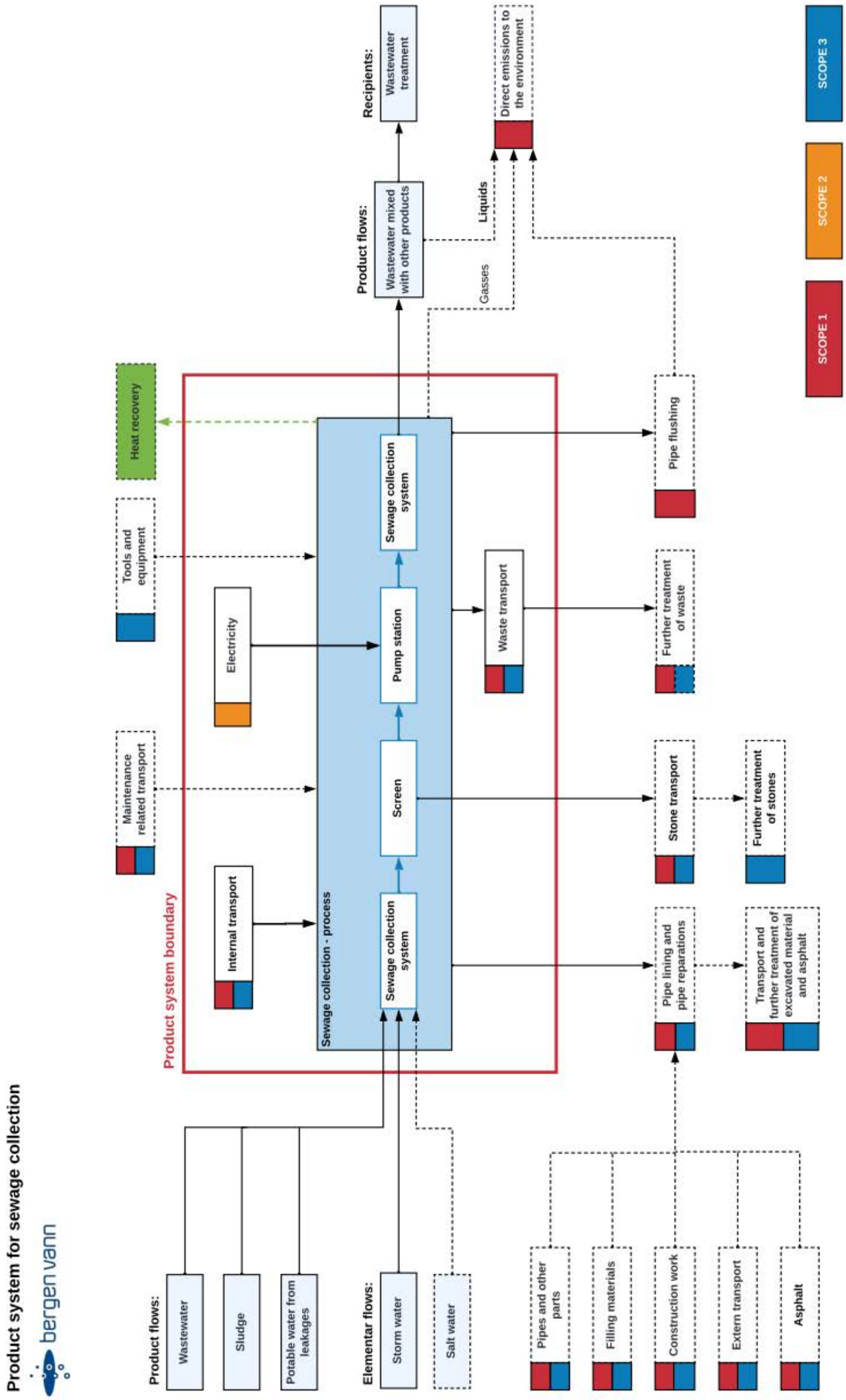
Example Good Practice GHG Emissions Reporting

Traditionally, water utility footprints from wastewater management have primarily concentrated on reporting Scope 1 and 2 emissions. However, as progressive utilities embrace science-based targets, such as those established by the SBTi™, and adopt life cycle carbon management approaches for infrastructure (e.g. the recently revised PAS2080), there is a growing emphasis on including Scope 3 emissions. We present two examples from leading utilities that demonstrate how reporting boundaries and scopes can be clearly defined and reported. Figure 2 shows *Bergen Wate*r's scope diagram for assessing the carbon footprint of their water resource recovery facility.

