Establishing a framework for a Sustainable Lending Product for the NZ Water sector

Planetary Boundary KPIs for Water Entities

New Zealand Local Government Funding Agency

25/6/2026

Executive Summary

New Zealand's water sector is at a critical juncture, facing ageing infrastructure, population growth, and mounting environmental pressures. The Department of Internal Affairs estimates between NZ$120 billion and NZ$185 billion will need to be invested over the next 30 years (DIA, 2021). To better manage these challenges, local governments are forming Council Controlled Organisations (Water CCOs) for water services delivery, which will have access to a new Sustainable Lending Product (SLP) through the New Zealand Local Government Funding Agency (LGFA). The SLP will consider holistic environmental impacts beyond carbon, with borrowers reporting against one compulsory and one of three optional key performance indicators (KPIs) aligned to the Planetary Boundaries.

The Planetary Accounting Network (PAN) was engaged to support LGFA to select and calibrate KPIs and Sustainability Performance Targets (SPTs) that align with Sustainability-Linked Loan Principles (SLLPs). This report sets out the KPIs and SPTs, and summarises how these have been determined according to SLLPs.

Planetary Boundaries & Planetary Accounting

The Planetary Boundaries is a scientific framework that defines a "safe operating space for humanity" — setting out the critical global environmental limits needed to avoid irreversible and catastrophic environmental change. In 2009, humanity was exceeding three of these nine boundaries. In 2026, we are exceeding seven.

PAN uses a scientifically peer-reviewed framework called Planetary Accounting, which translates the Planetary Boundaries to any scale of activity — extending carbon accounting to quantify broader environmental impacts in the context of these global limits. This enables informed decision-making on environmental trade-offs and supports transparent communication of environmental performance.

Approach

In the first phase of this work, PAN and LGFA ran workshops with water sector stakeholders to understand what environmental data is currently (or will be) captured by new water entities. PAN then completed a gap assessment against the Planetary Boundaries, to establish a heatmap to guide KPI selection. This phase resulted in a long-list of potential KPIs.

In the second phase, PAN undertook a national Planetary Accounting assessment of New Zealand's water sector, across drinking water supply, wastewater treatment, and capital works, to quantify the relative materiality of KPIs, and establish a national benchmark of the water sector impacts on the Planetary Boundaries.

The materiality was used to select final KPIs from the long-list; and to determine the compulsory vs optional KPIs.

The national assessment showed that phosphorus, nitrogen, biogenic greenhouse gases, water use, and carbon+ are the most material environmental impacts within the New Zealand water sector respectively. As such, a KPI was established for each of these impact categories.

Preliminary targets were established for each KPI. Both top-down and bottom-up approaches were considered; i.e. scaling the Planetary Boundaries to local scales as well as considering local environmental constraints such as nutrient assimilation capacity. Local regulations and consent conditions, feasibility , and transition periods were also taken into consideration. Targets were set at the most ambitious threshold from top-down and bottom-up approaches, within feasibility and transition constraints.

Industry feedback was sought on the preliminary targets from water sector stakeholders and SLLP subject matter experts. This feedback was considered in the finalisation of the KPIs and targets.

The KPIs

The KPIs recommended for the Sustainable Lending Product are:

- Nitrogen & Phosphorus (Compulsory): Percentage reduction in concentration of total N and P per litre of wastewater discharged, determined against Planetary Boundary-aligned reduction trajectories according to the discharge renewal consent year.
- Biogenic GHGs (Optional): Improved measurement of methane and nitrous oxide from wastewater treatment and biosolids disposal — Level 2 within 2 years of entering the programme, and facility-level Level 3 by 2040.
- Embodied Carbon (Optional): Measurement of prospective embodied GHG emissions of projected infrastructure capital spend programme, for at least 80% of anticipated spend in a 3-5 year period that starts one year after entering the programme.
- Water Efficiency (Optional): Reduction in gross water consumption (including losses) of at least 7% per five-year period from a three-year average baseline.

Nitrogen and Phosphorus is compulsory for all Water CCOs, reflecting the high materiality of nutrient discharge to New Zealand's already stressed freshwater systems. Water CCOs must select one additional KPI from the three optional.

Alignment with Sustainability-Linked Loan Principles

The recommended KPIs are designed to align with the SLLPs. They are material to water sector operations, measurable using consistent and transparent methodologies, externally verifiable, and benchmarked against credible external references — the Planetary Boundaries. Targets are ambitious, requiring meaningful acceleration beyond business-as-usual, while remaining technically and practically achievable given the sector's current starting position. PAN recommends that targets be reviewed every two years to support continued alignment with the best available science as the Planetary Boundaries framework continues to evolve, and continued ambition of the water sector as environmental maturity grows.

Planetary Boundary KPIs for Water Entities

Nitrogen (N) and Phosphorus (P)

Reduction in concentration of total nitrogen and phosphorus per litre of wastewater discharged to the environment.

Biogenic GHGs

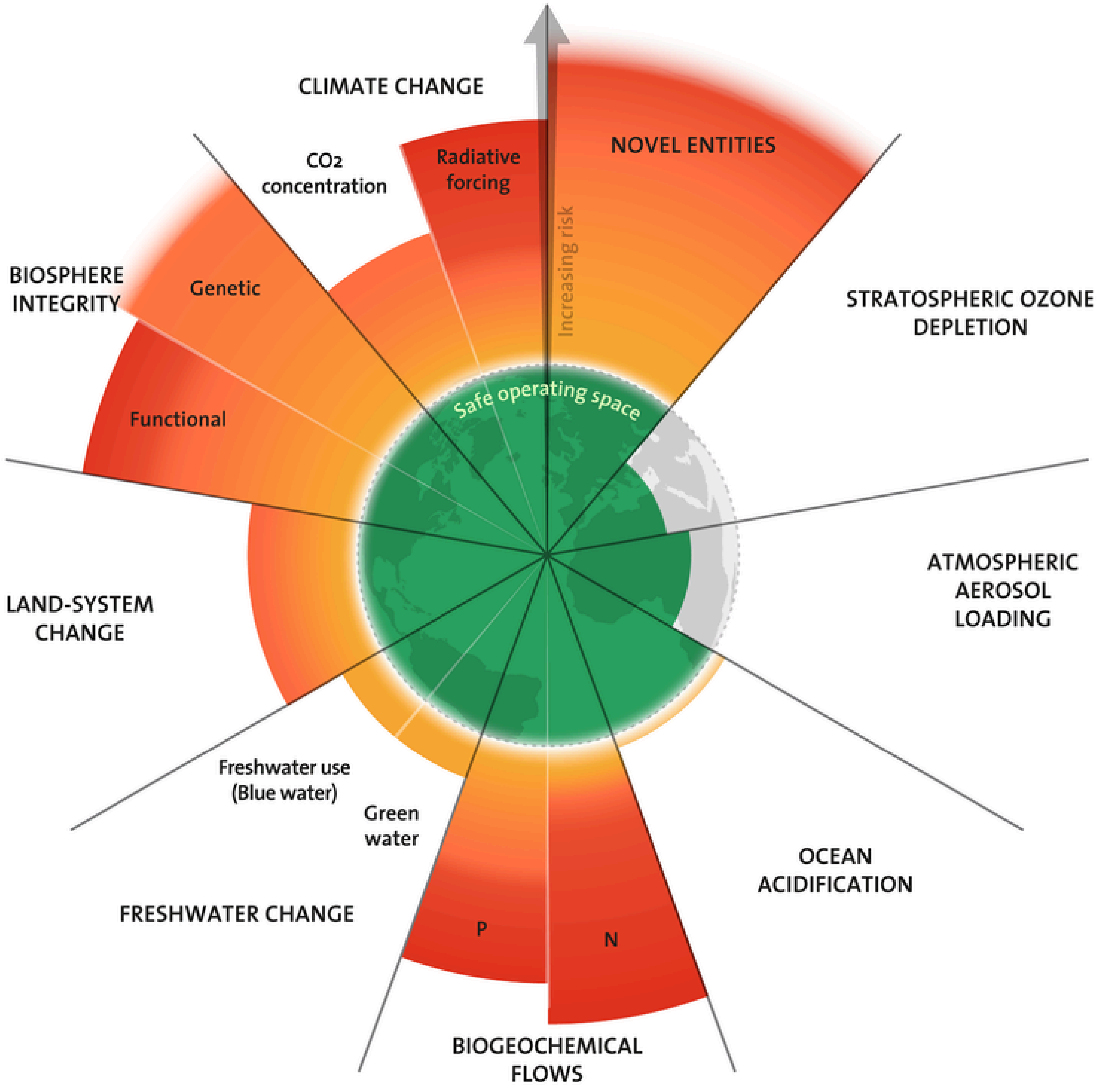
Improved measurement of greenhouse gases produced from wastewater treatment processes and biosolids disposal.

Carbon+

Measurement of carbon dioxide and fossil-based greenhouse gas emissions from capital works projects.

