Business guidance on the assessment of wastewater-related impacts

Contents

Executive summary

Untreated or partially treated wastewater poses a major threat to the quality of the world's freshwater resources and causes negative impacts on human health, ecosystems and biodiversity, economic activity and global development. Industrial wastewater is part of the broader wastewater issue. Therefore, business action driven by understanding and managing the impacts is critical to addressing this situation.

This Business guidance on the assessment of wastewater-related impacts provides a standardized pathway for companies to measure, value and manage the impacts from wastewater generated by their sites or the sites of their suppliers. It builds upon existing knowledge and resources and companies can apply it in combination with other tools and initiatives.

The outputs of the application guidance can provide decision-making support to companies as they navigate action to manage wastewater impacts. It can be a crucial input for enterprise risk management, helping to understand the impacts of the business on different stakeholders and business risks and opportunities, and to compare options. Companies can also use the guidance to report and disclose their wastewater-related impacts in line with reporting and disclosure standards.

WBCSD has designed the business guidance for application at the level of an industrial site that generates wastewater. Companies can apply it with other developing or existing initiatives and frameworks, including the Science Based Targets Network's (SBTN) freshwater guidance. It is an application of the Natural Capital Protocol; it aligns with the Protocol conceptually and in terms of terminology and provides specific guidance to companies on how to account for their wastewater-related impacts, set targets and manage them.

The application of the guidance can be effort- and resource-intensive for companies. Therefore, it is important for companies to ensure that they have the necessary strategic oversight and the business commitment to do so. In addition, companies should have conducted the initial screening exercises to prioritize sites before applying the guidance.

The application guidance provides a 4-step process for companies to understand, value and manage their wastewater-related impacts: (1) measure the impact driver; (2) measure changes in the state of natural capital; (3) quantify impacts and (optional) value impacts; (4) set targets and (5) manage impacts. For each of the five steps, it explains the key principles companies should apply, the sources of data, models and methodologies they should use and the key outputs they can expect to have.

We provide a high-level impact pathway diagram linking the key industrial activities with the impact drivers and possible impacts related to wastewater generation and discharge. Companies using the business guidance should customize the impact pathway diagram to their own operations and needs.

Companies can apply the business guidance in combination with version 1 of the Wastewater Impact Assessment Tool (WIAT), which is being released in parallel with the business guidance. The WIAT automates part of the process of applying the guidance by incorporating methodologies and generating outputs that measure some of the changes in the state of natural capital, which companies can then use to further assess the impacts and their value.

Measuring impacts, assessing their value and taking action to manage them is central to water stewardship. It benefits the business by de-risking operations and creating new opportunities. As the impacts of wastewater management get more attention, **the use of the business guidance will help companies prepare for upcoming developments in impact assessment and disclosure.**

1 Introduction

① Introduction

Good water quality is essential to human health, ecosystems and social and economic well-being. Increasing economic activity has put tremendous pressure on the world's freshwater resources, deteriorating them in terms of both quantity and quality. Poor water quality and water pollution impact human and ecosystem health and pose risks for various economic actors, including businesses. A major part of the solution lies in managing wastewater better.

WASTEWATER HAS VAST UNTAPPED POTENTIAL AND BUSINESS HAS AN IMPORTANT ROLE TO PLAY

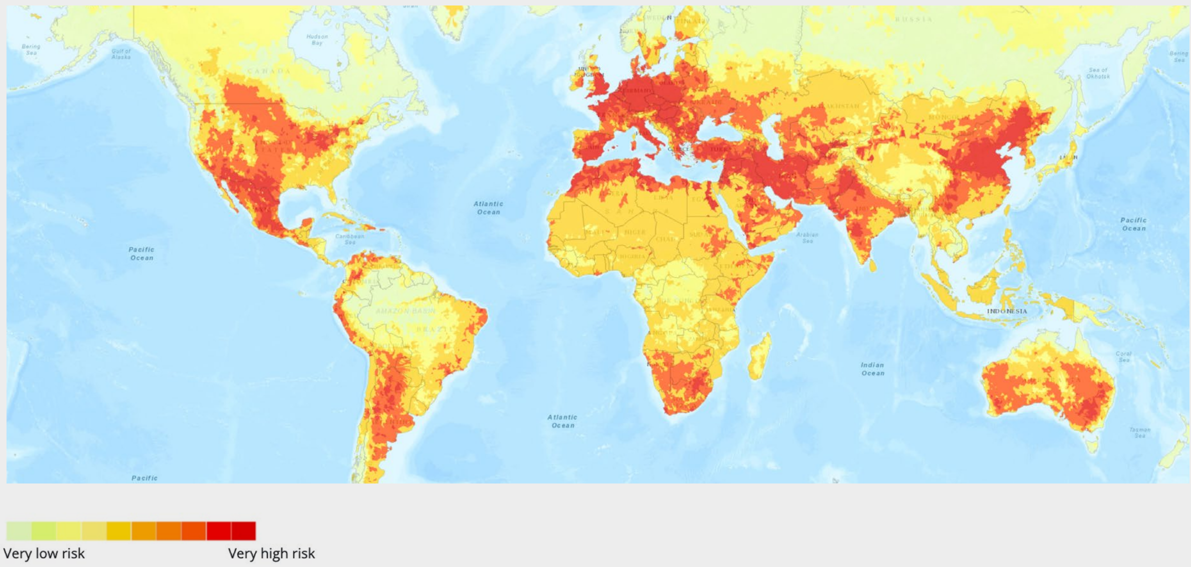
Globally, it is estimated that users discharge about 80% of all wastewater back into the environment untreated.[2] This is happening when demand for sufficient and safe freshwater from all sectors is rising and the world is struggling to meet the targets of Sustainable Development Goal (SDG) 6: Clean water and sanitation for all.

Wastewater has huge untapped potential in serving as a reliable alternative source of water while generating energy, nutrients and other useful by-products:

- Irrigation with reclaimed and treated wastewater, for example, can be one of its most important uses.
- Decentralized wastewater treatment on-site to remove the bulk of its organic material at the point of use can significantly reduce energy use and greenhouse gas (GHG) emissions, support energy production and provide an alternative freshwater source for industries.[3]
- On-site wastewater treatment can be a means for industries to control issues and expenditures related to discharge permits and the associated public perceptions.

Box 1: Global map of water quality risk obtained from the WWF Water Risk Filter[1]

The map indicates the deteriorating state of quality of the world's freshwater resources. It takes into account parameters with well-documented direct and indirect negative effects on water security for both humans and freshwater biodiversity, which are aligned with Sustainable Development Goal (SDG) 6.3.2 – Biological Oxygen Demand, Electrical Conductivity and Nitrogen – and pose a risk for business operations.



This potential goes beyond addressing human and environmental health, with implications for food and energy security and climate change mitigation and adaptation. A circular approach is therefore the best strategy for wastewater management.

Industrial wastewater is part of the broader wastewater issue. Untreated or partially treated wastewater presents risks to business in the form of fines, mandatory clean-up costs and reputational damage. Policy and societal pressures in recent years have led to a growing movement for industry to reduce its wastewater and treat it before discharge. However, industry efforts are still insufficient in addressing the issue of wastewater pollution. The world's freshwater systems face critical threats from industrial activity, including metal contamination, plastic pollution and eutrophication, most of which relate to the discharge of untreated or insufficiently treated wastewater discharged by industries.[4]

According to the analysis of answers to a water security questionnaire from 2,934 companies that reported information on their water risks, impacts and associated responses and strategies for CDP's 2020 Global Water Report, businesses still underappreciate and underestimate the issue of water quality. Not all companies monitor the quality of their wastewater discharges, while less than 5% are setting and reporting progress against water pollution reduction targets.[5]

The lack of data and transparency in reporting and the absence of stringent national and local regulations for industrial wastewater treatment are reasons for the slow progress.

MARKET RETURNS CAN DRIVE STRICTER ACTION WHILE MAXIMIZING POSITIVE IMPACT FROM WASTEWATER

Wastewater discharge from industries causes impacts on human and ecosystem health, such as GHG emissions, the discharge of nutrients or toxic compounds into freshwater bodies, etc. These impacts create externalities for other actors that generate hidden environmental, health and socio-economic costs. The natural, social and human capital connections of wastewater mean that everyone, everywhere bears the burden of these externalities but more so society's most disadvantaged populations.

If industries internalize the externalities generated by wastewater, they gain from winning stakeholder confidence, controlling their operational costs and securing their legal and social license to operate. Such value returns have the potential to drive better action on wastewater treatment and maximize the potential of resource recovery from wastewater. Given the significant but underappreciated potential of wastewater, it is important to understand the impact of wastewater in clearer economic terms.

STANDARDIZED APPROACHES ARE KEY TO DRIVING IMPACT

Businesses require standardized and practical tools to measure and value the impacts caused by their operations, including from wastewater discharge. This business guidance **provides a standardized pathway for companies to understand, value and manage their wastewater impacts.** It builds on existing knowledge and resources for impact assessment and applies them to wastewater.

The aim is to:

- Elevate the issue of industrial wastewater as a source of impact and a potential opportunity to deliver positive value.
- Provide a guide for businesses to assess the impacts from wastewater in economic terms.
- Offer an approach for other stakeholders, such as investors and policy-makers, to improve transparency and drive better business action on wastewater.

2 About the business guidance

② About the business guidance

WHO IS IT FOR?

The business guidance is for all companies that generate wastewater as part of their direct operations and supply chains. Companies with the largest wastewater-related impacts in their supply chains can encourage the application of the guidance to a part of their supply chain (characterized based on the type of process or nature of effluent, etc.) and use the results as a proxy for that part of their supply chain.

The outputs of the business guidance can provide decision-making support to companies as they navigate their wastewater impacts. Companies can also use the guidance to report and disclose their wastewater-related impacts in line with reporting and disclosure standards.

It can also be useful for investors to understand where major impacts from wastewater are and what the true economic value at stake is because of these impacts. Investors can use this guidance to inform their investment decisions (See Box 2).

WHY USE THIS BUSINESS GUIDANCE?

Businesses face pressure from governments, investors, customers and civil society to disclose information on environmental, social and governance (ESG) impacts. As wastewater represents a major area of business activity impacts, companies should measure those associated with wastewater and address them.

Further, with ongoing developments in non-financial capital accounting, such as from the Taskforce on Nature-related Financial Disclosures (TNFD) framework, it may soon be mandatory for companies to report on the impacts from their activities in clearer economic terms.

This business guidance:

1. Helps companies understand and measure the impacts caused by their wastewater-related activities, set targets and manage them. It also helps them understand the key principles for valuing the impact in qualitative, quantitative and value (monetary) terms and use these values to understand the business case for action.
2. Helps companies prepare for future reporting and disclosure requirements that assess the economic value of the company's impacts on ESG indicators.

The assessment and valuation of impacts, including from wastewater, can also be an important approach to enterprise risk management. Among others, it can help companies understand their risks and opportunities, recognize impacts on different stakeholders, and make sound management decisions.[7]

Box 2: Financial implications of addressing water-related externalities

In its recent financial materiality briefs, Ceres, the non-profit organization working with the world's most influential capital market leaders, highlights the magnitude of costs to consider in addressing water-related externalities by some of the world's largest and most polluting industrial sectors. The apparel sector brief[6] places the total annual expenditure in the range of approx. USD $190 million to USD $1.8 billion for large apparel firms, with the externalities associated with wastewater discharge from yarn preparation and processing as the costliest. These annual costs have a significant impact on the valuation of the apparel firms and are therefore critical in investment decisions. The importance of understanding the water-related impacts for investors is clear, as is their need to encourage companies to inform their operational costs to deal with these impacts.