Figure 3 shows emissions reporting by *Aarhus Vand* for their annual report in 2021. It shows the separate reporting of "avoided emissions", which is considered the current best practice, instead of combining them with Scope 1, 2 and 3 emissions. It is important to note that the reported (short cycle) carbon emissions avoided through afforestation for groundwater protection only include afforestation specifically carried out in drinking water catchments for source protection (in this case groundwater), not all afforestation activities undertaken by *Aarhus Vand*.

Avoided emissions, carbon removals (such as through sequestration) and their connection to resource recovery and environmental product declarations will be briefly discussed later in this white paper. Standard approaches and frameworks for these aspects are still under development. However, it's crucial to highlight that science-based GHG reporting and climate scientists worldwide emphasise the importance of reducing emissions. This should be the primary focus for water utilities.

Figure 2 Carbon Footprint Product System for Wastewater Treatment by Bergen Vann[10]



[10] Bergen Vann is a utility based in Norway. Discover their climate smart story and see more of their urban water product system diagrams here: iwa-network.org/climatesmartstory-bergen-water

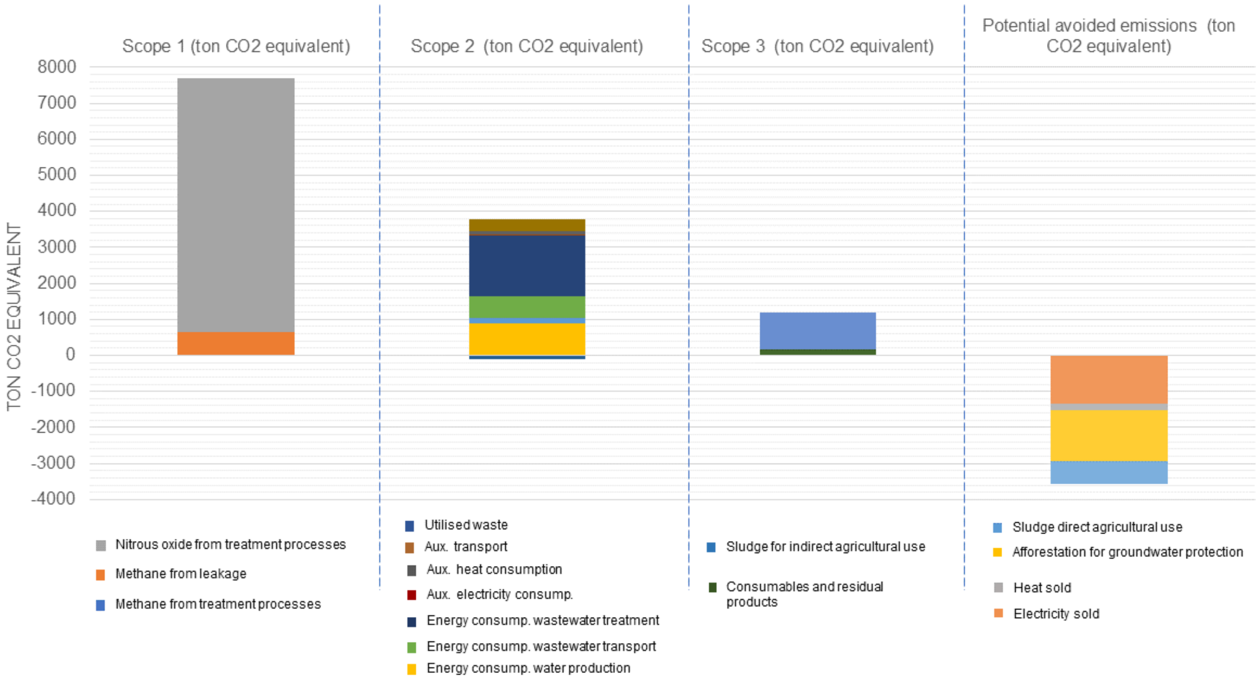


Figure 3 – GHG emissions reported for 2021 by Aarhus Vand [11]