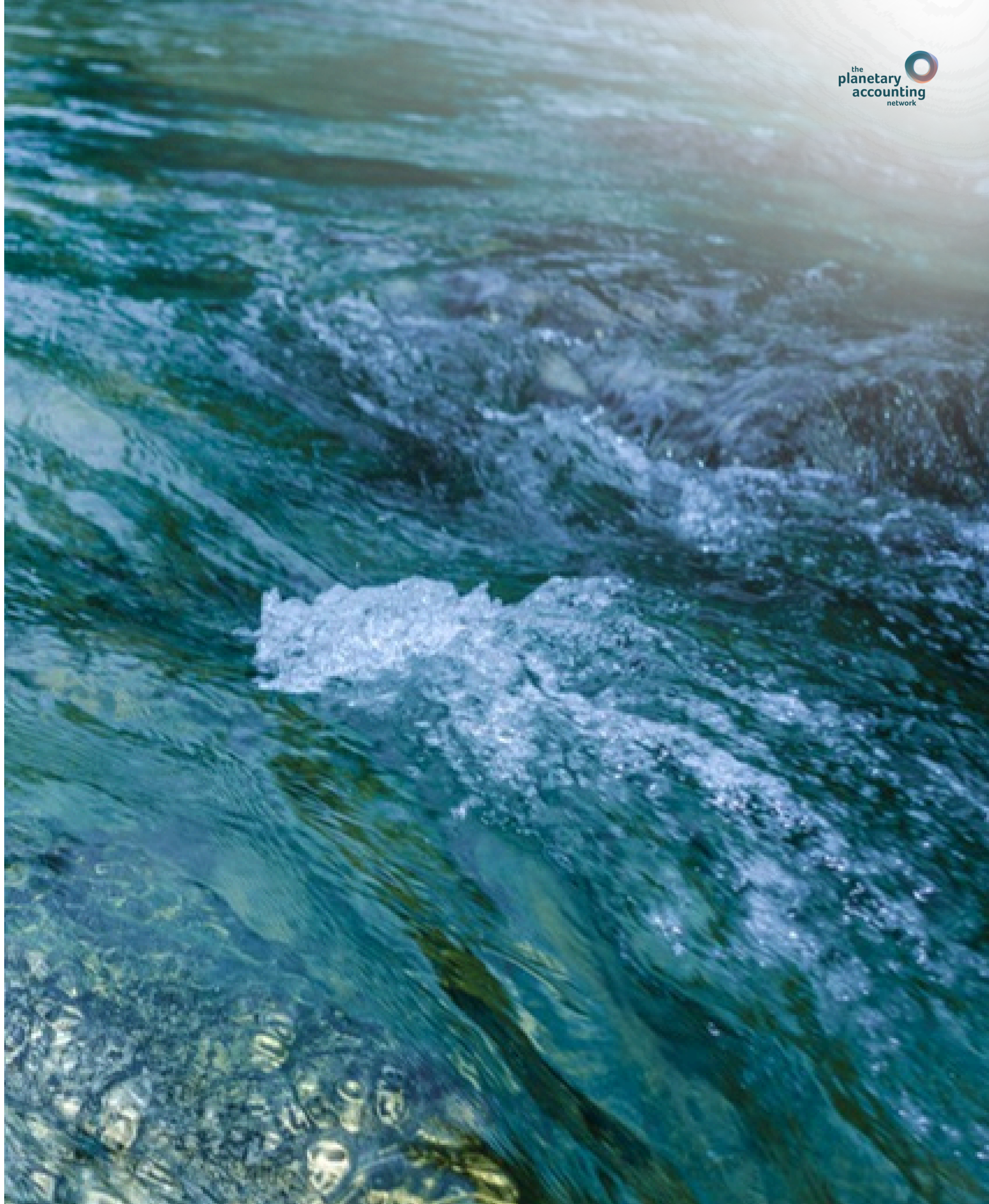
Water Efficiency Target

Reduction of gross water consumption across the network (including losses).



The 2025 update to the Planetary Boundaries.
Azote for Stockholm Resilience Centre, based on analysis in Sakschewski and Caesar et al. 2025.

Table of Contents



Introduction

Background

Water infrastructure is critical for the functioning of our societies. Networks of pipelines deliver water to our towns, cities, or pastures where it's needed; stormwater infrastructure diverts rainwater from where it's not wanted; and treatment facilities make our water safe to drink or to release back into the environment. The work of delivering water services never stops.

In Aotearoa New Zealand, local government bodies manage drinking water, wastewater, and stormwater infrastructure. The sector is facing a critical juncture characterised by aging infrastructure, significant funding gaps, population growth, and environmental challenges. The Department of Internal Affairs (DIA) estimates New Zealand will need to invest between NZ$120 billion and NZ$185 billion over the next 30 years (DIA, 2021), to replace and upgrade its drinking water, wastewater, and stormwater infrastructure.

In order to better manage these challenges, local governments are able to form new organisations specifically for managing water services - called Council Controlled Organisations, or Water CCOs. The Water CCOs will be eligible to borrow through the New Zealand Local Government Funding Agency (LGFA)'s existing CCO lending framework and have access to the existing suite of financial products that are currently made available to councils and CCOs. One of these borrowing schemes is a Sustainable Lending Product (SLP) for the Water Sector.

A Sustainable Lending Product for the Water Sector

The Planetary Accounting Network (PAN) has been engaged to support LGFA to establish key performance indicators and targets for a SLP for the NZ Water sector. Whilst similar to existing Climate Action Loans, this lending product will consider more holistic environmental impacts (beyond carbon emissions) with key performance indicators (KPIs) that borrowers (the Water CCOs) need to meet – aligned with the Planetary Boundaries.

The Planetary Boundaries

In 2009, a group of internationally renowned scientists identified nine non-negotiable environmental limits for the planet – which they called the Planetary Boundaries. Then, in 2009, we were exceeding three. Now, in 2026, we are exceeding seven.

The Planetary Boundaries is a scientific framework that defines a "safe operating space for humanity". It sets out the critical global environmental limits we need to stay within to avoid irreversible and catastrophic environmental change. In addition to climate change, it incorporates forest systems, biodiversity, water use, water pollution i.e., from nitrogen and phosphorus runoff, synthetic waste, the ozone layer, and air pollution.

Planetary Accounting

The Planetary Boundaries is groundbreaking science as it quantifies the magnitude, and urgency of our global environmental crisis. There is growing international consensus around their use in defining global environmental goals, the equivalent of the 1.5C goal for climate, but for nature. However, the Planetary Boundaries metrics do not make sense at the scales we make decisions.

PAN use a scientifically peer-reviewed framework called Planetary Accounting, that translates the Planetary Boundaries to any scale of activity. Carbon accounting can be used to quantify the impacts of human activity on climate change, in context of what is needed to limit global warming to 1.5C. Planetary Accounting extends carbon accounting, enabling us to quantify the broader environmental impacts of human activity, including on climate change, in context of the Planetary Boundaries. This context enables people to make informed decisions about managing environmental tradeoffs and supports communication of environmental performance.

Establishing KPIs for the Sustainable Lending Product

In the first phase of work PAN established a long-list of KPIs suitable for the lending product. To support KPI identification, PAN and LGFA ran workshops with stakeholders associated with a variety of new water entities to understand what data is already captured, or will be captured by new entities. Planetary Accounting was used to link results of these workshops to Planetary Boundaries, and establish a heatmap showing materiality and availability of data, to support KPI selection. The KPIs selected include:

- Carbon+, as emissions & uptake of carbon dioxide, greenhouse gases (GHGs) from fossil sources and refrigerants,
- Biogenic GHGs, as on-carbon dioxide GHG emissions from living organisms and wastewater treatment,
- Biodiversity loss,
- Nitrogen runoff to waterways,
- Phosphorus runoff to waterways,
- Waste, and
- Water use and water scarcity.

Further details on the long-list of KPIs is provided in Appendix A.

The second phase of work comprised a national Planetary Accounting assessment of the water sector to quantify the relative materiality of the KPIs above, and establish a national benchmark of the water sector. The results were used to select KPIs from the long-list; to determine the compulsory vs optional KPIs, and to support the establishment of science-aligned targets for the new sustainable lending product's KPIs.

This report summarises the results, approach, assumptions, and limitations for establishing the targets. It also describes the process for updating targets as science progresses, and how the target aligns with Sustainability-Linked Loan Principles.

Format of Indicators

Sustainability-Linked Loans (SLLs) are financing instruments that adjust the financial characteristics based on whether the issuer meets specific sustainability or environmental, social, governance (ESG) goals. Issuers commit to achieving measurable improvements in sustainability outcomes within a set timeframe. Progress is tracked using predefined KPIs and evaluated against Sustainability Performance Targets (SPTs).

The Sustainability-Linked Loan Principles (SLLPs), developed by the International Capital Market Association (ICMA), recommend that KPIs should be:

- Relevant and material to the issuer's core business or sustainability policies.
- Aligned with the issuer's overall sustainability strategy or transition plans.
- Measurable using consistent and transparent methods.
- Externally verifiable to ensure credibility.
- Benchmarkable, ideally against external references, to assess the ambition of the targets.

Workshops undertaken by PAN and LGFA show that water services delivery organisations are already measuring, or plan to measure, a wide range of sustainability and service quality metrics. However, many of these metrics have limited alignment with the SLLs recommendations, and only some can be easily linked to the Planetary Boundaries.