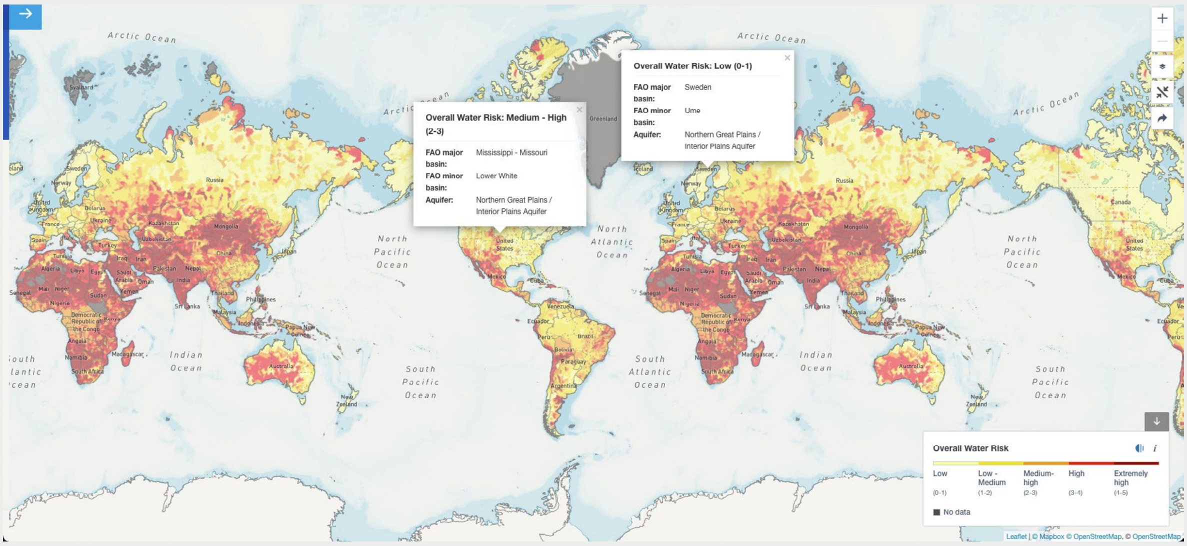
PRACTICAL PRELIMINARY ACTIONS TO THE BUSINESS GUIDANCE

WBCSD has designed the *Business guidance on the assessment of wastewater-related impacts* for application at the level of an industrial site, which is a resource-intensive exercise. Therefore, companies applying the guidance should ensure that they have the necessary strategic oversight and business commitment in place to conduct the exercise.

Wastewater as a topic is highly interconnected and can find strategic links with topics like water security, carbon emissions and management, hazardous waste management and enterprise risk management. As part of their water strategy, companies often inspect their sites for water risk and prioritize them for further analysis and action based on the type of risk and other business considerations (Refer to Box 3). The application of the business guidance can be a follow-up action to such screening exercises at sites where companies have found water quality to be a major risk.

Box 3: Open access tools for initial risk screening

Companies can use open access tools, such as the World Resources Institute's Aqueduct Water Risk Atlas[8] and WWF's Water Risk Filter,[9] for the initial screening for water risks based on a variety of parameters. For example, this illustration shows how companies can use the Water Risk Atlas to conduct an initial screening of their sites and supply chains for water risks.



OTHER KEY INITIATIVES AND HOW THE BUSINESS GUIDANCE RELATES TO THEM

The business guidance builds on existing knowledge, tools and resources in the area of impact assessment and management. Companies can apply it as part of or in combination with other resources and tools that may be relevant and useful.

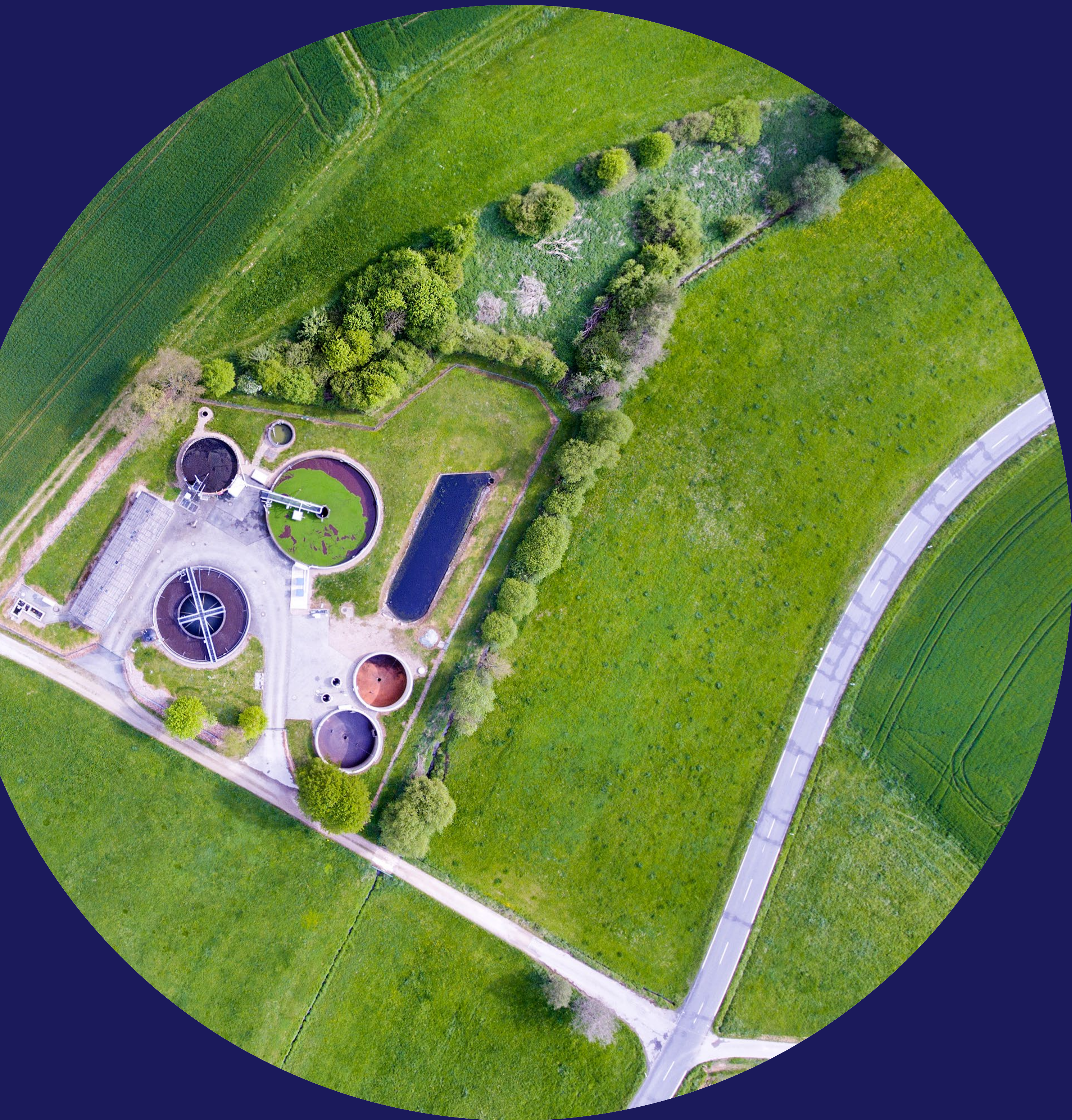
Table 1 lists some resources and ongoing developments on the topic and describes how the business guidance relates to them.

Note, however, that we have not aligned the guidance with industry-sector specific guidelines, such as those on pollutants of concern and their discharge limits. As part of implementing the guidance, companies should refer to sector-specific guidelines and materials.

Table 1: Key impact assessment and management initiatives and how the business guidance relates to them

Step	Key initiatives and resources	How the business guidance relates
1	Natural Capital Protocol[10]	The protocol is aligned in purpose and terminology. The protocol provides an overarching framework for capital assessment while the guidance zooms in on impact accounting for wastewater. The guidance does not address business dependencies or impacts on business.
2	Science Based Targets Network – Freshwater (SBTN – Freshwater)[11]	The guidance provides a cross-reference of principles. Companies can apply the guidance while setting science-based targets and also as the next step in actioning the targets. It also supports companies in valuing impacts from wastewater.
3	Alliance for Water Stewardship (AWS) Standard 2.0[12]	The AWS Standard 2.0 helps evaluate options and understand trade-offs in implementing solutions. Companies can implement the guidance as part of or a next step in AWS standard implementation, where it provides additional understanding of the valuation aspect of impact.
4	Taskforce on Nature-related Financial Disclosures (TNFD)[13]	The guidance helps companies prepare to apply the upcoming TNFD framework for reporting and action on nature-related risks. It also helps companies apply the "Evaluate" phase of TNFD's LEAP approach (nature-related risk and opportunity assessment approach).
5	Climate Disclosure Standards Board (CDSB) framework on water-related disclosures,[14] now part of the International Sustainability Standards Board (ISSB)[15]	Companies can use the business guidance as input for water-related disclosures in alignment with the Climate Disclosure Standards Board (CDSB) water guidance. Specifically, it helps companies identify their risks and opportunities, sources of environmental impact, and other elements that comprise fundamental requirements of the CDSB framework on water-related disclosures.

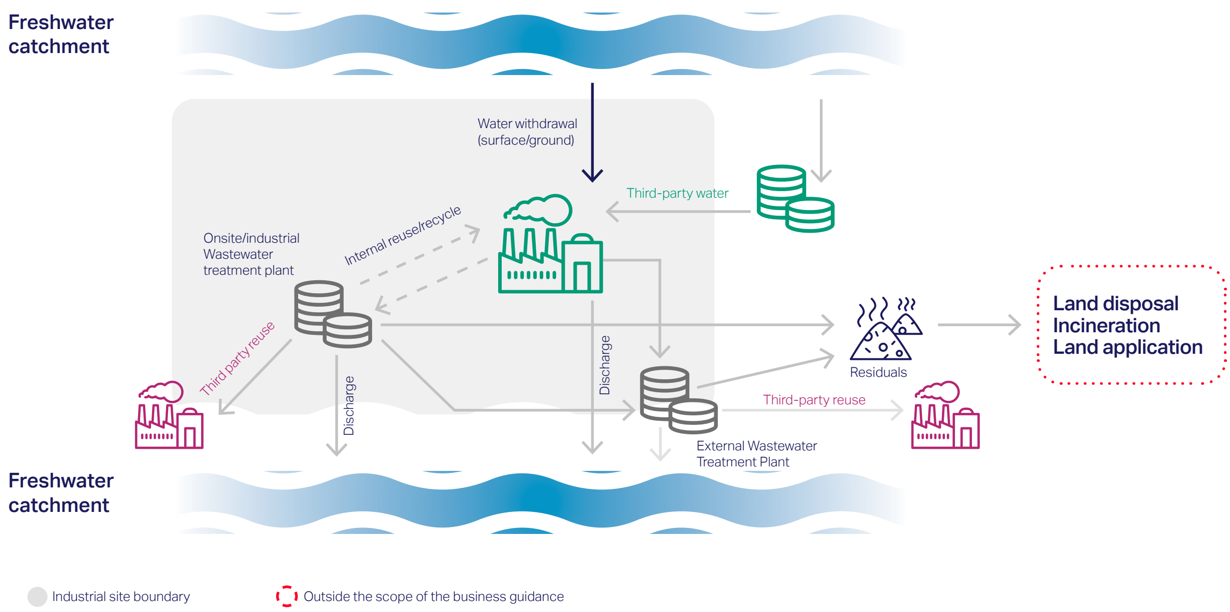
3 Scope of the business guidance



③ Scope of the business guidance

The business guidance is a site-level guide that covers impacts from pollution point sources. Its scope includes all activities related to the generation and discharge of wastewater by the site. Figure 1 provides a generic site water flow model. Table 2 lists the specific activities and elements that are in and out of the business guidance scope.

Figure 1: A typical water-flow model for an industrial site



Note: The business guidance includes all activities and elements except the ones highlighted in the red-dotted rectangle.

Table 2: Details of the scope definition of the business guidance

Impacts from the following are in scope	Impacts from the following are out of scope
Water withdrawal by the facility or by a third-party providing treated water to the facility, taken from freshwater bodies and groundwater	Disposal of residuals from wastewater treatment, including seepage into groundwater
Discharge of wastewater by the site into freshwater bodies, sea or oceans	Discharge of wastewater into the ground
Wastewater treatment (in-site or off-site)	Use of consumables such as chemicals used in wastewater treatment
Electricity/fuel use for wastewater treatment	Business dependencies such as wastewater treatment costs
Residuals released from wastewater management, except impacts on soil	

4 Steps of the business guidance

④ Steps of the business guidance

The five key steps of the business guidance are aligned conceptually as well as in terms of terminology used in the Natural Capital Protocol. "Measure and Value" (Stage 3) of the protocol[16] defines steps 1, 2 and 3 of the business guidance. In line with the SBTN – Freshwater methodology,[17] steps 4 and 5 guide companies to set targets to limit the impact drivers and define the approach to manage impacts.