Importance of Scope 1 Process Emissions of N_2O and CH_4

The IPCC guidelines support reporting at the country level by using established global emission factors (known as Tier 1 emission factors) and providing guidance for developing national (Tier 2) or facility specific (Tier 3) emission factors. While some emission factors can be accurately quantified, others, particularly Scope 1 Process Emissions of nitrous oxide (N_2O) and methane (CH_4), are more challenging to quantify accurately.

The IPCC Guidelines acknowledge the importance of countries progressing towards country-level (Tier 2) emission factors, which should be informed by facility-level (Tier 3) assessments to ensure precise quantification of these emissions. This requires facility level monitoring, with specific focus on direct process emissions of N_2O and CH_4. For a detailed guide on quantifying direct process Scope 1 emissions from wastewater treatment, see the 2022 IWA publication titled "Quantification and modelling of fugitive greenhouse gas emissions from urban water systems".

There are increasing examples in wastewater management where a science-based approach is used to accurately quantify emissions at Tier 2 and Tier 3 levels. For example, the Danish Environmental Protection Agency developed a monitoring programme that enabled facility-level monitoring to establish a national emission factor for N_2O (Tier 2)[12]. The aim is to utilise either facility-level monitoring (Tier 3) or this derived factor (obtained from the EPA funded monitoring programme across 9 WRRFs) to report emissions for utility assets, as outlined in their Guidelines for reporting in line with Paris model for a climate-and energy-neutral water sector.

[11] Aarhus Vand is a utility based in Denmark. Discover their climate smart story and access the diagram at: https://iwa-network.org/climatesmartstory-aarhus. Refer to the IWA Climate Smart Utilities case stories for more examples and resources from utilities worldwide iwa-network.org/projects/climate-smart-water-utilities

[12] This compiled results from 9 monitoring campaigns; ongoing work at some larger sites and over longer period has highlighted higher emissions and is likely to lead to revision of the derived N2O EF. See the original programme report mst.dk/service/publikationer/publikationsarkiv/2020/dec/mudp-lattergaspulje-dataopsamling-paa-maaling-og-reduktion-af-lattergasemissioner-fra-renseanlaeg/

At the country level, Sweden showcases a Tier 3 methodology through a voluntary biogas (CH_4) monitoring programme, although it is not mandated in national guidelines. This programme is used to baseline and reduce emissions.[13] In terms of national progress at Tier 2, a national emission factor as derived by Fredeslund et al. (2023) based on measurements at 69 biogas facilities in Denmark, representing 59% of Danish biogas production. A recent Swiss study by Gruber et al. (2021) examined N_2O emissions from WRRFs, providing estimates and recommendations for enhancing N_2O emissions reporting. This study also served as a foundation for developing mitigation instruments at the federal level.

At a pan-European level, Wechselberger et al. (2023) used a harmonised approach for estimating Scope 1 CH_4 losses across 33 European biogas plants. Parravicini et al. (2022) quantified sector level GHG emissions and identified mitigation opportunities across all scopes, using the best available scientific evidence for Scope 1 emissions across different WRRF types. Country and facility-level methodologies are essential for ensuring accurate national inventory assessments. They play a crucial role in demonstrating the impact of wastewater utility interventions on reducing GHG emissions.

Opportunities for life cycle assessment – beyond GHG emissions

Life cycle assessment (LCA) is an established tool for evaluating the environmental impacts and sustainability of products, services, and systems. It offers water utilities the ability to understand the carbon footprint and wider sustainability impacts of their wastewater management activities.

We are seeing water utilities starting to apply LCA approaches in combination with multi-criteria decision-making processes that consider cost and societal factors. While LCA can be used to quantify GHG emissions in a structured, standardised approach, it has far wider opportunities and is an emerging holistic approach that can well support the decision making required in the water sector.