To help organise the large range of environmental indicators, the United Nations Environment Programme (UNEP) developed the DPSIR framework, which categorises metrics as Drivers, Pressures, States, Impacts, or Responses. Descriptions and examples of each, are provided on the right, against their relevance to water entities, and alignment with the SLLs recommendations above.

Pressure metrics are recommended on the basis of their relevance to water entities, and alignment with SSLs recommendations. They link directly to human activity - meaning they are material to the activity being assessed, and have limited to no lag time, i.e. you can immediately assess the environmental consequences of an activity or decision.

Planetary Accounting metrics are all pressure metrics, for these reasons. As such, Planetary Accounting metrics have been used to group data measured by Water CCOs to support the establishment of a long-list of potential KPIs, which comprises some Planetary Accounting metrics and some additional metrics chosen to provide greater depth of assessment for the water sector. PAN's assessment of NZ's Water Sector uses Planetary Accounting - therefore, the footprints are all 'pressure 'metrics.

Metric Type	Description	Example	Relevance for Water Entities	SLL Alignment
Drivers	The underlying needs shaping water services.	• Population growth • Housing intensification rates • Tourism number • Per capita water consumption	Driver metrics help anticipate long-term trends and inform strategic planning, but they usually describe background conditions, and are often less actionable.	Low - Relevancy and materiality may be limited due to limited influence.
Pressure	Stressors or flows to and from the environment due to human activities.	• Water extracted • Gross (net) emissions • Emissions intensity • Nutrients in discharge • Waste generated	Pressure metrics link directly to human activities and indicate system strain or inefficiency - clearly supporting resource protection and efficiency. While some can require complex data, these metrics are often used for regulatory compliance	High - Can generally be measured consistently against benchmarks.
State	The current condition of the environment or water sources.	• Reservoir levels (% full) • Stream and river flow rates • Water quality in reservoirs	State metrics reflect service quality and reliability, which is important for regulation and operation. However, they are often influenced by factors beyond the water entity's control.	Low - Relevancy and materiality may be limited due to limited influence.
Impact	Effects of system performance on the environment	• Loss of aquatic species or habitats • Number of waterborne illness cases	Impact metrics show real-world consequences and support sustainability reporting, but are often lagging and influenced by external factors, making them difficult to link to SLLs requirements.	Low - Relevancy and materiality may be limited due to limited influence.

New Zealand’s Water Sector

Activities associated with the water sector can be categorised under one of three core components; drinking water, wastewater, and stormwater - also referred to as 3-waters.

The new Water CCOs will be managing delivery of drinking water and wastewater - key activities for each are described further below. The majority of the CCOs are choosing to exclude managing stormwater from their remit i.e., it will stay within city/district council responsibilities. As such, stormwater considerations have been excluded from the SLP KPIs and targets.

Drinking Water Supply

Drinking water supply systems abstract, treat, and distribute water from sources like rivers, bores, or springs to consumers via pipes or carriers. These processes include:

- Abstraction: Water is pumped from surface water (i.e., rivers) or ground water (i.e., underground aquifers) sources and pumped to a treatment plant.
- Screening & Treatment: The untreated water goes through a screening process to filter debris before entering the treatment plant. The specific treatment process applied depends on the source. The most common treatment is chlorination, where a chemical compound is mixed with the water to kill any bacteria from the source. Other treatment processes include coagulation (making fine particles drop out), filtration and the removal of other contaminants. Removal of cloudiness is important because chlorination is not as effective otherwise.
- Distribution: Treated water is transported to users through a network of pipes. Additional pumping may be required to hill suburbs. Larger cities have more than one treatment plant.

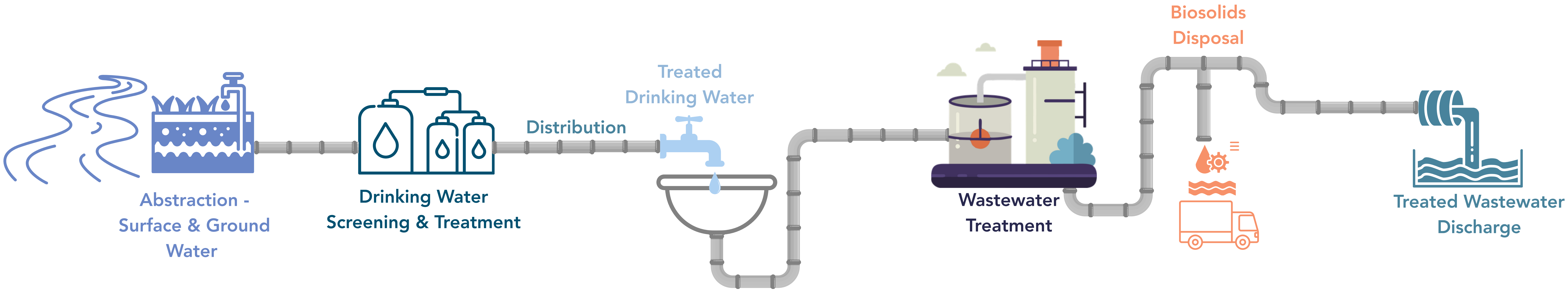
Wastewater Treatment and Discharge

Wastewater enters the city or town sewage network and is delivered via a network of pipes to the treatment plant. The goal of the wastewater treatment process is to remove pollutants, organic matter, and nutrients to prevent pollution in natural water bodies.

The untreated wastewater goes through a series of treatment processes:

- Primary: Physical removal of solids through sedimentation and screening.
- Secondary: Biological processes to break down organic matter.
- Tertiary: Advanced treatment to remove specific pollutants like nutrients or chemicals before release.

The outputs from the treatment process are treated wastewater - which is able to be discharged to the environment (either to land or to water) - and sewage sludge, the residue remaining after wastewater is processed. In New Zealand, the majority of sludge produced is treated like waste and sent to landfill, however some is processed into fertilisers.



Planetary Accounting

Planetary Accounting comprises 10 globally critical environmental footprints across three environmental domains, hau (air), whenua (land), and wai (water); with life (ora) considered within every footprint and associated limit. The footprints are summarised below:

Planetary Impact	Description
Air quality	Emissions or generation of aerosols / small particles or precursor gases (such as Sulphur dioxide)
Biogenic GHGs	Non-carbon dioxide greenhouse gas emissions (GHGs) from living organisms
Biodiversity loss	Species loss from land-use, land-use change, and ecotoxicity
Carbon+	Emissions & uptake of carbon dioxide, greenhouse gases from fossil sources and refrigerants.
Forestland	Area of deforestation (or reforestation)
Nitrogen	Nitrogen applied to land or runoff to waterways
Ozone	Emissions of ozone depleting substances (e.g. CFCs)
Phosphorus	Phosphorus applied to land or runoff to waterways
Waste	Imperishable & unrecycled waste
Water	Water consumption (direct and indirect) & contamination

To assist with interpretation of the Planetary Accounting assessment results for a product or service - such as water consumption - PAN uses *Planetary Facts* labels. Inspired by nutritional facts that disclose critical health indicators e.g., calories, fat, and protein in context of a *Recommended Daily Intake*, Planetary Facts disclose critical environmental footprints in context of a *Recommended Daily Limit* - derived from global environmental limits called the Planetary Boundaries.

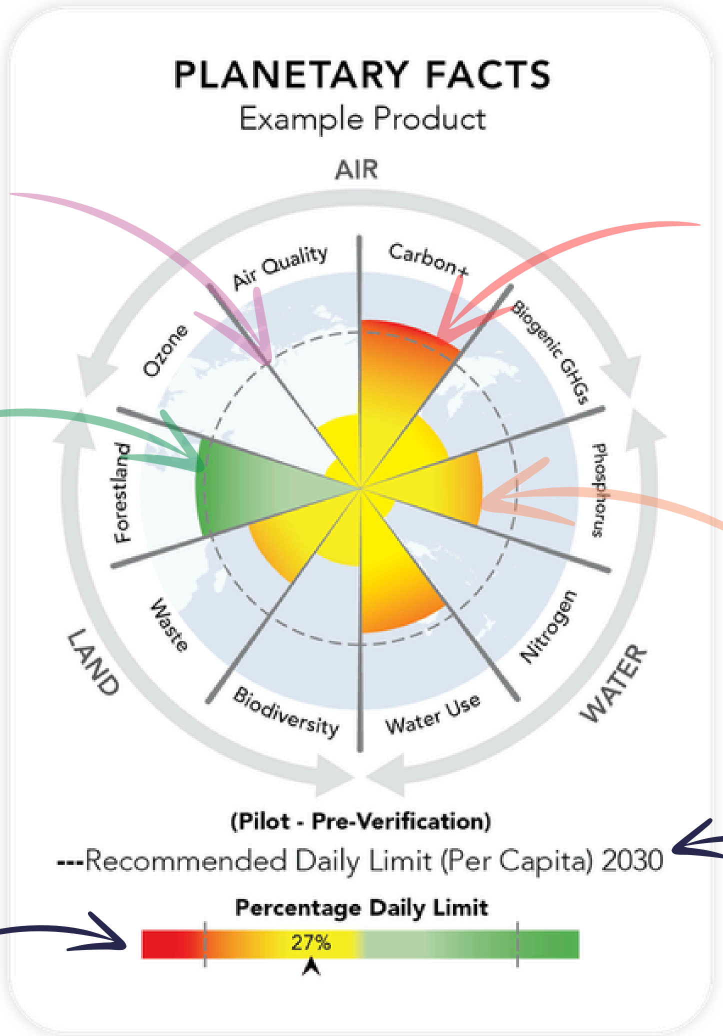
An example of a Planetary Facts label is shown below. Unlike other systems, Planetary Facts show relative performance between different impacts, as well as between different products. To provide a simple comparison of overall environmental performance between products, the average percentage of a daily limit across the 10 impacts can be derived and indicates the overall 'score' of the product; the lower the better, negative is good! You can add the Percentage Daily Limit across products and services.