DEVELOPING THE IMPACT PATHWAY

The business guidance uses the concept of impact pathways to illustrate how, as a result of a specific business activity, a particular impact driver results in changes in natural capital and how these changes impact different stakeholders. The discharge of wastewater containing organic matter by a dairy factory, for example, can lead to an increase in the biological oxygen demand (BOD) content of the water body, thereby killing fish and other aquatic animals.

Figure 3 shows the sources of impact drivers within the typical water flow model of the industrial site and the possible impacts. Companies using the business guidance should develop an impact pathway diagram specific to their own site operations and scope and use it as the starting point in understanding their own impacts from the wastewater generated by the site.

As companies develop the impact pathway diagram, they should balance the need to be exhaustive in their analysis of impacts with the need to be practical in accounting for major impacts and addressing them.

Figure 2: Key steps in the business guidance

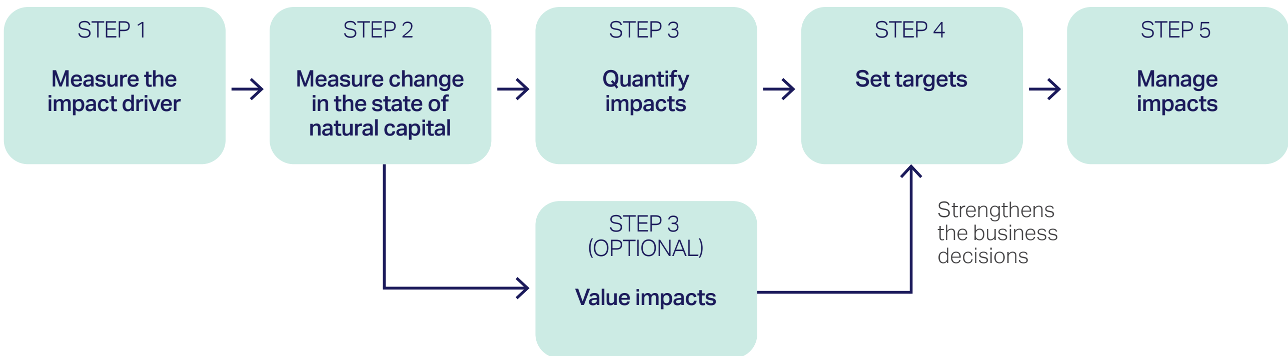
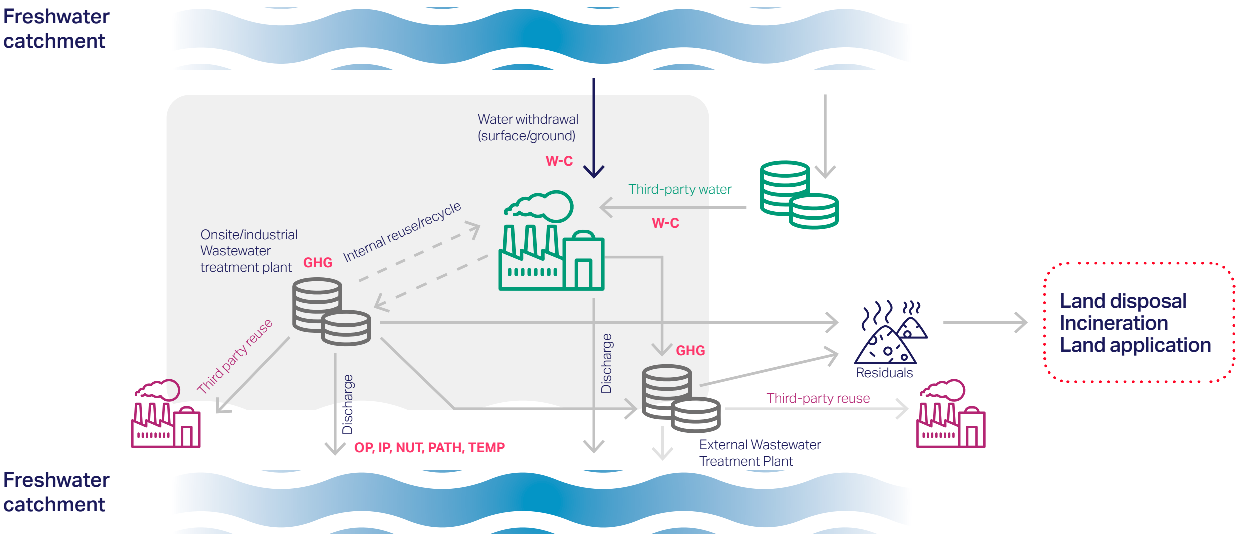
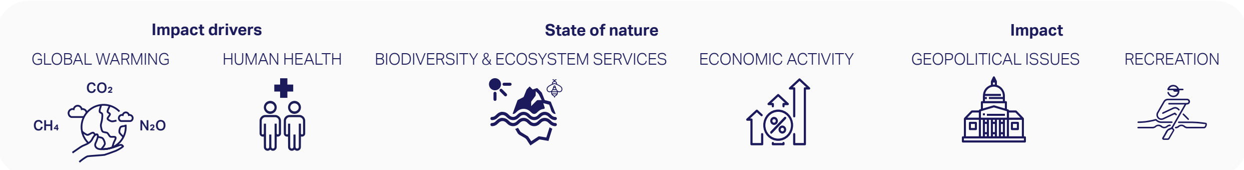


Figure 3: Schematic linking industrial activities with impact drivers and possible impacts related to wastewater generation and discharge

Impacts through soil such as those caused by residuals from wastewater treatment are not included in the scope of the guidance. Also, impacts from wastewater pollutant release into groundwater are not included in the scope.



Legend: W-C: water consumption; GHG: greenhouse gas emissions; OP: organic pollutant release; IP: inorganic pollutant release; Nut: nutrient release; Path: pathogen release; Temp: temperature change



Impact drivers	State of nature	Impact
Water consumption (W-C)	• Change in environmental flow • Change in groundwater level • Change of habitat	• Human health (waterborne diseases) • Biodiversity loss • Loss of ecosystem services • Impact on fishing, farming, etc. • Impact on economic growth
GHG emissions (GHG)	• Change in GHG concentration • Rise in temperature • Rise in sea level • Desertification • Change of habitat	• Human health (infectious diseases) • Agri-forest yield • Biodiversity loss • Loss of ecosystem services • Impact on fishing, farming, etc. • Material corrosion • Loss of economic activity due to supply chain disruption
Organic pollutant and nutrient (N, P) release (Nut)	• Eutrophication • Load accumulation	• Human health (waterborne diseases) • Biodiversity loss • Loss of ecosystem services • Impact on fishing, farming, etc. • Impact on recreation and aesthetics • Fall in property value
Inorganic pollutant (like heavy metals) release (IP)	• Bioaccumulation / ecotoxicity • Contamination*	• Human health (heavy metal toxicity) • Biodiversity loss • Impact on fishing, farming, other industrial activities
Pathogen release (Path)	• Change in water quality	• Human health (waterborne diseases) • Animal health (waterborne diseases)
Temperature of discharge (Temp)	• Temperature change relative to ambient temperature	• Biodiversity loss • Impact on other industrial activities

*Contamination as a state of nature can be measured by "toxic units" to account for the higher toxicity of some compounds.

Step 1: Measure the impact driver

An impact driver (called "Pressures" in the Science Based Targets Network guidance for nature[18]) is a measurable quantity of a natural resource used as an input in production or a measurable non-product output of the business activity.

In relation to wastewater, impact drivers stem from the following activities:

1. Consumptive water use by the site.
2. Discharge of effluent (treated/ untreated) by the site, leading to GHG emissions and the release of pollutants into the water body.
3. Wastewater treatment, which uses electricity or fuels as inputs and releases GHGs; apart from treated water, it generates residuals that, when disposed or treated further, can release GHG emissions and cause land degradation.

Box 4: Key definitions related to freshwater[19]

Water withdrawal or use describes the total amount of water withdrawn from its source for use. It is also referred to as the "raw water supply" of the facility.

Water consumption is the portion of water use not returned to the original water source after withdrawal. Consumption occurs when water evaporates into the atmosphere or is incorporated into a product and is no longer available for reuse.

Consumptive water use is the portion of water use not returned to the original water source after withdrawal and the portion returned to its original water source but with a quality lower than internationally agreed quality standards.

Water scarcity: Depleting water from a system generally leads to water scarcity, which is the lack of available water to meet demand, where demand can be from both humans and the natural environment.

Companies should measure the following impact drivers:

1. The consumptive water use by the site, by measuring:
   - The water used by the site that is not returned to its original freshwater source *(quantity not returned)*.
   - The water used by the site that is returned to its original freshwater source but with a quality lower than internationally agreed quality standards *(quantity returned but with a degraded quality)*.

   Further,

   - As part of this impact driver, companies should account for avoided freshwater use, which is the wastewater generated by the site that is either reused by the same site or supplied to another user to replace the surface water withdrawal in the same water body.
   - If the company supplies wastewater generated by the site to a user in another basin or catchment, then it does not account for the volume of wastewater as avoided freshwater use from the said catchment or basin.
   - The amount of treated wastewater discharged to the same water body as the withdrawal of a lower quality than internationally agreed environmental quality standards is considered consumptive use, as it cannot properly support ecosystems or downstream users.
2. Mass of GHGs (carbon dioxide, methane and nitrous oxide) attributable to the type of wastewater treatment, type of biosolid management and energy consumption for wastewater treatment.
3. Mass of pollutants (organic such as nutrients; inorganic such as heavy metals; pathogens) released as part of the effluent (treated/ untreated).
   - It is also important to study the physical nature and behavior of the pollutants, such as solubility, tendency to spread, toxicity, etc. Are the pollutants part of the list of priority pollutants identified by the regional or national governmental agencies?

For more information, refer to the Annex on pollution-related impacts) and read more about the European Union's Priority Substances,[20,21] and the United States Environmental Protection Agency's Priority Pollutants.[22]

4. Other factors, such as the temperature of the effluent, that have an impact on ecosystems.

Companies can rely on the following options or data sources to measure the impact driver:

1. Primary data – the preferred and most direct measurement of the impact driver. Primary data collection, however, is not always feasible, especially as it may require putting in place complex systems that may be resource-intensive.

2. Secondary sources – making adjusted estimates to available data from other sources, such as life-cycle assessment (LCA) databases, environmentally extended input-output models, etc. Companies should select secondary data sources taking into consideration factors such as scientific validity, representativeness of the site's condition, etc. More information on considerations for selecting (secondary) data sources is available in the Transparent Project's Methodology.[23] Further, the Wastewater Impact Assessment Tool (WIAT) tool provides estimated data for different types of industries and treatment types. See Annex II for more on WIAT.

3. A combination of primary and secondary data.

Step 2: Measure changes in the state of natural capital

Changes in the state of natural capital (referred to as "State of Nature" in the Science Based Targets Network guidance for nature)[24] are what may ultimately lead to impacts. The impacts can be on various actors and in various forms, such as on human health, biodiversity richness, economic activity of other actors, etc.

The key changes in natural capital due to water withdrawal from or discharge into water bodies are dependent on the local condition of the watershed, including its geophysical, hydrological and biological parameters and its current physical stress level and other water users operating in the watershed. As an example, some watersheds may support rich and unique biodiversity, making them vulnerable to stresses and highly important for preservation. It is therefore critical for companies to understand the local context of the watershed in which they operate. Publicly available resources exist to support this process; but companies will gain the greatest understanding by engaging with local stakeholders who work within the catchment.[25] We provide some examples of the currently available data sources and indicators that can help companies understand the local watershed below. Companies may, however, have other information sources to gain this understanding. The information sources below are also subject to further updates.

- Baseline Water Stress by Aqueduct Water Risk Atlas,[26] water depletion from WWF's Water Risk Filter,[27] and Blue Water Scarcity[28] defined by the Water Footprint Network for water availability status.
- Surface water contamination risk indicator from WWF's Water Risk Filter,[29] the Global Assessment of Nutrient Water quality by McDowell et al.[30] and Coastal Eutrophication Potential by Aqueduct;[31]
- The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species[32] and the River Fragmentation Status from WWF's Water Risk Filter[33] for the ecological status of the basin or watershed.
- Key Biodiversity Areas[34] and biodiversity status available through the Integrated Biodiversity Assessment Tool.[35]

The Volumetric Water Benefit Accounting (VWBA) method developed by the World Resources Institute, LimnoTech, Quantis and Valuing Nature provides a set of practical methodologies that correlate the volumetric water savings of companies with the key water impact-related indicators that can lead to social, economic and environmental impacts.[36]The methodologies determine in volumetric terms how companies can reduce their impact and generate benefits for watersheds in which they operate through activities such as reducing water use or improving discharge practices. We recommend these methodologies based on the published literature, practitioner experience and best practices.