LCA typically comprises 4 distinct phases (i) Goal and Scope (ii) Life Cycle Inventory (iii) Impact Assessment, and (iv) Interpretation (Figure 4). Life cycle assessment, at an international level, is underpinned by ISO 14044:2006 (last reviewed and confirmed in 2022) and for organisations by ISO 14072.

[13] See discussion of the programme here www.europeanbiogas.eu/wp-content/uploads/2020/10/Minimum-requirements-for-European-voluntary-systems.pdf

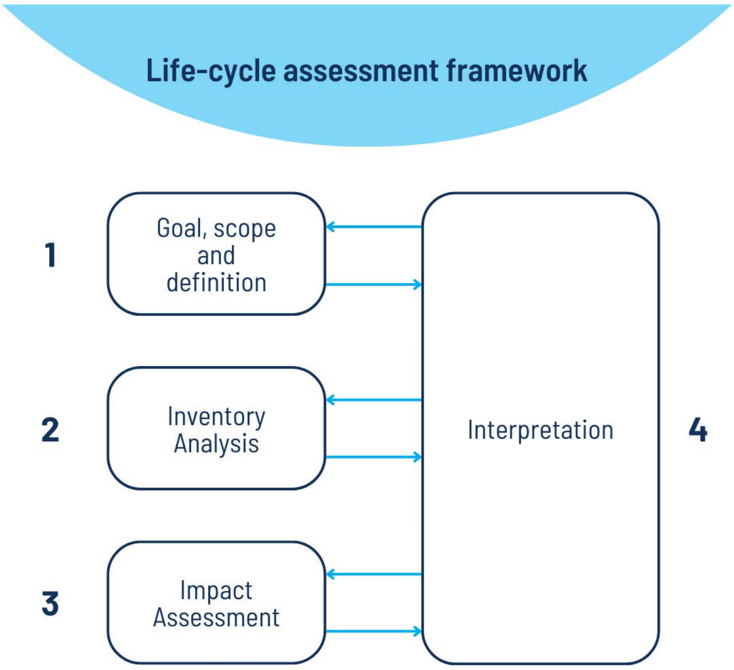


Figure 4: The four stages of Life Cycle Assessment

These standards are supplemented by general international guides such as the International Reference Life Cycle Data System, which provides consistent and accurate methods and assessments for life cycle data. The development of standard measurement methods for sustainability in the construction sector (e.g. EN15978) and the EU-led environmental product declaration (EPDs) (EN15804 – with +A1 and +A2 revisions) particularly impact the civil engineering and construction sector, as well as supplying sectors. The revision to EN15804 (+A2) aligned these standard-based environmental product declarations with the product environmental footprint formats, which provide a broad measure of the environmental performance throughout the life cycle of a service or product. These approaches can be adopted or leveraged internationally to enable utilities to quantify construction and operational emissions and evaluate product life cycles as part of procurement processes. Currently, the use of EPDs is voluntary, but it is increasingly demanded by both public and private sector stakeholders and supports procurement processes focused on more sustainable solutions.

Examples of LCA and wastewater management

Utilities are increasingly recognising the need to apply LCA in order to quantify greenhouse gas emissions associated with decision making and to assess environmental impacts beyond GHG, including critical sustainability trade off considerations. In combination with cost and societal impacts, LCA can be used to support effective decision making and design. LCA can offer a more holistic assessment which, combined with inclusive, multi-stakeholder decision making, provides utilities with an effective means of achieving their vision and aspirations. This includes alignment with UN SDGs, science-based net zero targets, and delivering value and safety for citizens. While meeting GHG emissions targets and environmental regulatory compliance will remain important concerns for utilities, life cycle assessment can be a powerful tool for evaluating overall impacts at facility or utility level and modelling the potential impacts of sustainability initiatives. LCA also provides a framework for modelling the potential benefits associated with resource reuse within the sector (e.g. carbon benefits of sludge to energy) or outside the sector (e.g. nutrient and carbon benefits in nutrient reuse).