Planetary Facts reflect impacts across the full life of a product until purchase - including mining of materials, manufacture, transport, and packaging.

The "Recommended Limit" is shown by the dotted line.

Impacts exceeding the recommended limit are shown in red

Positive impact on the environment is shown in green, the bigger the green the better!



Impacts within a recommended limit are shown in yellow

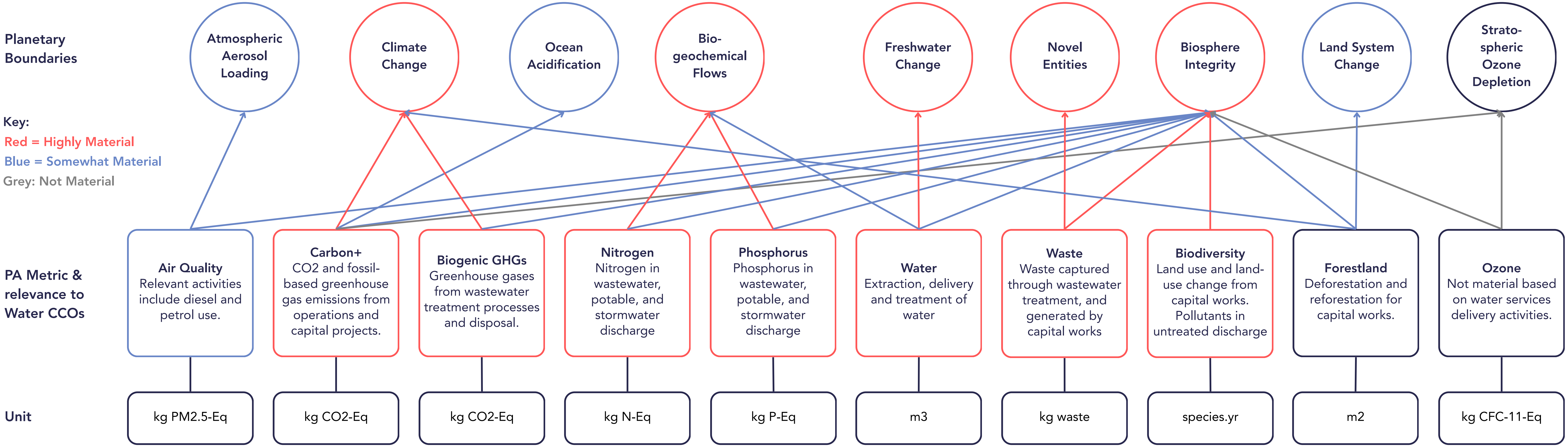
The percentage of a daily limit indicates overall (average) performance.

The Recommended limit is for the year 2030.

Planetary Boundary Materiality - Water Entities

Due to the high interconnectivity of environmental systems, there is not a linear one-to-one relationship between the Planetary Boundary (PB) and Planetary Accounting (PA) metrics. The diagram below shows the interconnectivity between the PBs and PA metrics, and summarises the relevance of each PA metric to water services delivery activities.

Colour coding has been used to highlight the anticipated materiality of Planetary Boundary and corresponding Planetary Accounting metrics, prior to the national Planetary Accounting assessment. Red indicates high, blue indicates moderate, and grey indicates low or no materiality. Most of these metrics have at least moderate relevance to Water CCOs, with the exception of ozone, as the use of ozone depleting substances are not typically part of Water CCO operations. The PA metrics identified as material to Water CCO operations were used to form the long list of KPIs - see Appendix A for further details.



Planetary Accounting Baseline for NZ Water Sector

To establish benchmarks across the Planetary Boundaries, PAN undertook a Planetary Accounting assessment of New Zealand's Water Sector. This involved using NZ specific data e.g., volume of water consumed, volume of wastewater treated related to drinking water and wastewater treatment processes, combined with life-cycle assessment datasets and industry factors to quantify the environmental impacts of NZ's drinking water supply and wastewater treatment processes. Key assumptions and data points used for developing the baseline are summarised below. Refer to Appendix B for further details on the data, methodology, and assumptions employed for the Planetary Accounting assessment of drinking water and wastewater.

Note; stormwater was excluded from the assessment as the responsibility of managing stormwater does not sit with one entity i.e., it is jointly managed by city/district councils, regional councils, private landowners, and the Waka Kotahi New Zealand Transport Agency and most CCOs are choosing to exclude stormwater management from their remit.

Drinking Water Supply

Key assumptions and data for the assessment of drinking water abstraction, treatment, and supply are as follows:

- Total water abstracted ~728 million m^3 (Taumata Arowai, 2025a).
  - 64% comes from surface water (~460 million m^3/year), with the remaining 36% from ground water (~262 million m^3/year) (Taumata Arowai, 2025a).
- Total water loss of 162 million m^3/year (Taumata Arowai, 2025a).
- Electricity use for water supplied ~241 million kWh/year (Taumata Arowai, 2025a).

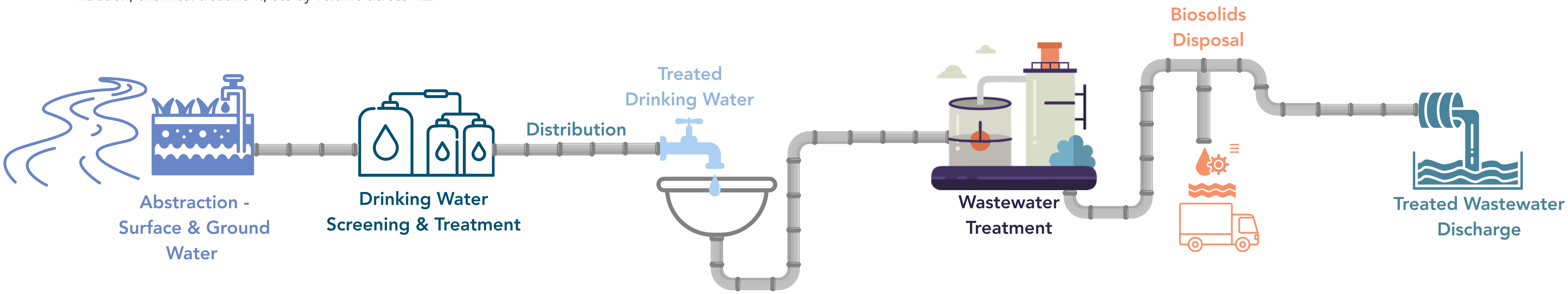
A desktop scan was undertaken to estimate the proportion of drinking water treatment types i.e., by UV, sand filtration, chemical treatment, etc by volume across NZ.

Wastewater Treatment and Discharge

Key assumptions and data for the assessment of wastewater treatment and discharge are as follows:

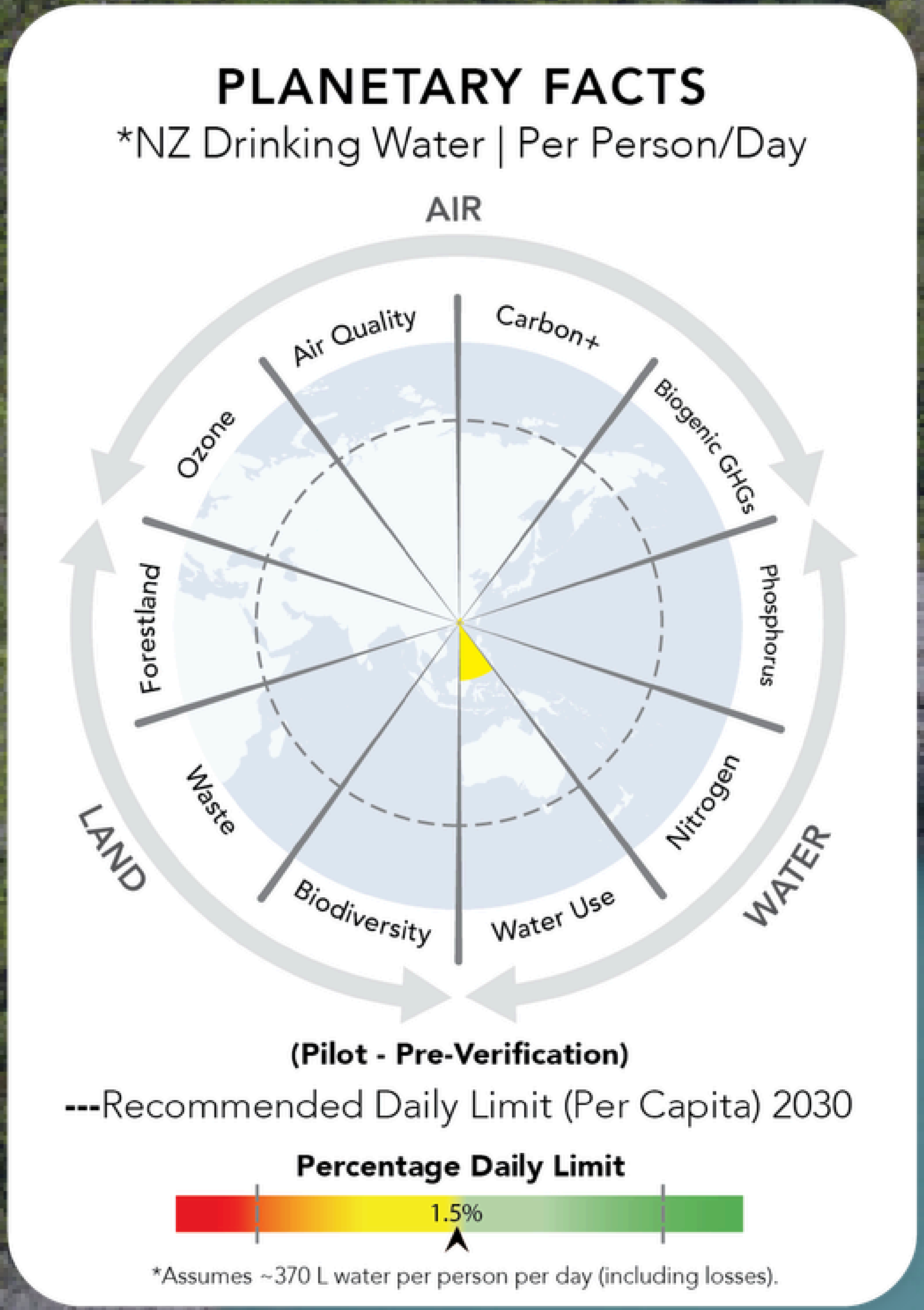
- The volume of wastewater treated in NZ is ~547.5 million m^3 per year derived from New Zealand Wastewater Stocktake report by GHD, Beca, & Boffa Miskell, 2020.
- The amount of biosolids produced based on a global life cycle dataset from Ecoinvent 'treatment of wastewater - RoW'. For every 1 m^3 of wastewater treated, 3.7 kg of biosolids (wet weight) are produced. This results in 2 million tonnes of biosolids (wet weight) per year.
- For disposal pathways, it has been assumed that 70% of sludge is disposed to landfill, with the remaining 30% disposed to land (Tinholt, 2019)
- For secondary treatment, ~13% of of New Zealands sludge that is produced goes through a thermal drying process (Tinholt, 2019).

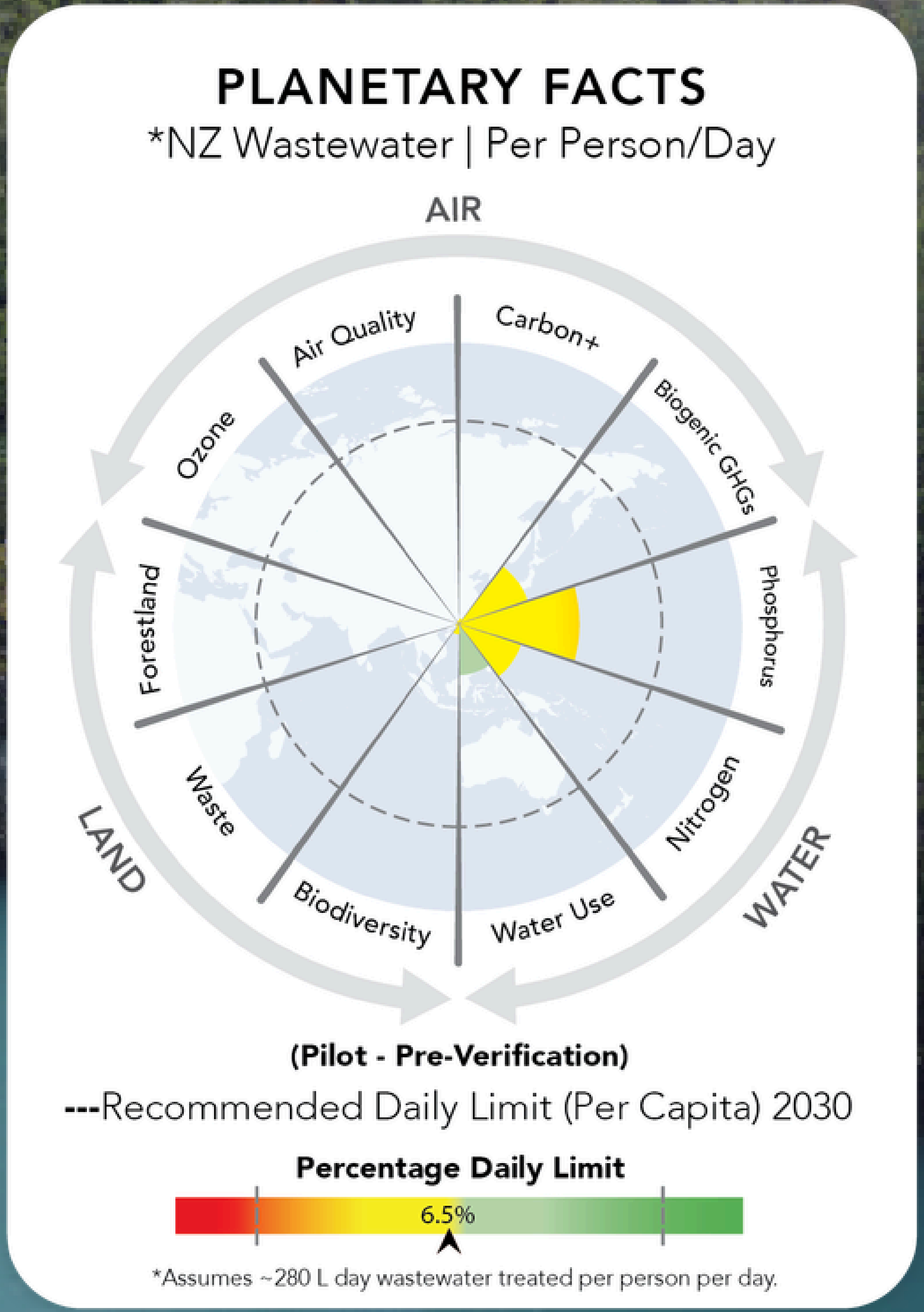
The proportion of treatment types by volume of wastewater treated is based on the NZ Wastewater Stocktake report GHD, Beca, & Boffa Miskell, 2020.



Results - Planetary Facts

Results for drinking water and wastewater are shown in the Planetary Facts labels below. These highlight that wastewater treatment has a higher footprint than provision of drinking water, and that phosphorus impacts have the highest materiality overall, followed by biogenic GHGs, nitrogen, and then water use (noting the positive, regenerative water footprint of wastewater treatment). Capital carbon was modelled separately. Its' materiality falls between that of nitrogen and water use. Results are shown in detail in the subsequent pages.