Modeling methods and LCA studies and databases are often the basis for measuring changes in the state of natural capital. Companies should develop a detailed map of impacts that impact drivers may cause (through changes in natural capital) and assess models and approaches to use to measure changes in the state of natural capital and the corresponding impacts they may cause. Information from the databases provided above and indicators that inform catchment conditions may be required as inputs in the models and methods that companies choose to apply in a given catchment.

Table 3 provides a detailed list of the impact drivers, the corresponding changes in the state of natural capital and the resulting impacts that wastewater may cause. The Annex I provides the key models or approaches that companies can apply to calculate the changes in the state of natural capital from key impact drivers and the corresponding impacts. Companies should, however, make informed decisions about the models or approaches to apply based on their needs and the local context within which their site operates.

The SBTN methodology (under development) will support the assessment of the share of responsibility of a given facility in the change of the state of nature at the sub-basin scale, to drive action at the facility level and drive industries to support other basin stakeholders in improving their operations to more effectively reduce impacts.

Table 3: Indicative list of key impact drivers, changes in the state of natural capital and impacts caused due to wastewater

Impact driver	Measure of change in state of natural capital	Possible impact
Consumptive use of water from surface-water bodies and groundwater (*Scarcity-related impacts*)	• Change in environmental flow (due to quantity never returned) • Change in groundwater level • Changes in habitats • Change in water quality (due to quality never returned)	• Human health (malnutrition, waterborne diseases due to lack of access to safe water) • Biodiversity loss • Other ecosystem services • Impact on drinking water supplies and other domestic uses • Impact on other activities like fishing, farming and other industries • Reduced economic growth • Stakeholder conflict
GHGs: CH_4, CO_2, N_2O (*Carbon-related impacts*) measured as CO_2 equivalents or global warming potential	Change in GHG concentration in the atmosphere	• Climate change/global warming > Rise in temperature > Rise in sea level > Desertification > Change of habitat • Human health • Biodiversity loss • Agri-forest yield • Corrosion of materials • Other ecosystem services • Supply chain disruption
Organic pollutants and nutrients: N, P in water body (*Pollution-related impacts*)	• Eutrophication • Load accumulation (Cumulative load in the river increasing the risk of eutrophication further downstream)	• Human health (infectious diseases) • Agri-forest yield • Biodiversity loss • Loss of ecosystem services • Impact on other economic activities, like farming, fishing & other industry, leading to increases in poverty, impact on GDP • Fall in property value • Impact on recreation and aesthetics • Increase in conflict among water users
Inorganic pollutants: heavy metals, chemical compounds, etc. (*Pollution-related impacts*)	• Bioaccumulation/ecotoxicity • Contamination	• Human health (heavy-metal toxicity) • Biodiversity loss • Impact on fishing, farming and other economic activities
Pathogen in water body (*Pollution-related impacts*)	Change in pathogen content of the water body	• Human health from drinking water source • Animal health from drinking water source
Temperature of discharge (*Pollution-related impacts*)	Change in temperature relative to the ambient temperature of the water body	• Loss of biological species • Impact on other economic activities such as fishing and industry

Step 3: Quantify impacts

The quantification of impacts helps companies to move to take appropriate action to address the impacts. This step allows companies to determine how much impact their activities may have had on the actors concerned and determine the type and level of action required accordingly.

Quantification may include measuring impacts on the environment (measured in the form of change of agri-forest yield, disruption of ecosystem services, loss of biological species, etc.), human health (measured as number of cases, or DALYs – disability-adjusted life years – where one DALY represents the loss of the equivalent of one year of full health) and impact on other economic activity (measured as loss in farming, loss in fish yield or other economic activities).

Note that the quantification of the impacts are related to the sub-basin scale change in the state of nature. As mentioned in Step 2, the facility the company is assessing is partially responsible for these changes, as are other stakeholders within the basin. Applying the upcoming SBTN methodology to assess the share of responsibility of a given facility will enable companies to assess (1) the share of the impacts that the facility itself is causing and (2) the share of impacts the industry contributes to reducing when supporting other basin stakeholders to improve their operations.

Standard characterization factors from life-cycle assessments can help companies quantify such impacts. Further, the WIAT tool provides a quantitative assessment of the "change in the state of nature" resulting from wastewater management. Locally led studies accounting for the local context can translate this change into impacts.

Box 5: Why quantify impacts and value?

The world's water challenges, including wastewater, are a key driver of business risks worldwide and across a variety of industry sectors. Companies that fail to understand and address these risks put themselves in danger of causing disruptions and damage to their business, such as through high operational costs and loss of social license to operate. Such issues also pose risks for investors and shareholders, such as through stranded assets and reputational risk. Quantifying the impacts caused by business operations on other stakeholders and measuring their value leads to a clear understanding of business risks and, therefore, to planning mitigation action. The concept of quantifying impacts and measuring value is central to water stewardship action and provides returns by strengthening businesses and creating new opportunities for businesses and investors.

Step 3 bis (optional): Value impacts

Once companies have quantified the impacts caused by their activities, they may undertake a valuation exercise to understand the monetary or financial value linked to the impacts. Impact valuation helps strengthen the business case for taking action and prepares companies for future reporting and disclosure requirements. The objective is to accelerate action to reduce wastewater impacts by communicating on the value of these impacts for society.

This is, however, an optional step in the business guidance that companies should only undertake if they have the time and resources available. Companies should act in the interest of taking urgent action to manage the impacts, even if they have not done a complete assessment of the value of these impacts.

Specific valuation techniques and approaches can achieve financial valuation of impacts when applied as a standalone act or as part of existing models and assessments, such as an LCA. Depending on data availability and time and resource constraints, the level of stakeholder engagement desired, and the degree of accuracy required, companies may identify valuation techniques that they would like to use.

Table 7.1 of the Natural Capital Protocol summarizes different valuation techniques and their key features. Annex 2 of the protocol provides detailed information on the techniques. Box 7.1 provides information on "Value transfer", which is imperfect but is an alternative to valuing impacts when primary valuation studies are not feasible in a given context.

Table 4 provides some techniques often used for the valuation of impacts from wastewater.

Valuation methods and approaches are only as robust as the data that underlies them. It is therefore critical for companies to ensure that they collect the best data available to measure baseline and current conditions. Also, given the uncertainty linked to the nature of natural and social capital, a sensitivity analysis is crucial to impact accounting and valuation.

Table 4: Commonly used valuation techniques and useful resources for wastewater impact areas

Impact area	Commonly used valuation techniques and useful resources
Climate change	• Intergovernmental Panel on Climate Change (IPCC) models to calculate quantitative value from climate change on a variety of interdependent aspects (e.g., human health, ecosystems, corrosion, etc.) in a combined way[37] • Social cost of carbon for monetary valuation of economic damages of emitting one additional ton of carbon dioxide[38]
Human health	Stated or revealed preference approaches to calculate the value of mortality or morbidity See Box 5, Table 4 and Table 5 of the Transparent Methodology for further guidance on valuation approaches and metrics used for mortality and morbidity: Value of Statistical Life or Value per Statistical year[39]
Ecosystem services	Cost-based approaches including application of standard valuation factors for ecosystem services associated with the basin, from the Ecosystem Services Valuation Database[40] and Environmental Value Look-Up Tool[41]
Economic activities	Market price-based valuation approaches, including the following for the respective sectors: **Agriculture:** change in value (or market price) of crops due to varying yields as a function of low water availability and poor quality; added value of crops due to irrigation when compared to lack of irrigation **Industrial output:** output value lost in shutdowns, disruption of operations **Tourism:** lost economic value due to no tourism **Fisheries**: lost incomes of fishing communities operating in the catchment
Recreation and aesthetics	Stated or revealed preference approaches to calculate the willingness to pay for the environmental good; for example, for an aquatic site, the cost of travel to the site or a survey to know the willingness of the community to pay to use the site for recreational purposes

Step 4: Set targets

The Science Based Targets initiative (SBTi) specifies for companies and by sector how much and how quickly they should reduce specific impact and dependencies as guided by science.[42] Companies setting science-based targets for GHG emissions must ensure they take emissions from wastewater into account while setting targets. The Science Based Targets Network's Freshwater initiative is currently developing its freshwater methodology[43] to provide guidance on how business activities affect water quantity and quality and how companies should take the catchment context into consideration when determining targets based on science.

We provide some key principles that companies should take into account while setting targets for wastewater below.

Companies should set targets for the impact driver based on a pre-determined allowable level of change in the state of natural capital. For science-based approaches, a local or global catchment-level model that is science-based and takes into account all water uses in the catchment provides the pre-determined allowable level of change in the state of natural capital. Companies should follow this approach for both water quantity and quality indicators. For example, the company should define its target in terms of the quantity of pollutant it can discharge while staying within a given eutrophication potential that maintains the desired state of the catchment.

Companies can use approaches based on social, economic, technological and political aspects to determine their share of allocated resource or their fair share of responsibility. The latest available draft of SBTN's

Box 6: Wastewater and GHG emissions

Wastewater is a source of GHG emissions in the atmosphere. McKinsey Sustainability estimates that wastewater accounts for 7% to 10% of anthropogenic emissions of methane, which represents the second-largest contributor to global warming after carbon dioxide.[44] Most of these emissions come from untreated wastewater, while wastewater treatment also involves some GHG emissions.

Site operations often do not account for or underreport GHG emissions from wastewater in total reported GHG emissions (often only considered for energy use). While companies develop and adopt target-setting processes (such as science-based targets – SBTs) for GHG emissions fairly well, it is critical that they ensure they include wastewater-related emissions in the associated GHG accounting frameworks.

According to the International Water Association, treating domestic wastewater cuts its GHG emissions to about one-third.[45] Similarly, treating industrial wastewater that contains biological oxygen demand (BOD) and nitrogen can significantly reduce GHG emissions compared to having no treatment. In the case of organically loaded industrial wastewater, the treatment can become carbon neutral through energy recovery.

Typically, the three components of wastewater treatment emissions are methane, nitrous oxide and carbon dioxide. These emissions result from the energy consumed and direct emissions during treatment and the storage of wastewater and the associated sludge.

Some of the most effective solutions to GHG emissions abatement from wastewater include:

- Increasing the volume of wastewater collected and treated, using low energy solutions where feasible.
- Suitably modifying the operating conditions of wastewater treatment plants so as to avoid the release of GHGs and increase their retention in the system in other forms.
- Modernizing existing treatment infrastructure, such as by using energy-efficient equipment, renewable energy sources, covered lagoons and microalgae to harvest methane and other bioproducts, and digitalization to provide real-time controls to reduce energy use or nitrous oxide emissions.

Technical Guidance for Set Targets (Step 3) on Freshwater,[46] however, prescribes the use of the allocation approach called "equal contraction of efforts". This approach assumes that all water users in the basin will reduce their withdrawals or pollutant discharges by the same percentage, which doesn't properly acknowledge that some stakeholders might already have invested in improvements when others have not yet. For further guidance, refer to sections 3.3.2 and 3.4.2 of the methodology.[47]

Technical guidance document number 2 for Sustainable Development Goal (SDG) 6.3.2 for Clean Water and Sanitation[48] expands on the target value concept for water quality and provides guidance on how to set meaningful water quality targets. Water quality depends on measurement location and conditions and target values should take both ecosystem and human health into consideration.

The technical guidance document provides optional target values for water quality parameters that are often close to target values that countries report on. For phosphorus, for example, the optional target value for rivers is 20 micrograms per liter for total phosphorus and 10 micrograms per liter for orthophosphate.

Step 5: Manage impacts

SBTN provides an action framework (AR³T) for companies to take relevant actions to address the impacts they have identified.[49] The framework is based on well-known conservation and mitigation hierarchies and applies to the case of freshwater. The hierarchies require that companies prefer actions to eliminate pressure over those to reduce pressure and that they prefer those over actions that offset pressures.