While LCA has not yet been widely adopted in this sector so far, whether for analysing greenhouse gas emissions alone or for assessing wider sustainability impacts, the IWA Working Group on LCA for water and wastewater treatment has recently published best-practice guidance on the application of LCA to wastewater treatment (Corominas et al. 2020). Emerging examples include Risch et al. (2021) who assessed the overall environmental performance of decentralised versus centralised wastewater treatment systems in two case-study towns in France. The study also investigated the use of different technologies in each scenario, providing a guideline for such analysis. In a recent EU-level wastewater infrastructure assessment, Parravicini et al. (2022) used life cycle carbon assessment approaches to estimate GHG emissions and reduction strategies at the EU level. They concluded on the importance of on-site energy efficiency, methane recovery, and reduced nitrous oxide emissions through nitrogen removal. There have also been targeted studies analysing the use of societal life cycle assessment approaches in the wastewater sector. For example, García-Sánchez and Güereca (2019) studied the environmental and social impacts on water system workers in the Mexico City water system. These approaches are relatively new and subject to ongoing development. LCA can be combined with life cycle costing (LCC) to support green procurement decisions and to model environmental and economic impacts of proposed upgrades to process, infrastructure or systems, and operational changes. For example, (Faragó et al., 2021) modelled the additional environmental and cost impacts of retrofitting resource recovery and highlighted the importance of nitrous oxide control as the greatest mitigation measure for climate change impacts.

It is important to recognise that LCA is a complex process, particularly at the utility level. Currently, it may be more applicable for analysing individual facilities or specific parts of a utility operation, as well as supporting sustainable procurement and investment decisions. The accurate quantification and subsequent reduction of greenhouse gas emissions are critical initial steps that have not been consistently or accurately implemented across utilities. This paper aims to support these efforts. It is crucial for the water sector to adopt accurate GHG reporting and utilise approaches like LCA for a more comprehensive assessment of impacts. These approaches will become increasingly interconnected moving forward.

Carbon Tunnel Vision: Advantages and limits of the carbon footprint approach versus wider LCA and beyond

While reducing GHG emissions is often a primary focus of utility policies in response to climate change, life cycle assessment allows utilities to evaluate their impacts from a broader Perspective, considering environmental and societal aspects. This approach aligns with more holistic aims and frameworks such as the UN SDGs and the concept of planetary boundaries.[14] In many cases, these considerations intersect with climate change, and trade-offs may need to be considered. For example, reducing N_2O emissions may lead to increased energy consumption and additional GHG impacts in certain cases, while on the other hand, it may also result in emissions reductions.

Achieving GHG emission reductions for N_2O may also require investments in monitoring, optimisation solutions, new technologies, and additional resources for upskilling and enhancing asset health. The SDGs encompass societal and systemic attributes and challenges that must be acknowledged by the water sector. It is crucial to recognise the risks associated with a narrow carbon tunnel vision and to embrace wider societal and systemic changes in the sustainability transition (Figure 5).

[14] As developed by the Stockholm Resilience Centre – see https://www.stockholmresilience.org/research/planetary-boundaries.html