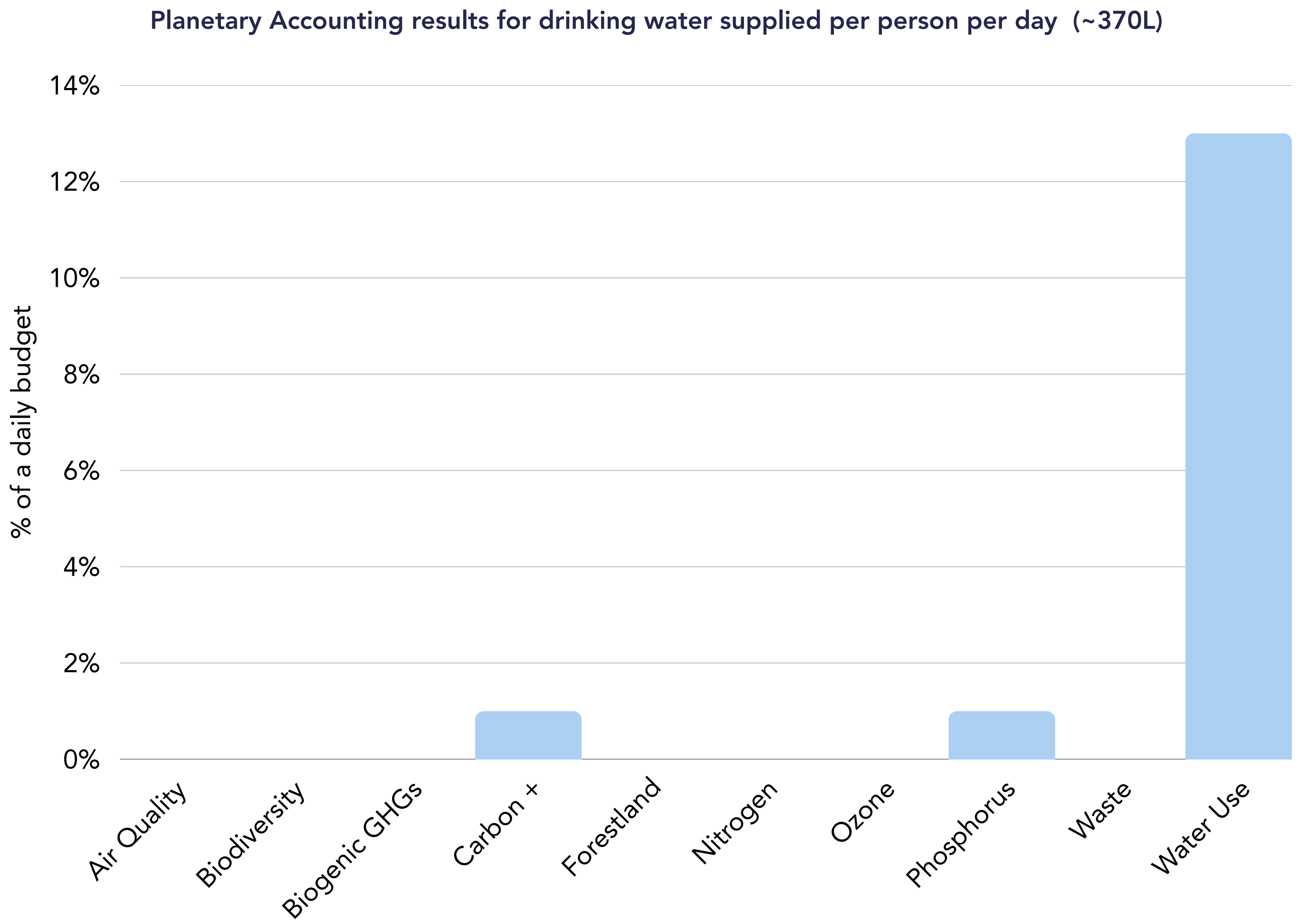


Results - Drinking Water

The assessment of drinking water captures operational impacts, including abstraction, treatment, and distribution of potable water.

The graph below shows the impact of an average amount water used per person per day (~370L including network losses) against the daily per capita environmental budgets in 2030.

The table of drivers shows the key activities contributing to each of the environmental impacts of drinking water supply, treatment, and delivery.



The results show water use impacts are the most material impact - this reflects the direct abstraction of water. Carbon+ was the second-largest impact category. The drivers behind carbon+ include energy usage and in the treatment and delivery of drinking water along the network, as well as the production of chemicals / additives used in the treatment process. Phosphorus is the third highest impact; the drivers were primarily linked to upstream impacts from electricity generation where coal is used i.e., Huntly, as phosphorus runoff is created in the coal extraction process. All other impacts were less than 1% of a daily limit per capita.

Metric	Key Drivers
Air Quality	• Upstream impact of electricity generation (burning coal)
Biodiversity	• Upstream impact of electricity generation (burning coal). • Production of chemicals used in treatment • Land use of treatment facility
Biogenic GHGs	• Water lost during treatment (subsequently treated as wastewater)
Carbon+	• Electricity usage • Production of chemicals
Forestland	• Upstream impact of electricity production
Nitrogen	• Electricity usage • Production of chemicals
Ozone	• Electricity usage • Production of chemicals • Natural gas usage (for heat)
Phosphorus	• Upstream impact of electricity generation (coal) • Production of chemicals
Waste	• Upstream impact of electricity generation (coal) • Production of chemicals • Water lost during treatment
Water Use	• Water abstraction

Refer to Appendix B for details on the data, methodology, and assumptions, and Appendix C for detailed results.

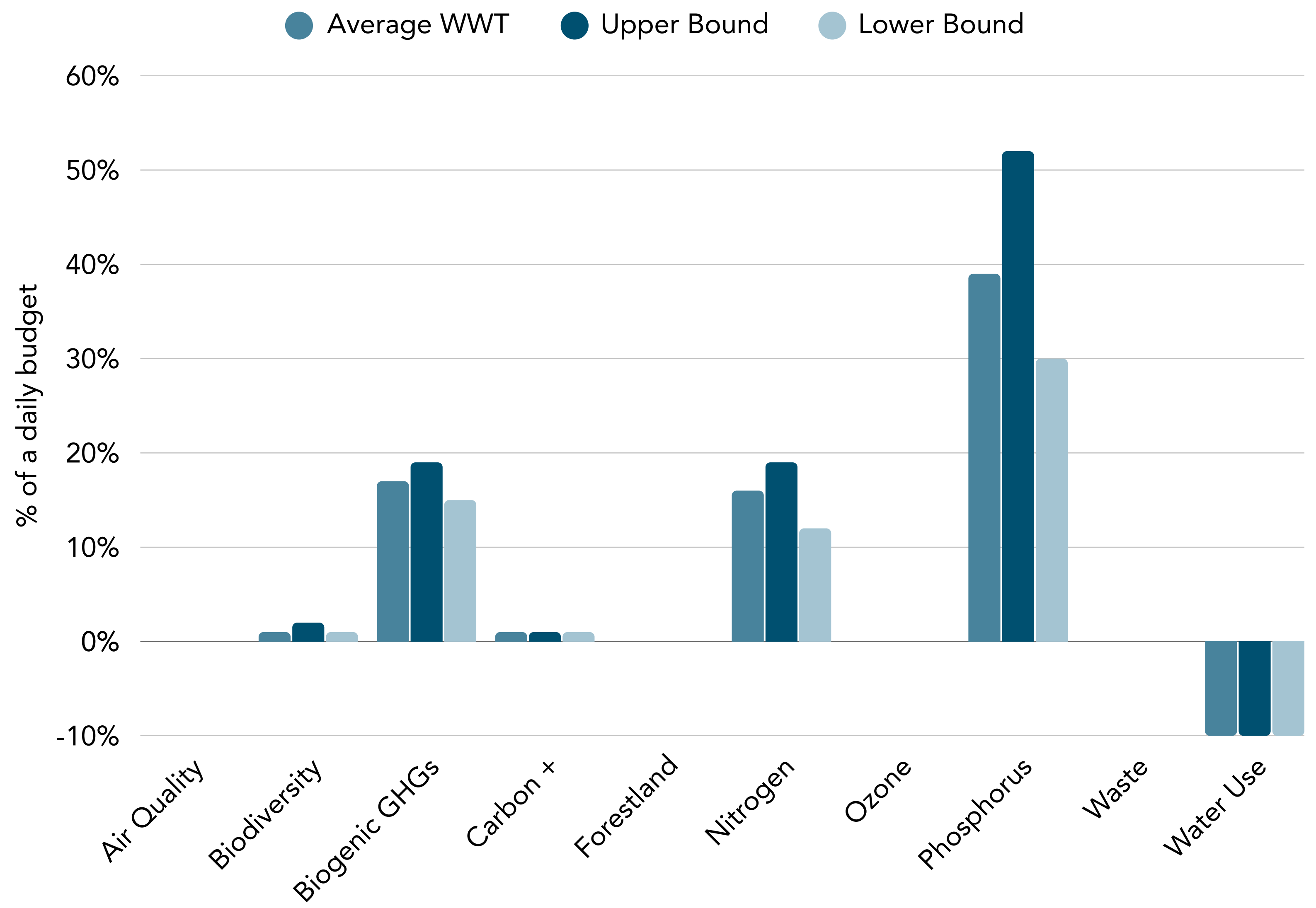
Results - Wastewater

The assessment of wastewater includes wastewater treatment, biosolids disposal and discharge of the treated wastewater to the environment.

The graph below shows the impact of average amount of wastewater treated per person per day (~280L) against the daily per capita environmental budgets in 2030.

The table of drivers shows the key activities contributing to the 10 impacts from wastewater treatment, discharge, and disposal.

Planetary Accounting results (including sensitivity) for wastewater treated per person per day (~280L)



Phosphorus impacts are the most material. This is due to direct emissions of phosphorus in wastewater discharge. Biogenic GHGs was the second-largest impact category, with is driven by nitrous oxide and methane released during both the treatment and breaking down of biosolids. Closely following biogenic GHG is nitrogen, which is the third highest impact, driven by the nitrogen discharge. The water use impact is shown as negative. This is because the input is untreated wastewater, which is then treated and discharged as clean water to the environment.