1. **Avoid** implies eliminating pressure entirely, thereby preventing the impacts from happening. This is the most preferred set of actions, keeping in view that some impacts from human activities are irreversible and humans at best should avoid them. Actions related to avoidance are also often more cost-effective than remedial actions. However, water is often linked to other inputs and resources, such as energy and cost. In practical terms, a company would need to understand the nexus between these factors and take a balanced approach in optimizing the available resources and cost. Forbidding the use of toxic compounds in the production facility or switching to less water-intensive products are examples of avoidance of pressure.

2. **Reduce** implies the reduction of pressure, thereby reducing the level of impacts caused. Reductions in water withdrawals by companies through technological improvements that allow greater water reuse, process improvements, etc. qualify as "reduce" actions.

3. **Regenerate and restore** implies using remedial measures to deal with impacts that it is not possible to avoid or reduce. Regeneration refers to ecosystems that improve the state of nature without changing the use classification, while restoration targets changing the system from a degraded state to a more natural state. Managed aquifer recharge or the restoration of natural channel morphology are examples of regeneration and restoration.

4. **Transform** implies acting on the fundamental drivers of impacts through technological, economic, institutional and social factors and changes in underlying values and behaviors. Policy engagements and collaborative institutional efforts to promote sustainable water management are examples of transformative actions.

WBCSD, as part of its Wastewater Zero initiative, provides an action framework for companies to act on wastewater. Supported by enabling factors such as policy and regulation, finance and innovation, businesses can create partnerships within and across sectors and value chains and engage with government and civil society to find solutions that address the social and environmental challenges posed by inadequate wastewater management. The six action areas of the framework are:[52]

1. Incorporate principles of circularity throughout your organization
2. Establish targets and metrics based on science and context
3. Invest in public-private partnerships
4. Incentivize and support value chain partners
5. Value water to minimize externalities and incentivize reuse
6. Improve disclosure beyond compliance.

It is important to note that companies that conduct impact valuation may already be implementing some water stewardship or management actions within their operations. Companies should integrate or implement the management actions that they identify from using the application guidance jointly with existing water stewardship actions. In accounting for cumulative impacts from these actions, however, companies should ensure the aggregation of impacts and not impact drivers.

The continuous monitoring and evaluation of the actions to address impacts is key to tracking the progress of the company against the targets set.

Box 7: Wastewater and hazardous chemicals

The release of hazardous substances such as heavy metals and highly toxic and persistent chemicals called "forever chemicals" pose a significant risk to humans and ecosystems.[50] Certain sectors are using several such chemicals heavily despite being banned globally. In alignment with the principles of the mitigation hierarchy, eliminating these substances from the production processes is the best way to manage them. There is increasing recognition of the harmful impacts of these substances worldwide and certain industry initiatives are picking up to help eliminate them from production value chains. One such initiative is the Reducing uses and releases of chemicals of concern in the textile sector program, a partnership between the governments of four leading textile producing countries financially supported by the Global Environment Facility (GEF). It seeks to improve knowledge and skills aiming to eliminate such chemicals from textile production processes.[51]

Annex I

KEY MODELS AND APPROACHES TO MEASUREMENT OF CHANGE IN THE STATE OF NATURAL CAPITAL

The following table lists the key models and approaches that companies can apply to calculate the changes in the state of natural capital, followed by estimating impacts in some cases.
We provide details on certain models and methodologies below. We have taken some of the methodologies from version 1 of the WBCSD Wastewater Impact Assessment Tool (WIAT). The WIAT incorporates globally applicable models and calculations to calculate changes in natural capital. Wherever possible, companies should use local studies to supplement the results from WIAT Version 1. The methodologies used in WIAT v1 may also improve in due course as tool users and the scientific community provide additional feedback.

The multiple models and methods listed under each impact category are independent from the others, with their own set of assumptions and conditions for application. Companies should not apply these together unless specified or relevant in a particular context.

Key changes in the state of natural capital	Recommended models and methodologies
Change in environmental flow (water scarcity-related impacts)	• Dilution factor (from WIAT v1; details in Annex II) • Consumption available ratio (from WIAT v1; details in Annex II)
Change in concentration of GHGs or CO_2 equivalents (carbon-related impacts)	• Direct and indirect emissions calculations from various industrial processes, including wastewater treatment (from WIAT v1; details in Annex II) *We do not provide further details on the calculations of carbon-related impacts in this guidance as the Science Based Targets Network (SBTN) covers these in detail in the greenhouse gas (GHG) accounting procedures and science-based targets (SBTs) for GHGs. Companies must account for the wastewater-related emissions in these broader accounting and target setting processes.*
Eutrophication (pollution-related impacts)	• Eutrophication potential (from WIAT v1; details in Annex II) • Life-cycle impact assessment (LCIA) models like Impact World Plus 2016, TRACI 2.1 and ReCiPe 2016 that help to calculate eutrophication potential and the corresponding endpoint impacts. The "Critical review of eutrophication models for lifecycle assessment" paper[53] provides a useful comparison of LCIA models used to estimate the impacts from eutrophication.
Ecotoxicity (pollution-related impacts)	• Dilution factor (from WIAT v1; details in Annex II) • Toxic units (from WIAT v1; details in Annex II) • USEtox[54] provides human and ecotoxicity factors for thousands of chemicals that can be used in life-cycle assessment (LCA) models to calculate the toxicity impact from the release of toxic chemicals including from wastewater. • The recently developed ECOTOX Explorer[55] and the associated research paper[56] provide updates made to the USEtox characterization factors (CFs) to overcome some of its limitations as part of the EU Environmental Footprint (EF) 3.0 pilot phase.
Change in pathogen content of the water body (pollution-related impacts)	• Dilution factor (from WIAT v1; details in Annex II) • Estimating the impact of pathogens on human health may involve use of Quantitative Microbial Risk Assessment studies incorporated in LCA models. The "Including Pathogen Risk in Life Cycle Assessment of Wastewater Management. 1. Estimating the Burden of Disease Associated with pathogens" paper[57] provides a case example on the use of such an integrated approach.

Change in temperature of the water body relative to the ambient temperature	• Estimating the impacts of thermal pollution on ecosystems requires the use of LCAs that integrate the appropriate characterization factors for thermal pollution. The following studies have developed characterization factors for thermal pollution and have applied them to specific cases.
	    • "Assessing the environmental impacts of freshwater thermal pollution from global power generation in LCA"[58]
	    • "Characterization factors for thermal pollution in freshwater aquatic environments".[59]

Annex II

METHODOLOGIES FROM WASTEWATER IMPACT ASSESSMENT TOOL (WIAT) V1

SECTION 1: CHANGE IN ENVIRONMENTAL FLOW

Name	Dilution factor
Description	The dilution factor (DF) can be defined as the ratio between receiving water body flow to total industrial wastewater effluent generated within a catchment. Higher values indicate less impact on the river.
Unit	-
Equation	$$DF = \frac{W_a + W_{effl} - W_w}{W_{effl}}$$ Where: W_a: amount of water available in the river, which is extracted from the stream flow global indicator W_{effl}: amount of water that the industry discharges on the river W_w: amount of water withdrawn from the river
Impact categories	• >100 Low impact • 10 – 100 Medium impact • 1 – 10 High impact • <2 Very high impact (Rice & Westerho, 2017)

Name	Withdrawal ratio (level of water stress)
Description	This metric is calculated from the relationship between the amount of water withdrawn by the industry and the amount of water available *remove the text "and multiplied by 100". It indicates the percentage of the available water withdrawn by the industry's consumption. This metric may have values ranging from 0%, to a value greater than 100%, indicating that the demand for water within the watershed is higher than the available.
Unit	%
Equation	$$W_S = \frac{W_W}{W_a} \cdot 100$$ **Where:** W_S = the relationship between the amount of water withdrawn by the industry and the amount of water available W_a: amount of water available in the river, which is extracted from the stream flow global indicator W_W: amount of water withdrawn from the river
Impact categories	• 0 – 2 % Low impact • 2 – 5 % Medium impact • 5 – 20 % High impact • + 20 % Very high impact The impact categories have been established by a panel of ICRA experts.

Name	Consumptive use from different watersheds
Description	Amount of water that comes from external sources (e.g. purchased) located in a different watershed than the discharge point.
Unit	m3/day
Equation	Value as entered by the user
Impact categories	• >0 Very high impact • 0 Low impact The impact categories have been established by a panel of ICRA experts.

Name	Groundwater withdrawals (only in areas with GW decline)
Description	Amount of groundwater withdrawals that take place in areas where the water table declines.
Unit	m3/day
Equation	Value as entered by the user
Impact categories	• >0 Very high impact • 0 Low impact The impact categories have been established by a panel of ICRA experts.

SECTION 2: POLLUTION RELATED IMPACTS

The following metrics calculate the impact of pollutants on the river. There are 3 main groups of metrics, those related to industrial effluent, those related to the impact on the ecosystem and those dealing with the efficiency of water treatment. The list of pollutants measured to calculate the impact are COD, Total Nitrogen, Total phosphorus, and a selection of Priority Pollutants (PP). The PP can threaten human health or ecosystems. The list of the 33 priority substances (complete list in Appendix 6.1) was composed by the European Commission with a panel of experts in the field of chemistry and maritime pollution, delegates of the member states and European firms and the European Environment Agency (Priority Substances - Water - Environment - European Commission, n.d.). The table below shows which of those PP the ecosystem impact metrics considered for WIAT v1. The choice of these 11 pollutants has been made based on the availability of data by type of activity (or ISIC code). The other 22 pollutants might be just as relevant, but as no default values are available by type of industry for those, therefore WIAT does not include them at this point. For these other 22 pollutants, there is few scientific evidence on the relationship between ISIC classes and the generated pollutants, except for few studies such as the French one relating a subset of pollutants with the ISIC classes

(LES SUBSTANCES DANGEREUSES POUR LE MILIEU AQUATIQUE DANS LES REJETS INDUSTRIELS, 2016).

PP Name
1,2-Dichloroethane
Cadmium
Hexachloro-benzene
Mercury
Lead
Nickel
Chloroalkanes
Hexachlorobutadiene
Nonylphenols
Tetrachloroethylene
Trichloroethylene

2.1.1 Pollution load to the environment

Name	Increase in toxic units in the receiving water body after discharge
Description	Toxic units in the receiving water body indicates if the concentration after the effluent discharge on the water body exceed the EC50, supposing the receiving water has a concentration of 0. This metric does not calculate values for COD, TN, TP, just for PP.
Unit	TU/day
Equation	$delta\_ecotox_{pp} = \frac{1000 \cdot D_{PP}}{EC50_{PP}} \cdot 100$ **Where:** $Delta\_ecotox_{PP}$: Increase in TU in the receiving water body caused by the PP D_{PP}: Delta load of PP EC50PP: Value of EC50 from the databases for PP
Impact categories	• > 2 Very high impact • 1 – 2 High impact • 1 – 0,2 Medium impact • < 0,2 Low impact The impact categories have been established by a panel of ICRA experts.

Name	Increase of the concentration of the pollutants in the receiving water body after discharge (with respect to EQS)
Description	Increase of the concentration of the pollutant after dilution in the receiving water body compared to the EQS concentration of the pollutant. Indicates if the increase in concentration caused by the effluent discharge on the water body exceeds the Environmental Quality Standards (> 100%) remove the text "assuming the….when available". This metric does not calculate values for COD, TN, TP, just for PP.
Unit	%
Equation	$DeltaEQS_{PP} = \frac{D_{PP}}{EQS_{PP}} \cdot 100$ **Where:** $DeltaEQS_{PP}$: Increase in the concentration of a PP in the receiving water body (with respect to the maximum allowable concentration in the EU's Water Framework Directive) D_{PP}: delta load of a PP concentration of a PP after dilution of the effluent in the river EQS_{PP}: Maximum allowable concentration of a PP in the EU's Water Framework Directive

Name	Increase in temperature in the receiving water body due to industry discharge
Description	Increase in the temperature in the receiving water body after discharging water
Unit	°C
Equation	$\Delta T = \frac{(W_a - W_w) \cdot T_{WB} + W_{effl} T_{effl}}{W_a + W_{effl} - W_w} - T_{WB}$ Where: amount of water available in the river (streamflow global indicator) (m3/day) amount of water withdrawn from the river (m3/day) temperature in water body before discharge (°C) Amount of water discharged (m3/day) Temperature of water discharged (°C)
Impact categories	• > 0.5 Low impact • 0.5 -1 Medium impact • 1-2 High impact • >2 Very high impact The impact categories have been established by a panel of ICRA experts.