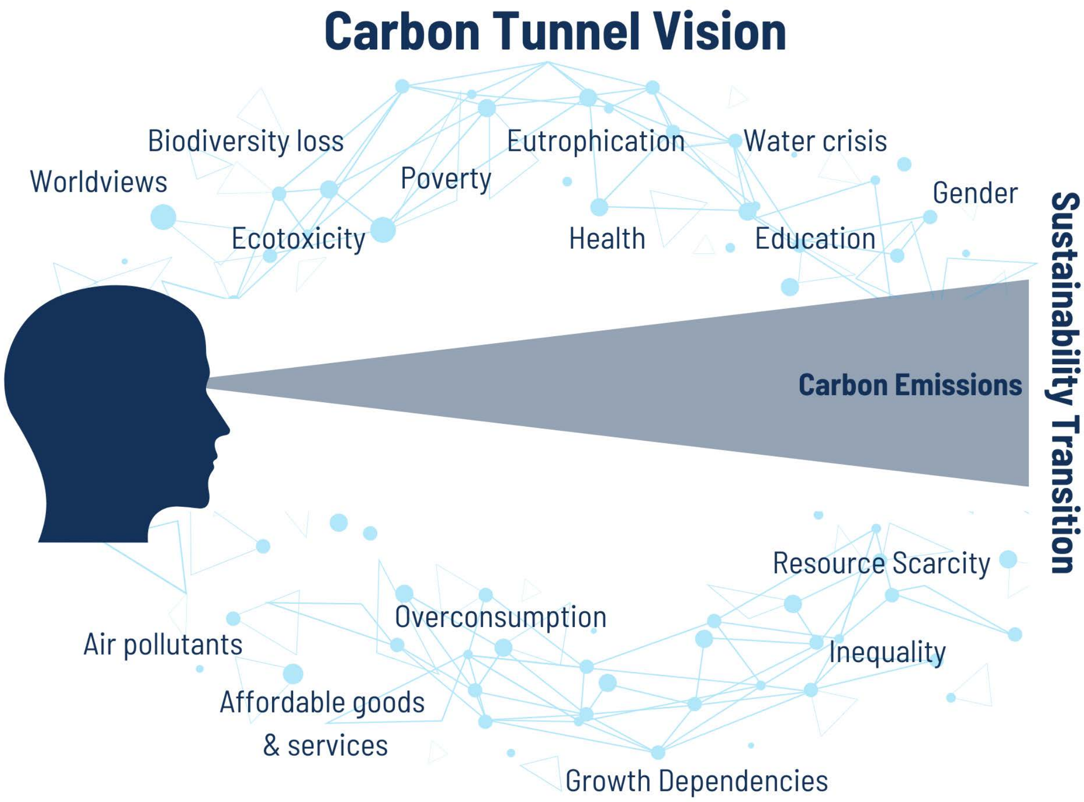


Figure 5: Risks of Carbon Tunnel Vision - adapted from figure by Jan Konietzko (Cognizant, 2021)

Beyond GHG emissions, and in addition to typical economic cost implications of decisions, it is crucial to consider factors such as social justice, equality, gender, consumption patterns, societal norms, ideologies and indigenous wisdom. When combined with participatory decision-making processes, addressing the risks associated with carbon tunnel vision becomes more feasible, leading to best societal outcomes. This should be an immediate goal for water utilities. However, achieving this goal still relies on accurate quantification and reporting of GHG emissions from WRRFs and the wider water cycle, as these data inputs are essential.

Greenhouse gas emissions and their broader impacts are now being tied to financial policies, as exemplified by the European Union Green Deal's emphasis on sustainable finance. Sustainable finance involves considering environmental, social, and governance aspects when making investment decisions. It aligns strongly with both GHG quantification broader LCA approaches.

Avoided emissions and carbon accounting for climate neutrality

In the process of carbon accounting, It is important to consider the broader role of wastewater management and WRRFs in analysing the potential for avoided emissions or the production of products and other benefits from the system (Li at al., 2020). For example, a WRRF can generate products or outputs that can replace those available in the market, such as nutrients, reused water or energy. Additionally, the WRRF can contribute to overall societal emissions reduction by treating wastewater instead of releasing raw wastewater into the environment. Furthermore, WRRFs can undertake upstream catchment restoration and regeneration efforts, which help avoid GHG emissions.

Emissions can be avoided in utility production through the use of other forms of renewable electricity such as solar and wind power generated within utility properties.[15] These carbon benefits may be accounted for within utility reporting boundaries or may be associated with downstream or upstream emissions.

Under current corporate reporting guidance, utilities are required to separately report avoided emissions and carbon credits or benefits, rather than combining them or 'netting off' their impact. This approach ensures a clear focus and accurate accounting of emissions reductions.