Metric	Drivers
Air Quality	• Upstream impact of electricity generation (burning coal). • Production of chemicals used in treatment • Disposal of waste
Biodiversity	• Electricity production • Production of chemicals • Land use of treatment facility
Biogenic GHGs	• Direct emissions (methane and nitrous oxide) from wastewater treatment • Disposal and breakdown of biosolids
Carbon+	• Upstream impact of electricity generation (burning coal). • Production of chemicals used in treatment
Forestland	• Electricity production
Nitrogen	• Direct emissions of nitrogen in wastewater discharge
Ozone	• Electricity generation • Production of chemicals
Phosphorus	• Direct emissions of phosphorus in wastewater discharge
Waste	• Disposal of waste
Water Use	• Output of treated water

A sensitivity analysis was also undertaken to understand the range in results for the most material footprints. This involved testing input factors (upper and lower bound) for nitrous oxide and methane released in the treatment process, and nitrogen and phosphorus in wastewater discharge. Refer to Appendix B for details on the data, methodology, and assumptions used for the assessment. Refer to Appendix C for detailed results, including sensitivity results.

Results - Capital Works

The Department of Internal Affairs has noted that $47.9b is forecast to be spent on water services infrastructure in the 10 years to June 2034 - including $17b on drinking water infrastructure, $22.5b on wastewater infrastructure and $8b on stormwater infrastructure (DIA, 2021). The 10-year forecast represents the near-term portion of the longer-term $120–185 billion investment requirement.

This level of investment will result in environmental impacts, such as greenhouse gas emissions associated with the materials and construction plant used to build new infrastructure. These emissions are commonly referred to as embodied carbon emissions.

To estimate the embodied carbon associated with drinking water and wastewater infrastructure investment, (~$3.95 billion per year) PAN undertook an Environmentally Extended Input-Output (EEIO) analysis. This approach uses economic expenditure data to estimate the carbon emissions embedded across supply chains, providing a high-level picture of the emissions associated with capital works programmes. The EEIO analysis used EXIOBASE v3.

The analysis was benchmarked against Watercare's carbon emissions baseline (Watercare, 2020) for its 10-year capital works programme. They estimated the carbon footprint of their infrastructure programme to be 374,700tCO_2e, approximately 37,470tCO_2e per year. Watercare's funding plan notes that over a similar 10 year time frame (2018 to 2028), the forecasted spend is ~$4.6 billion (Watercare Services Limited, 2018). This was used to derive a carbon intensity per $ spent. This factor was applied to DIA's annual forecasted spend to compare to the result from the EEIO analysis.

Results showed an estimated range of ~0.3 million (Watercare factor) to ~1.7 million tCO_2e (EEIO factor). When divided by NZ's population (~5.025 million) this results in approximately 0.2 - 0.9 kg CO2eq per person per day. In order to compare against the results from the operational footprint, PAN have used Planetary Accounting to put these results into context. These results represent approximately 3-15% of a recommended daily per capita carbon budget in 2030.

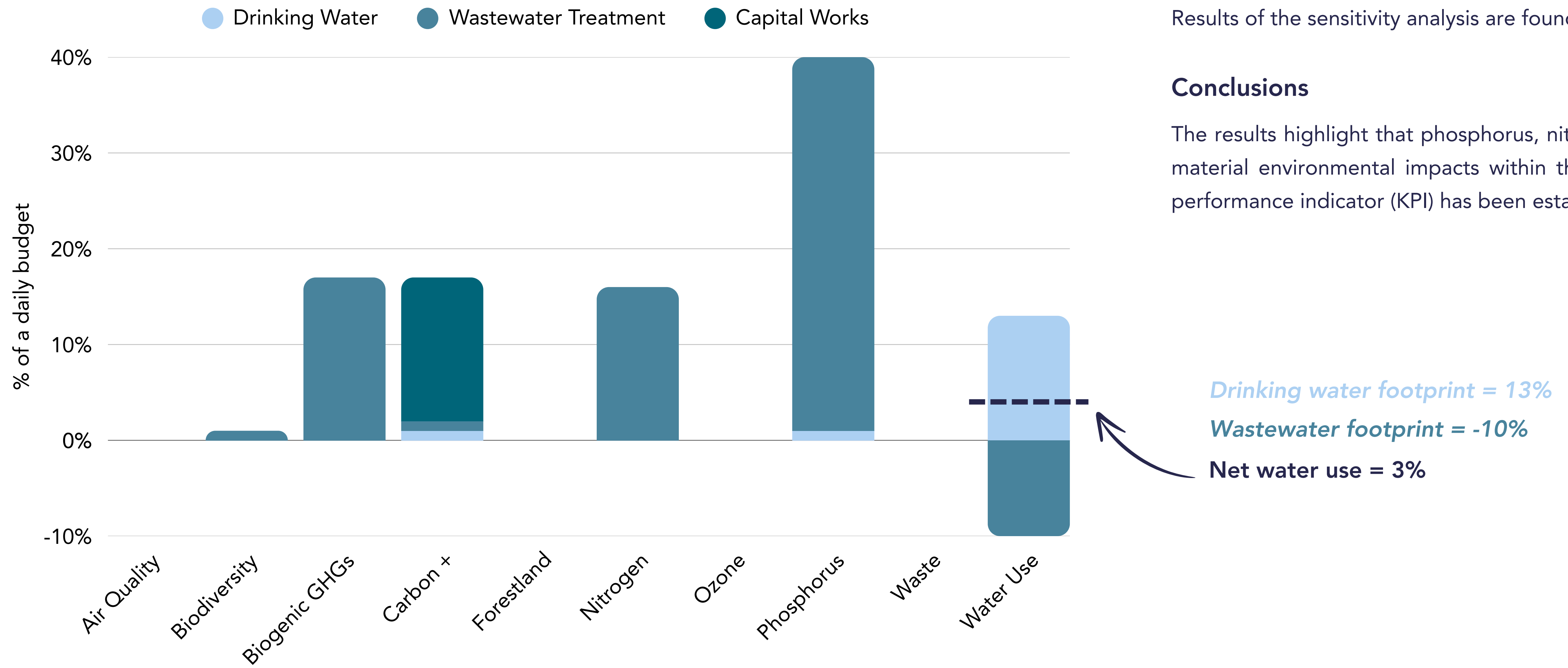
Results - Combined results

The chart below shows the breakdown of the combined results for New Zealand water system. Phosphorus impacts were the highest, which largely arise from the wastewater treatment stage. Biogenic GHGs was the second-largest impact category, of which the wastewater treatment stage makes up the entirety of the impact. Nitrogen is the third highest impact, again entirely driven by the treatment of wastewater.

The water use impact from drinking water represents 13% of a recommended daily limit. However, a large portion of water supplied to the municipal water network is returned and treated as wastewater. Therefore, when considering both water use and wastewater the net impact is 3% of a recommended daily limit.

The carbon+ impact from capital works reflect the upper bound result from the EEIO analysis, in line with results for biogenic GHGs and nitrogen. This highlights the material scale of embodied emissions from water infrastructure, even before accounting for operational emissions over the assets' lifetimes.

Summary of Planetary Accounting assessment results (as average impacts per capita) for drinking water, wastewater treatment, and capital works



Validation

Given the materiality of nitrogen and phosphorus footprints, the results were validated by comparing them to publicly available data, including typical nutrient concentrations in wastewater discharges in *The New Zealand Wastewater Sector* (GHD, Beca, & Boffa Miskell, 2020), and actual discharge records and consent limits from local councils in New Zealand.

The New Zealand Wastewater Sector (GHD, Beca, & Boffa Miskell, 2020) provides typical effluent quality ranges following primary treatment. Our results fall within the reported ranges for both N and P. A comparison against actual discharge records from Watercare, QLDC, and Waihola shows that both the nitrogen and phosphorus results are broadly consistent with these council discharges.

Biogenic greenhouse gases represent another material impact. The biogenic GHGs results were validated by comparing results at a national scale to WaterNZ estimate (Singhal. N., et al. (2023)), and at an Auckland scale to Watercare's 2020 baseline (Watercare (2023)).

Results of the sensitivity analysis are found in Appendix C.

Conclusions

The results highlight that phosphorus, nitrogen, biogenic greenhouse gases, water use, and carbon+ are the most material environmental impacts within the New Zealand water sector. To drive meaningful improvement, a key performance indicator (KPI) has been established for each of these impact categories.

Establishing the Targets

PAN used Planetary Accounting to establish targets for the water sector across four environmental dimensions: carbon emissions from capital works, freshwater use, nutrient loading (nitrogen and phosphorus), and biogenic greenhouse gas emissions from wastewater treatment that align with the Planetary Boundaries. The targets integrate both top-down and bottom-up approaches so that targets are both grounded in science, while remaining meaningful at the operational level.

Global Framing - The Planetary Boundaries

For each metric, globally defined boundary thresholds were identified from the Planetary Boundaries framework. These represent the biophysical limits beyond which there is a risk of large-scale, potentially irreversible environmental change. Relevant boundaries include climate change, biogeochemical flows (nitrogen and phosphorus cycles), and freshwater use.

Top-Down Approach

To establish targets using a top-down approach PAN have employed two target setting methods: 1) equal per capita, and 2) absolute contraction.

1. Equal per capita share: This allocation principle assigns each country a share of the global safe operating space proportional to its population, providing a transparent basis for national-level budgets and accounts. The resulting national-level limits represent New Zealand's per capita share of the global environmental space for each metric.