Name	Eutrophication potential
Description	Eutrophication potential (EP) is defined as the potential to cause over-fertilization of water and soil, which can result in increased growth of biomass. It will always have positive values; higher values indicate higher potential impact. It converts the pollutants to PO4 equivalent to calculate the total Eutrophication potential.
Unit	gPO4eq/m³
Equation	The Table of PO4 equivalent is used
Impact categories	• < 0.5 Low impact • 0.5 – 1 Medium impact • 1 – 2 High impact • > 2 Very high impact Note: Please note that these varies greatly depending on the source consulted.

Tables of PO4 equivalent

Pollutants	Kg pollutant	Kg PO4 eq
Ammonia	1	0,35
Ammonium, ion	1	0,33
COD, Chemical Oxygen Demand	1	0,022
Nitrate	1	0,1
Nitric acid	1	0,1
Nitrite	1	0,1
Nitrogen	1	0,42
Nitrogen oxides	1	0,13
Nitrogen, total	1	0,42
Phosphate	1	1
Phosphoric acid	1	0,97
Phosphorus	1	3,06
Phosphorus pentoxide	1	1,34
Phosphorus, total	1	3,06

(CML-IA Characterisation Factors - Leiden University, n.d.)

2.1.2 Effluent toxicity level

Name	Toxic units in the effluent
Description	Toxic units in the effluent aims to calculate haw toxic is industry effluent for the ecosystem. To calculate the ecotoxicity potential, we have used the PP concentrations values from which in 24h cause the deaths or lack of movement of 50% of Daphnia magna individuals. These values (EC50) have been extracted from different studies compiled into two different databases, the ECOTOX Knowledgebase from the United States Environmental Protection Agency (ECOTOX | Home, n.d.) and from the NORMAN Ecotoxicology Database. (NORMAN Ecotoxicology Database, n.d.) This metric has no impact categories because it calculates with respect to the industry effluent and not with respect to the water body.
Unit	TU/m3
Equation	$EC_{toxPP} = \frac{PP_{effl}}{W_{effl}} \cdot \frac{1}{EC50_{PP}}$ **Where:** EC_{toxPP} : ecotoxicity potential of one PP PPeffl: load of the PP in the effluentPPeffl: load of the PP in the effluent Weffl: amount of water discharged to the water bodyWeffl: amount of water discharged to the water body EC50PP: Values of EC50 from the databasesEC50PP: Values of EC50 from the databases

Table of EC50 values

PP name	Scientific name	Duration (h)	Endpoint	Effect	Concentration (µg/L)	Source Freitag et a
1,2-Dichloroethane	Daphnia magna	24	EC50	immobile	150000	(Freitag et al., 1994)
Cadmium	Daphnia magna	24	EC50	mortality	9,5	(Kim et al., 2017)
Hexachloro-benzene	Daphnia magna	24	EC50	Immobile	30	(Calamari D et al., 1983)
Mercury	Daphnia magna	24	EC50	mortality	1,4	(Kim et al., 2017)
Lead	Daphnia magna	24	EC50	mortality	440	(Kim et al., 2017)
Nickel	Daphnia magna	24	EC50	immobile	1000	(Haley & Kurnas, 1993)
C10-13 Chloroalkanes	Daphnia magna	24	EC50	mortality	65000	(Freitag et al., 1994)
Hexachloro-butadiene	Daphnia magna	24	EC50	immobile	500	(Knie et al., 1983)
Nonylphenol	Daphnia magna	24	EC50	immobile	150	(Brennan et al., 2006)
Tetrachloro-ethylene	Daphnia magna	24	EC50	immobile	3200	(Bringmann & Kuehn, 1982)
Trichloroethylene	Daphnia magna	24	EC50	Immobile	76000	(Bazin et al., 1987)

Name	Concentration of the pollutants in the effluent (with respect to EQS)
Description	The Environmental Quality Standards (EQS) are the limits approved by the EU's Water Framework Directive. The directive sets environmental quality standards for priority pollutants (PP) and eight other pollutants. These substances include the metals cadmium, lead, mercury and nickel, and their compounds; benzene; polyaromatic hydrocarbons (PAH); and several pesticides. Several of these priority substances are classed as hazardous. Each PP has a maximum allowable concentration (MAC) for inland surface waters. The metric of impact indicates if the concentration of the pollutant in the industry effluent is higher than the MAC (> 100%) or lower (< 100%). (Priority Substances - Water - Environment - European Commission, n.d.) This metric has no impact categories because it calculates with respect to the industry effluent and not with respect to the water body.
Unit	g/m^3
Equation	$EEQSI_{PP} = \frac{PP_{effl}}{W_{effl}} \cdot \frac{1}{EQS_{PP}} \cdot 100$ Where: $EEQSI_{PP}$ *Indicates the* concentration of a given PP in the effluent compared to its maximum allowable concentration in the EU's Water Framework directive PPeffl: load of the PP in the effluent Weffl: amount of water discharged to the water body EQSPP: Maximum allowable concentration of a PP in the EU's Water Framework directive

Table of EQS values

PP Name	EQS [mg/l]
1,2-Dichloroethane	0,01
Cadmium	0,001
Hexachloro-benzene	0,0005
Mercury	0,00007
Lead	0,0072
Nickel	0,02
C10-13 Chloroalkanes	0,0014
Hexachloro-butadiene	0,0006
Nonylpheno	0,002
Tetrachloro-ethylene	0,01
Trichloro-ethylene	0,01

(Priority Substances - Water - Environment - European Commission, n.d.)

2.1.3 Treatment efficiency

Name	Percentage of treatment efficiency (compared to WWTP influent)
Description	This metric indicates what is the percentage of pollutant load that the WWTP eliminates from the industry water.
Unit	%
Equation	$$Eff_P = \frac{P_{infl} - P_{effl}}{P_{infl}} \cdot 100$$ **Where:** EffP: percentage of treatment efficiency of p (compared to WWTP influent) Pinfl: load of P in the influent Peffl: load of P in the effluent
Impact categories	• > 25 Very high impact • 25 – 50 High impact • 50 – 75 Medium impact • < 75 Low impact The impact categories have been established by a panel of ICRA experts.

2.1.4 Dilution of the discharge

The below indicators support understanding the dilution of the discharge and the relative weight of the discharge compared to the river flows and concentrations. The lever for action is actually Reducing the volume and/or concentrations of the effluent discharged, as this will reduce the concentration of pollutants in the receiving water body.

Name	**Concentration of the pollutant in the water body after discharge**
Description	Concentration of pollutants in the water body after discharge of the effluent. It accounts for the river body concentration prior to discharge if river quality data prior to discharge was entered by the user. If the river concentration prior to discharge is not documented by the user, the tool assumes a concentration of Zero, and this indicator becomes the same as the next indicator "increase of the concentration".
Unit	g/m3
Equation	$C = \frac{C_{WB} \cdot W_a - C_{WB} \cdot W_w + C_{effl} \cdot W_{effl}}{W_a - W_w + W_{effl}}$ Where: Concentration of pollutant in the same water body where water was withdrawn after discharging water C_{WB}:river concentration prior to discharge (g/m3) W_a :amount of water available in the river (streamflow global indicator) (m3/day) W_w: amount of water withdrawn from the river (m3/day) C_{effl}: concentration of pollutant in the industry effluent discharged to the same water body where water was withdrawn (g/m3) W_{effl}: amount of water dischaarged to the water body (m3/day) Note: If no data was entered by the user on the intake concentration, this indicator will display the same value as the next indicator "increase of the concentration".

Name	**Increase of the concentration (in the receiving water body)**
Description	Increase in the concentration of the pollutant in the receiving water body calculates the increment of the industry pollutants on the receiving water, it calculates the final concentration in the river supposing the receiving water has a concentration of 0. This is why this indicator is named "increase", as the value obtained needs to be added to the river concentration prior to the discharge point, in order to obtain the concentration after discharge (see previous indicator "concentration of pollutants"
Unit	g/m3
Equation	$Delta = \frac{PP_{effl}}{W_a - W_w + W_{effl}}$ Where: Increase in the concentration in the receiving water body after industry discharge, considering the concentration of the industry discharge before industry discharge is 0 (g/day) (m3/day) (m3/day) (m3/day)

Name	Toxic units in the receiving water body
Description	Toxic units in the receiving water body after dilution of the industry discharge into the water body.
Unit	TU/Day
Equation	$$TU = \frac{1000 \cdot C_{PP}}{EC50_{PP}}$$ Where: *TU: ecotoxicity potential of a PP* C_{PP}: Concentration of PP in the water body after discharging water (g/m3) $EC50_{PP}$: Values of EC50 from the database

Name	Concentration of the pollutants in the water body (with respect to EQS)
Description	The Environmental Quality Standards (EQS) are the limits approved by the EU's Water Framework Directive. The directive sets environmental quality standards for priority pollutants (PP) and eight other pollutants. These substances include the metals cadmium, lead, mercury and nickel, and their compounds; benzene; polyaromatic hydrocarbons (PAH); and several pesticides. Several of these priority substances are classed as hazardous. Each PP has a maximum allowable concentration (MAC) for inland surface waters. This metric indicates if the concentration of the pollutant in the industry effluent is higher than the MAC (> 100%) or lower (< 100%). (Priority Substances - Water - Environment - European Commission, n.d.)
Unit	%
Equation	$$EQS = \frac{100 \cdot C_{PP}}{EQS_{PP}}$$ Where: C_{PP}: Concentration of PP in the receiving water body after industry discharge (g/m3) EQS_{PP}: Maximum allowable concentration of a PP in the EU's Water Framework directive

Name	Percentage of treatment efficiency (compared to intake water)
Description	This metric indicates whether there is an improvement in water quality due to its use by the industry. If the quality of the water after treatment is better than the industry withdrawal water quality (surface water only), then the value of this metric is greater than 100. This is only calculated for COD, TN and TP when the "advanced inputs" provide a value under "Industry withdrawal water quality (surface water only)"
Unit	%
Equation	$$Eff_P = \frac{P_{effl}}{P_{industry}} \cdot 100$$ **Where:** EffP: percentage of treatment efficiency (compared to industry influent) of a pollutant Peffl: load of a pollutant in the effluent of the WWTP $P_{industry}$: load of a pollutant in the influent of the industry
Impact categories	• > 100 Negative Impact • < 100 Positive impact The impact categories have been established by a panel of ICRA experts.

Name	Treated water factor
Description	This metric indicates the ratio between the water remaining after the industry consumption and the water that is treated in the WWTP.
Unit	%
Equation	$$TWF = \frac{W_t}{OWWTP_i + EWWTP_i + DD} \cdot 100$$ **Where:** TWF: ratio between the water remaining after the industry consumption and the water that is treated Wt: amount of water used by the industry that is treated in a WWTP OWWTPi: Onsite industrial WWTP influent EWWTPi: External WWTP influent DD: Directly discharged water
Impact categories	• > 25 Very high impact • 25 – 50 High impact • 50 – 75 Medium impact • < 75 Low impact The impact categories have been established by a panel of ICRA experts.

Name	Increase in the concentration of the pollutant in the receiving water body
Description	Increase in the concentration of the pollutant in the receiving water body is a calculation of the increment of the industry pollutants on the receiving water, it calculates what are the final concentration on the river will be supposing the receiving water has a concentration of 0. The delta load is calculated for COD, Total Nitrogen, Total phosphorus, and the PP. This lever for action is shown in the web tool as "concentration of pollutants" alongside with the concentration of the industry water discharged.
Unit	g/m3
Equation	$Delta = \frac{PP_{effl}}{W_a + W_{effl} - W_w}$ **Where:** Delta: Increase in the concentration of pollutant in the receiving water body PPeffl: load of the PP in the effluent W_a: amount of water available in the river, which is extracted from the stream flow global indicator Weffl: amount of water that the industry discharge in the river WW: amount of water withdrawn from the river

SECTION 3: CARBON-RELATED IMPACTS

3.1 GHG emissions

This metric indicates the GHG emissions from the industry. It counts the amount of CO_2 equivalent that is produced during the water treatment, water discharge, the emissions from sludge management and the emissions from biogas. It will always have positive values; higher values indicate higher impact. The methodology to calculate the global warming potential is from the Energy Performance and Carbon Emissions Assessment and Monitoring Tool (ECAM). (Sanitation Treatment, n.d.).