However, the use of avoided emissions still requires further research and standardisation. The World Resources Institute Greenhouse Gas Protocol has published a working paper that outlines the uncertainties and challenges associated with avoided emissions (WRI, 2019). These challenges include varying practices in measuring the impacts of products, the lack of frameworks for reporting comparative impacts, and the need to both report negative as well as positive impacts. In this context, the European Union has recommended the use of Environmental Footprint methods to systematically calculate environmental performance. Product Environmental Footprint (PEF) and Organisational Environmental Footprint (OED)[16] are important steps in establishing consistent methods for allocating environmental burdens and credits to suppliers and users of recycled materials, as well as energy resources.

For example, under emerging EU EPD guidance, avoided emissions can be attributed as 'credits' in life cycle analysis to the water utility and/or the downstream user, such as a farmer using sewage sludge biosolids or recovered nitrogen fertiliser. However, it is important to note that the use of such credits, which can be referred to as carbon offsets or carbon insets depending on their purpose, is not permitted under science-based reporting frameworks. Additionally, the definition and application of carbon insets have been limited thus far. Irrespective of who benefits from the GHG reduction, such benefits should be considered and included in life cycle analysis comparisons.

In conclusion

We are confronted with an urgent need to mitigate GHG emissions and adapt to the present and future impacts of climate change. Achieving net zero is imperative for all sectors, utilities, and society as a whole. Taking action in the water sector is crucial, and in this paper, we have presented emerging best practices and key considerations in GHG accounting and reporting. Furthermore, we showcased inspiring case studies of utilities actively engaging with their catchments and communities to mitigate and adapt to climate change, including those recognised by the IWA's Climate Smart Utilities initiative at iwa-network.org/projects/climate-smart-water-utilities

[15] The purchase of renewable energy is not covered here but reference should be made to the hierarchy of renewable energy procurement, with self-generation and supply from onsite renewables preferential to signing a power purchase agreement (PPA) with local supplier and at bottom (least preferable), a 100% renewable electricity tariff with an electricity retail supplier. Read more about the hierarchy: https://www.ofwat.gov.uk/publication/net-zero-technology-review/

[16] Refer to https://ec.europa.eu/environment/eussd/smgp/pdf/EF%20simple%20guide_v7_clen.pdf for more details.

It is of utmost importance to explore climate action opportunities both upstream in catchments and downstream through resource recovery, while also considering the wider systemic impacts and the need for change. Both mitigation and adaptation are critical - as we confront uncomfortable realities of a *rapidly* closing (if not closed) window of opportunity to limit global warming to 1.5 degrees Celsius.

In order to connect action and effort, we must establish a clear, science-based understanding of GHG emissions throughout the urban water cycle. This understanding will enable us to support the mitigation required, focus on reducing these emissions and prioritise urgent global action required of us. Together, as water sector professionals, at utility, city, and country levels, we have the power to take decisive steps in shaping the future we need – and one that we can be proud to leave to future generations.

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Climate Smart Water https://climatesmartwater.org/

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IWA Climate Smart Utilities Initiative

Urban water management is one of the urban services most affected by the impacts of climate change, which threatens the capacity of service providers to deliver safe water, protect rivers and oceans, as well as protect people and assets from flooding, in alignment with the SDGs. Utilities need to increase their resilience to the impacts of climate change to improve or maintain service levels. While water, sanitation and urban drainage utilities are the cornerstone of cities' climate adaptation strategies, they can also contribute up to 15% to their cities' greenhouse gas (GHG) emissions. Utilities can take action towards global decarbonisation. Explore our **resources for water, wastewater, and urban drainage companies** to improve climate resilience by adapting to a changing climate while contributing to significant and sustainable reduction of carbon emissions. Practitioners can join our **community of practice** around adaptation and mitigation to climate change to support bridging science and practice and trigger the necessary cultural shifts and actions.

IWA Specialist Groups

IWA offers a range of Specialist Groups (SGs) for members to join, and participate in. SGs are IWA's central programme for encouraging interaction, debate and innovation on scientific, technical and governance topics. SGs allow like-minded specialists to build communities focused on specific water related topics, connect with others in the sector and pool expertise. Spread across IWA's membership in more than 140 countries, the IWA Communities reflect the breadth and depth of the water sector globally. Specialist Groups are an exceptionally effective means of international networking, sharing information and skills, and making good professional and business contacts.

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