Name	**Indirect emissions from electricity consumption (IEFEC)**
Unit	$KgCO_2eq/day$
Equation	$$\text{IEFEC} = convkwh \cdot nrgcons \cdot W_t$$ **Where:** convkwk: Emission factor for grid electricity; nrgcons: Electricity consumed from the grid for wastewater treatment per cubic meter treated; W_t: Amount of water treated

Name	**Emissions from fuel engines (EFFE)**
Description	Direct CO_2 emitted from on-site engines in wastewater stages based upon sum of CO_2, CH_4 and N_2O emission from stationary combustion
Unit	$KgCO_2eq/day$
Equation	$$ECO_2 = \frac{V \cdot FD_{CO_2} \cdot NCV_{CO_2} \cdot EF_{CO_2}}{1000}$$ $$EN_2O = \frac{V \cdot FD_{N_2O} \cdot NCV_{N_2O} \cdot EF_{N_2O} \cdot EQ_{N_2O}}{1000}$$ $$ECH_4 = \frac{V \cdot FD_{CH_4} \cdot NCV_{CH_4} \cdot EF_{CH_4} \cdot EQ_{CH_4}}{1000}$$ $$\text{EFFE} = ECO_2 + ECH_4 + EN_2O$$ **Where:** V: Volume of fuel consumed; EQN_2O: Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$); $EQCH_4$: Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$)

Table of equation values

Fuel type	$EFCH_4$ (kg/TJ)	EFN_2O (kg/TJ)	$EFCO_2$ (kg/TJ)	FD (kg/L)	NCV (TJ/Gg)
Diesel	3	0,6	74100	0,84	43
Gasoline/Petrol	3	0,6	69300	0,74	44,3
Natural Gas	10	0,1	56100	0,75	48

(Wagner & Walsh, n.d.)

Name	Emissions from treatment (EFT)
Unit	$KgCO_2eq$/day
Equation	$$CH_4 = (bodinfl - bodslud) \cdot CH_4efactre \cdot CH_4eq$$ $$N_2O = (\text{tninfl}) \cdot N_2Oefactre \cdot NtoN_2O \cdot N_2Oeq$$ $$EFT = CH_4 + N_2O$$ **Where:** bodinfl: influent COD load bodslud: COD removed as sludge CH_4efactre: CH_4 emission factor CH4eq: conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) tninfl: Total Nitrogen load in the influent N_2Oefactre: N_2O emission factor $NtoN_2O$: N_2O-N to N20 conversion factor (1.57 gN_2O/gN_2O-N) N_2Oeq: conversion of N_2O to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) (Deborah Bartram et al., 2019)

Name	Sludge composted
Description	Amount of CO_2eq emissions due to sludge composted
Unit	$KgCO_2eq/day$
Equation	$Ncont = \frac{slucompNcont}{100}$ $TVS = \frac{slucompTVS}{100}$ $\textbf{If emissions are treated, or piles covered}: CH_4 = 0$ $\textbf{Else}:$ $CH4 = sludgemass \cdot TVS \cdot TVStoOC \cdot \text{upEF} \cdot \text{OCto}CH_4 \cdot ctCH_4eq$ $\textbf{If ratio CN} > \textbf{30}: N_2O = 0$ $\textbf{Else if: solid content of compost} > \textbf{55}: N_2O = 0$ $\textbf{Else}:$ $N_2O = sludgemass \cdot Ncont \cdot lowCNEF \cdot \text{ctNto}N_2O4428 \cdot ctN_2Oeq$ $CO_2SC = CH_4 + N_2O$ **Where:** sludgemass: Amount of sludge that is sent to composting (dry weight) slucompTVS: Total Volatile Solids (TVS) content of sludge composted (% of dry weight). TVStoOC: Organic Carbon content in Volatile Solids (0,56 gOC/gVS) upEF: CH_4 emission factor for uncovered pile (fraction of initial C in solids) OCtoCH_4: Organic C to CH_4 conversion factor (=16/12 gCH_4/gOC) ctCH4eq: Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) slucompNcont: N content of sludge stored (% of dry weight) lowCNEF: N_2O emission factor for low C:N ratio ctNtoN_2O4428: N_2O-N to N_2O conversion factor (44/28 gN_2O/gN_2O-N) ctN_2Oeq: Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) CO_2SC: Amount of CO_2eq emissions due to sludge composted
Source	Section 12.8 "Composting", Beam page 147 (page 169 in PDF)

Name	Land application of sludge
Description	Amount of CO_2eq emissions due to land application of sludge. The emission are nitrous oxide emissions converted to CO_2 equivalent.
Unit	$KgCO_2eq/day$
Equation	Where: $CO_2LA = N_2O$ $\boldsymbol{If\ ratioCN > 30}: N_2O = 0$ $\boldsymbol{Else\ if\ biosolids\ are > 80\%\ Dry\ Matter}:$ $N_2O = 0{,}5 \cdot sludgemass \cdot Ncont \cdot EF \cdot ctNtoN_2O4428 \cdot ctN_2Oeq$ $\boldsymbol{Else:}$ $N_2O = sludgemass \cdot Ncont \cdot EF \cdot ctNtoN_2O4428 \cdot ctN_2Oeq$ **Where**: $Ncont = \frac{slulaNcont}{100} \qquad TVS = \frac{slucompTVS}{100}$ $Ccontent = sludgemass \cdot TVS \cdot TVStoOC$ $Ncontent = sludgemass \cdot Ncont$ $ratioCN = \frac{Ccontent}{Ncontent}$ Where: ***sludgemass:*** Amount of sludge that is sent to land application (dry weight) (kg/day) ***TVStoOC:*** Organic Carbon content in Volatile Solids (0,56 gOC/gVS) ***slulaNcont:*** N content of sludge sent to land application (% of dry weight) ***SlucompTVS:*** Total Volatile Solids (TVS) content of sludge composted (% of dry weight). ***EF:*** Amount of Nitrogen converted to N_2O (kgN_2O-N/kgN) ***ctNtoN₂O4428:*** N_2O-N to N_2O conversion factor (=44/28 gN_2O/gN_2O-N) ***ctN₂Oeq:*** Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) ***CO₂LA:*** Amount of CO_2eq emissions due to land application of sludge
Source	Section 12.11 "Land application", Beam page 166

Name	Sludge incineration
Description	Amount of CO_2eq emissions due to sludge incineration CO_2 emissions from the organic carbon burnt is considered biogenic, so the CO_2eq emissions correspond to CH_4 and N_2O emissions, which occur when the incinerator temperature is below 1023deg K.
Unit	$KgCO_2eq$/day
Equation	***If SNCR methods are used****: $CO_2SI = CH_4 + N_2O$ Where: $CH_4 = (4{,}85e-5) \cdot sludgemass \cdot ctCH_{4eq}$ $N_2O = 1{,}2 \cdot sludgemass \cdot Ncont \cdot n \cdot ctN_2Oeq$ with: $n = \frac{161{,}3 - 0{,}14 \cdot Tf}{100}$ $\textbf{Considering that if } \boldsymbol{Tf < 1023} \text{ then use } Tf = 1023$ $\textbf{If } \boldsymbol{n < 0}\textbf{, then use } n = 0$ Where: ***sludgemass:*** Amount of sludge that is sent to incineration (dry weight) (kg/day) ***ctCH4eq:*** Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) ***Ncont:*** N content of sludge incinerated (% of dry weight) ***Tf:*** Average highest temperature of combustion achieved in a Fluidized Bed incinerator (K) ***ctN₂Oeq:*** Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) ***CO₂ SI:*** Amount of CO_2eq emissions due to sludge incineration *SNCR (Selective Non-Catalytic Reduction) uses the injection of ammonia or urea into the backend of the combustion chamber to reduce NO to N2
Source	Section 12.10 “Combustion (Incineration)”, Beam, page 161

Name	Landfilling of sludge
Description	Fugitive methane emissions from biosolids decomposition in the landfill during the first 3 years after placement, and N2O emissions from landfilled biosolids
Unit	KgCO2eq/day
Equation	$CO_2LFS = CH_4 + N_2O$ **Where:** $CH_4 = sludgemass \cdot TVS \cdot TVStoOC \cdot un \cdot OCtoCH_4 \cdot CH_4gas \cdot DOCf \cdot dc3yr \cdot MCF \cdot ctCH_4eq$ $N_2O = sludgemass \cdot Ncont \cdot lowCNEF \cdot NtoN_2O \cdot ctN_2Oeq$ **Where:** $DOCf = \frac{slulfDOCf}{100}$ $CH_4gas = \frac{slulfCH_4ingas}{100}$ $TVS = \frac{slucompTVS}{100}$ $Ncont = \frac{slulfNcont}{100}$ $dc3ry = \frac{slulfdecomp3yr}{100}$ Where: ***sludgemass:*** Amount of sludge that is sent to landfilling (dry weight) (kg/day) ***slucompTVS:*** Total Volatile Solids (TVS) content of sludge composted (% of dry weight) ***TVStoOC:*** Organic Carbon content in Volatile Solids (0,56gOC/gVS) ***un***: Model uncertainty factor ***OCtoCH₄:*** Organic C to CH_4 conversion factor (=16/12 gCH_4/gOC) ***slulfCH₄ingas:*** CH_4 in landfill gas ***slulfDOCf:*** Decomposable organic fraction of raw wastewater solids ***slulfdecomp3yr:*** Percentage decomposed in first 3 years of the decomposable organic fraction of raw wastewater solids. ***MCF:*** Methane correction for anaerobic managed landfills ***ctCH₄eq:*** Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) ***slulfNcont:*** N content of sludge sent to landfilling (% of dry weight) ***lowCNEF:*** N_2O emission factor for low C:N ratio (kgN_20-N/kgN) ***NtoN₂O:*** N_2O-N to N_2O conversion factor (=44/28 gN_2O/gN_2O-N) ***ctN₂Oeq:*** Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) ***CO₂ LFS:*** Amount of CO_{2eq} due to Landfilling of sludge
Source	Section 12.9 “Landfill disposal”, page 153, Beam methodology document

Name	Sludge stockpiling
Description	Amount of CO2eq emissions due to sludge stockpiling
Unit	$KgCO_2eq/day$
Equation	$$CO_2SP = CH_4 + N_2O + CO_2$$ $$CH_4 = lifespan\_dec \cdot rate_{CH4}(lifespan\_int) + \sum_{i=0}^{lifespan\_int-1} rate_{CH4}(i)$$ $$N_2O = lifespan\_dec \cdot rate_{N2O}(lifespan\_int) + \sum_{i=0}^{lifespan\_int-1} rate_{N2O}(i)$$ $$CO_2 = lifespan\_dec \cdot rate_{CO2}(lifespan\_int) + \sum_{i=0}^{lifespan\_int-1} rate_{CO2}(i)$$ $$lifespan\_int = \lfloor lifespan \rfloor$$ $$lifespan\_dec = lifespan - lifespan\_dec$$ $$rate_{CH4}(i) = \begin{cases} sludgemass \cdot 0.2 \cdot 10^{-3} & \text{if } i < 1 \\ sludgemass \cdot 2 \cdot 10^{-3} & \text{if } 1 <= i < 3 \\ sludgemass \cdot 9.8 \cdot 10^{-3} & \text{if } 3 <= i < 20 \\ 0 & \text{if } i >= 20 \end{cases}$$ $$rate_{N2O}(i) = \begin{cases} sludgemass \cdot 60 \cdot 10^{-3} & \text{if } i < 1 \\ sludgemass \cdot 26.8 \cdot 10^{-3} & \text{if } 1 <= i < 3 \\ sludgemass \cdot 17.4 \cdot 10^{-3} & \text{if } 3 <= i < 20 \\ 0 & \text{if } i >= 20 \end{cases}$$ $$rate_{CO2}(i) = \begin{cases} sludgemass \cdot 30.1 \cdot 10^{-3} & \text{if } i < 1 \\ sludgemass \cdot 30.5 \cdot 10^{-3} & \text{if } 1 <= i < 3 \\ sludgemass \cdot 10.1 \cdot 10^{-3} & \text{if } 3 <= i < 20 \\ 0 & \text{if } i >= 20 \end{cases}$$ Where: ***sludgemass:*** Amount of sludge that is stockpiled (dry weight) (kg/day) ***lifespan:*** Expected timespan than the biosolid stockpile (BSP) will be emitting GHGs (years) ***CO_2SP:*** Amount of CO2eq emissions due to sludge composted
Source	Majumder, R., Livesley, S., Gregory, D., & Arndt, S. (2014, 05 15). Biosolids stockpiles are a significant point source for greenhouse gas emissions. Journal of Environmental Management, 143, pp. 34-43.

Name	Sludge storage
Description	Amount of CO_{2eq} emissions related to sludge storage. The emission are methane emissions converted to CO_2 equivalent.
Unit	$KgCO_{2eq}$/day
Equation	$CO_2SS = CH_4$ $CH_4 = CH_4potencial \cdot CH_4EF \cdot ctCH_4eq$ **Where**: $CH_4potential = sludgemass \cdot TVS \cdot TVStoOC \cdot OCtoCH_4 \cdot FCH_4$ $TVS = \frac{slustoTVS}{100}$ $FCH_4 = \frac{slustoFCH_4}{100}$ $CH_4EF = \frac{slustoEF}{100}$ Where: ***sludgemass:*** Amount of sludge that is stored prior to disposal (kg) ***slustoEF:*** Emission factor due to storage (%) (%) ***slustoTVS:*** Total Volatile Solids (TVS) content of sludge stored (% of dry weight). ***$slustoFCH_4$:*** CH_4 potential factor (%) ***TVStoOC:*** Organic Carbon content in Volatile Solids (0,56gOC/gVS) ***$OCtoCH_4$:*** Organic C to CH_4 conversion factor (=16/12 gCH_4/gOC) ***$ctCH_{4eq}$:*** Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) ***CO_2SS:*** Amount of CO_2 eq due to sludge storage
Source	(ECAM V3, n.d.)

Name	Truck transport of sludge
Description	Indirect CO_2 emitted from sludge transport off-site
Unit	$KgCO_2eq/day$
Equation	$CO_2 = \frac{vol \cdot fuelFD \cdot fuelNCV \cdot fuelEFCO_2vehicles}{1000}$ $N_2O = \frac{vol \cdot fuelFD \cdot fuelNCV \cdot fuelEFN_2Ovehicles \cdot ctN_2Oeq}{1000}$ $CH_4 = \frac{vol \cdot fuelFD \cdot fuelNCV \cdot fuelEFCH_4vehicles \cdot ctCH_4eq}{1000}$ $CO_2TTS = CO_2 + N_2O + CH_4$ Where: V: Volume of fuel consumed ctN_2Oeq: Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) $ctCH_4eq$: Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) CO_2TTS: Amount of CO_2 eq due to truck transport of sludge.
Source	IPCC 2006, Volume 2, Chapter 3: Mobile Combustion, Table 3.2.2 (page 21)

Table of equation values

Fuel type	$EFCH_4$ (kg/TJ)		EFN_2O (kg/TJ)		$EFCO_2$ (kg/TJ)	FD (kg/L)	NCV (TJ/Gg)
	engines	vehicles	engines	vehicles			
Diesel	3	3.9	0.6	3.9	74100	0.84	43
Gasoline/ Petrol	3	3.8	0.6	1.9	69300	0.74	44.3
Natural Gas	10	92	0.1	0.2	56100	0.75	48

Name	Total emissions from Sludge management
Description	GHG emissions from sludge management operations (storing, composting, incineration, land application, landfilling, stockpiling and truck transport).
Unit	$KgCO_2eq/day$
Equation	$$CO_2SM = CO_2SC + CO_2SI + CO_2LA + CO_2LFS + CO_2SP + CO_2SS + CO_2TTS$$ CO_2SM: Total emissions from Sludge management CO_2SC: Amount of CO_2eq emissions due to sludge composted CO_2SI: Amount of CO_2eq emissions due to sludge incineration CO_2LA: Amount of CO_2eq emissions due to land application of sludge CO_2LFS: Amount of CO_2eq due to Landfilling of sludge CO_2SP: Amount of CO_2eq emissions due to sludge composted CO_2SS: Amount of CO_2eq emissions related to sludge storage CO_2TTS: Amount of CO_2eq due to truck transport of sludge.

Name	Water reuse transport (EFWRT)
Unit	$KgCO_2eq/day$
Equation	$$ECO_2 = \frac{V \cdot FD_{CO_2} \cdot NCV_{CO_2} \cdot EF_{CO_2}}{1000}$$ $$ECH_4 = \frac{V \cdot FD_{CH_4} \cdot NCV_{CH_4} \cdot EF_{CH_4} \cdot EQ_{CH_4}}{1000}$$ $$EN_2O = \frac{V \cdot FD_{N_2O} \cdot NCV_{N_2O} \cdot EF_{N_2O} \cdot EQ_{N_2O}}{1000}$$ $$E_{TOTAL} = ECO_2 + ECH_4 + EN_2O$$ V: Volume of fuel consumed EQN_2OEQN_2O: Conversion of N_2O emissions to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$) $EQCH_4EQCH_4$: Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$)

Table of equation values

Fuel type	$EFCH_4$ (kg/TJ)	EFN_2O (kg/TJ)	$EFCO_2$ (kg/TJ)	FD (kg/L)	NCV (TJ/Gg)
Diesel	3,9	3,9	74100	0,84	43
Gasoline/Petrol	3,8	1,9	69300	0,74	44,3
Natural Gas	92	0,2	56100	0,75	48

(Davies Waldron, 2006)

Name	Emissions from water discharged (EFWD)
Unit	$KgCO_2eq/day$
Equation	$$CH_4 = bodeffl \cdot CH_4efacdis \cdot CH_4eq$$ $$N_2O = tneffl \cdot N_2Oefacdis \cdot NtoN_2O \cdot N_2Oeq$$ $$DW_e = CH_4 + N_2O$$ Bodef fl: Effluent COD load CH_4ef acdis: CH_4 emission factor CH_4eq: conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$) tnef fl: Total Nitrogen load in the effluent N_2O ef acdis: N_2O emission factor N to N_2O: N_2O-N to N_20 conversion factor (1.57 gN_2O/gN_2O-N) N_2O eq: conversion of N_2O to CO_2 equivalent emissions (298 $kgCO_2eq/kgN_2O$)

Name	Biogas (anaerobic digestion of sludge)
Description	GHG emissions from biogas
Unit	$KgCO_2eq/day$
Equation	$$biogas_{produced} = \frac{P \cdot V}{R \cdot T}$$ $$biogas_{leaked} = biogas_{produced} \cdot \frac{biogas_{leaked}}{100} \cdot \frac{biog_{CH_4}}{100} \cdot \frac{16}{1000} \cdot EQ_{CH_4}$$ $$EFB = biogas_{leaked}$$ Where: P: $1.013 \cdot 10^5$ Pa V: Volume of biogas produced in the WWTP R: 8,31446261815324 J/K.mol T: 273,15K $BiogCH_4$: Percent of the methane content in the produced biogas $Biog_{leaked}$: Biogas leaked to the atmosphere (%volume) $EqCH_4$: Conversion of CH_4 emissions to CO_2 equivalent emissions (34 $kgCO_2eq/kgCH_4$)
Source	IPCC 2006, Volume 5, Chapter 4 Biological treatment of solid waste, equation 4.1, page 5

Name	Fuel (digester)
Description	Amount of CO_2 eq emissions due to fuel employed for digester
Unit	$KgCO_2eq/day$
Equation	$CO_2 = \frac{vol \cdot fuelFD \cdot fuelNCV \cdot fuelEFCO_2engines}{1000}$ $N_2O = \frac{vol \cdot fuelFD \cdot fuelNCV \cdot fuelEFN_2Oengines \cdot ctN_2Oeq}{1000}$ $CH_4 = \frac{vol \cdot fuelFD \cdot fuelNCV \cdot fuelEFCH_4engines \cdot ctCH_4Oeq}{1000}$ $fuel = CO_2 + N_2O + CH_4$ Where: vol: Volume of fuel consumed ctN_2Oeq: Conversion of N_2O emissions to CO_2 equivalent emissions ($298\ kgCO_2eq/kgN_2O$) $ctCH_4eq$: Conversion of CH_4 emissions to CO_2 equivalent emissions ($34\ kgCO_2eq/kgCH_4$) fuel: Amount of CO_2 eq due to fuel employer for digester.
Source	IPCC 2006, Volume 2, Chapter 3: Mobile Combustion, Table 3.2.2 (page 21)

Table of equation values

Fuel type	$EFCH_4$ (kg/TJ)		EFN_2O (kg/TJ)		$EFCO_2$ (kg/TJ)	FD (kg/L)	NCV (TJ/Gg)
	engines	vehicles	engines	vehicles			
Diesel	3	3.9	0.6	3.9	74100	0.84	43
Gasoline/ Petrol	3	3.8	0.6	1.9	69300	0.74	44.3
Natural Gas	10	92	0.1	0.2	56100	0.75	48

Name	Total emissions
Description	Total emissions of GHG. This metric has no impact categories because it is not possible to put a limit on the amount of GHG emitted, each company must set its impact categories.
Unit	$KgCO_2eq/day$
Equation	$$TE = IEFEC + EFFE + EFT + EFB + EFD + EFWRT + + EFWD + EFSM$$ Where: IEFEC: **Indirect emissions from electricity consumption** EFFE: **Emissions from fuel engines** EFT: **Emissions from treatment** EFB: **Emissions from biogas leaked** EFD: **Emissions due to fuel employed for digester** EFWRT: **Emissions from water reuse transport** EFWD: **Emissions from water discharged** EFSM: **Emissions from sludge management**

GLOSSARY

Dependency	The reliance of a business on its use of a natural capital.
Externality	A consequence of an action that affects someone other than the actor undertaking the action and for which the actor neither receives compensation nor bears penalties. Externalities can be either positive or negative.
Impact driver	A measurable quantity of a natural resource used as an input in production (example, freshwater used to manufacture a food product) or a measurable non-product output of business activity (such as effluent discharged from the industrial activity). Impact drivers are generally expressed in quantitative units and companies may already include them in non-financial reporting or generate them through life-cycle assessments.
Impact	The positive or negative effect of a business activity on one or more dimensions of well-being. A single impact driver may be associated with multiple impacts.
Impact pathway	Describes how, as a result of a specific business activity, a particular impact driver results in changes in natural capital and how these changes impact different stakeholders.
Impact valuation	The monetary assessment of the impact or the valuation of the change in economic value attributable to the business activity.
Life-cycle assessment (LCA)	Also known as life-cycle analysis, this is a technique used to assess the environmental impacts of a product or service through all stages of its life cycle, from material extraction to end of life (disposal, recycling or reuse). The International Organization for Standardization (ISO) has standardized the LCA approach under ISO[60] 14040. Several life-cycle impact assessment (LCIA) databases provide a useful library of published estimates of different products and processes.
Shadow price	The estimated financial value of a natural capital for which no market price exists. The shadow price of an impact driver is the change in economic value from capital changes due to one additional unit of the impact driver.
Water footprint	The amount of water a process, product, company or sector uses. It includes both direct and indirect water use and wastewater polluted.
Water withdrawal (or use)	Describes the total amount of water withdrawn from its source for use. Measures of water use help evaluate the level of use demand.
Water consumption	The portion of water use not returned to the original water source after withdrawal. Consumption happens when water evaporates into the atmosphere or is incorporated into a product and is no longer available for reuse.

Endnotes

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This report has been developed in the name of WBCSD. Like other WBCSD publications, it is the result of a collaborative effort by WBCSD staff, experts and executives from member companies. A wide range of members reviewed drafts, thereby ensuring that the document broadly represents the perspective of the WBCSD membership. Input and feedback from stakeholders listed above was incorporated in a balanced way. This does not mean, however, that every member company or stakeholder agrees with every word.

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WBCSD is the premier global, CEO-led community of over 200 of the world's leading sustainable businesses working collectively to accelerate the system transformations needed for a net zero, nature positive, and more equitable future.

We do this by engaging executives and sustainability leaders from business and elsewhere to share practical insights on the obstacles and opportunities we currently face in tackling the integrated climate, nature and inequality sustainability challenge; by co-developing "how-to" CEO-guides from these insights; by providing science-based target guidance including standards and protocols; and by developing tools and platforms to help leading businesses in sustainability drive integrated actions to tackle climate, nature and inequality challenges across sectors and geographical regions.

Our member companies come from all business sectors and all major economies, representing a combined revenue of more than USD $8.5 trillion and 19 million employees. Our global network of almost 70 national business councils gives our members unparalleled reach across the globe. Since 1995, WBCSD has been uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues.

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