2. Absolute contraction: Absolute contraction is a target setting methodology which follows the same reduction pathway (i.e., year-on-year % reductions) as the global trajectory. The trajectories translate static boundary thresholds into dynamic, time-bound targets against which progress can be measured. For each metric, PAN have used the corresponding Planetary Boundary (global current status and end goal) to define year-on-year reduction pathways that bring performance within Planetary Boundary limits over a defined timeframe. The timeframe for reaching the Planetary Boundaries is assumed to be at mid-century (year 2050) unless there is a scientific basis for alternative temporal assumptions. PAN have applied these trajectories to the baseline developed in the Planetary Accounting assessment.

Bottom-Up Approach

The bottom-up approach complements the top-down approach by incorporating locally specific environmental limits such as water availability and nitrogen and phosphorus assimilation capacity. In addition to scientific local consideration, local regulatory limits were also considered. These include:

- Regional freshwater allocation limits and catchment-level constraints
- Receiving environment standards for nutrient discharges (nitrogen and phosphorus)
- Consent conditions and regulatory thresholds applicable to wastewater treatment operations

Local limits serve as a critical cross-check, ensuring that targets derived from the top-down approach take into account the specific environmental conditions and regulatory requirements of the catchments and communities in which the water sector operates.

Other considerations

PAN worked closely with LGFA to consider and incorporate the current state-of-play of the water sector in defining the type and format of the KPIs. Considerations included current levels of maturity in regards to measuring against the KPIs, the current state of operational practice and technology adoption, and technical feasibility and reduction potential for the KPIs. Recommendations also consider whether KPIs could be achieved via operational efficiencies and/or behaviour change, or if an infrastructure investment (and considering lead times for this investment) would be needed to deliver a step-changes in environmental performance.

Targets were set at the most ambitious threshold from top-down and bottom-up approaches, within feasibility and transition constraints.

Some of the targets consider near-term action and long-term ambition. Near term targets have been developed such that they are still ambitious — requiring meaningful acceleration beyond business-as-usual — while remaining technically and practically achievable given the sector's starting position. They function as milestones to increase the robust measurement of data and support the achievement of long-term science-based targets.

Planetary Boundary KPIs for Water Entities

The four recommended KPIs and how these relate to Water CCO activities is summarised in the table below.

PAN understands that LGFA will structure the lending product so that of these four targets, there will be one compulsory KPI, with an additional KPI selected from the remaining three targets (Water CCOs will be able to decide which additional one to adopt).

Requirement	KPI	Target Overview	Relevance to Water CCO Activities	Target Requirement
Compulsory	Nitrogen and Phosphorus	Reduction in concentration of total nitrogen and phosphorus per litre of wastewater discharged to the environment.	Total nitrogen per litre of wastewater discharge. Total phosphorus per litre of wastewater discharge.	Concentration of total Nitrogen and Phosphorus per litre of discharge is no greater than the most stringent of: • Wastewater Environmental Performance Standards (WEPS) 2025 OR • A percentage reduction compared to CCO concentration baselines - determined by the discharge consent renewal year - for all land and freshwater receiving environments to be achieved within 5 years of new consent. See table for % improvement requirements. [2] Note - reduction targets can be waived for high-performing CCOs if A) They are already achieving better than WEPS standard concentrations, AND B) They can demonstrate that they already achieve the best currently feasible concentrations of N and P
Optional	Biogenic GHGs	Improved measurement of greenhouse gases produced from wastewater treatment processes and biosolids disposal.	Greenhouse gases (GHG) produced from wastewater treatment processes and disposal.	Level 2 measurement implemented within 2 years of entering the programme* Level 3 - facility level measurement implemented by 2040 ** *Greenhouse gas emissions measurement to be in accordance with the most current Water New Zealand wastewater carbon accounting guidelines, and future guidance for Level 3 measurement. **A materiality threshold will be confirmed once the global methodology for Level 3 (Tier 3) measurement has been established. In the interim, the Level 3 measurement will be required for the CCOs largest wastewater treatment plant until global methodology has been established.
	Embodied Carbon	Assessment of embodied GHGs in CCOs forward capital works programme.	Carbon dioxide and fossil-based greenhouse gas emissions embodied in materials (i.e., from manufacturing) used in capital projects (e.g., concrete, steel, pipe materials, etc), released during construction (e.g., diesel and petrol vehicles, construction plant, electricity usage), and due to clearing land for capital works projects.	Measure prospective emissions from the CCOs forward capital works programme for at least 80% of anticipated spend in a 3-5 year period that starts at least one year after joining the programme. The inventory for embodied carbon emissions should be estimated using a prospective life-cycle assessment (LCA) approach, consistent with the principles and framework of ISO 14040 / ISO 14044 (or equivalent recognised LCA methodology such as the NZGBC embodied carbon methodology or MBIE Whole of Life Embodied Carbon Assessment Methodology adapted for water infrastructure).
	Water Efficiency	Reduction of gross water consumption across the network (including losses).	Extraction, delivery and treatment of potable water.	Reduction in gross water consumption per capita across the network (includes withdrawals and losses) of at least 7% reduction per 5-year period (average of 1.4% per year) from a three-year average baseline immediately prior to entering the programme. Gross water consumption includes water abstracted for household use, commercial use, and water losses.

Guidance for Water CCOs on Selecting KPIs

Step 1 - Choose KPIs

All CCOs must report against two KPIs; Nitrogen & Phosphorus (compulsory), and any one of the three optional targets; Biogenic GHGs, Embodied Carbon, or Water Efficiency.

Not all KPIs will carry equal weight for every water entity. The framework covers four environmental footprints, but their relative materiality will vary depending on the Water CCOs's operations, assets, and local environmental context. For example, one CCO may find that biogenic emissions and nutrient discharges are its most significant impacts, while another may find water efficiency and embodied carbon from capital works more relevant.

It is recommended Water CCOs assess which footprints are most material to their operations and use this to inform their selection of the KPIs.

Requirement	KPI	Target Overview	Target Requirements
Compulsory	Nitrogen & Phosphorus	Reduction in concentration of total nitrogen and phosphorus per litre of wastewater discharged to the environment.	Concentration of total Nitrogen and Phosphorus per litre of discharge is no greater than the most stringent of: • Wastewater Environmental Performance Standards (WEPS) 2025 OR • A percentage reduction compared to CCO concentration baselines - determined by the discharge consent renewal year - for all land and freshwater receiving environments to be achieved within 5 years of new consent. See table for % improvement requirements. [2] Note - reduction targets can be waived for high-performing CCOs if A) They are already achieving better than WEPS standard concentrations, AND B) They can demonstrate that they already achieve the best currently feasible concentrations of N and P
Optional	Biogenic GHGs	Improved measurement of greenhouse gases produced from wastewater treatment processes and biosolids disposal.	Level 2 measurement implemented within 2 years of entering the programme.* Level 3 - facility level measurement implemented by 2040.** *Greenhouse gas emissions measurement to be in accordance with the most current Water New Zealand wastewater carbon accounting guidelines, and future guidance for Level 3 (Tier 3) measurement. **A materiality threshold will be confirmed once the global methodology for Level 3 (Tier 3) measurement has been established. In the interim, the Level 3 measurement will be required for the CCOs largest wastewater treatment plant until global methodology has been established.
	Embodied Carbon	Assessment of embodied GHGs in CCOs forward capital works programme.	Measure prospective emissions from the CCOs forward capital works programme for at least 80% of anticipated spend in a 3-5 year period that starts at least one year after joining the programme. The inventory for embodied carbon emissions should be estimated using a prospective LCA approach, consistent with the principles and framework of ISO 14040 / ISO 14044 (or equivalent recognised LCA methodology such as the NZGBC embodied carbon methodology or MBIE Whole of Life Embodied Carbon Assessment Methodology adapted for water infrastructure).
	Water Efficiency	Reduction of gross water consumption across the network (including losses).	Reduction in gross water consumption per capita across the network (includes withdrawals and losses) of at least 7% reduction per 5-year period (average of 1.4% per year) from a three-year average baseline immediately prior to entering the programme. Gross water consumption includes water abstracted for household use, commercial use, and water losses.

Nitrogen & Phosphorus

Background

Nitrogen and phosphorus are essential nutrients for all life, critical for DNA, proteins, and plant growth, forming the basis of agricultural productivity through synthetic fertilisers. While some of these nutrients are absorbed by plants and end up in the food humans consume, excess fertiliser runs off into waterways - triggering algal blooms that create oxygen-depleted dead zones in rivers, lakes, and oceans.

Global Framing

The Planetary Boundary for biogeochemical flows sets limits on nitrogen (N) and phosphorus (P) to avoid large-scale eutrophication of freshwater and ocean ecosystems. The global limits are 62 Tg N and 11 Tg P per year Richarson et al. (2023). Current use substantially exceeds these limits at ~233 Tg N (Rockström et al., 2025), and ~20 Tg P (Cross et al., 2025) [1] applied by the agricultural sector each year.

Wastewater is a significant pathway for these nutrients. Globally, humans consume approximately 40 Tg N and 3.5 Tg P through food, and the vast majority of this passes into wastewater — around 90% of N and 98% of P. While wastewater treatment processes extract a portion of these nutrients, the remainder is discharged to the environment in treated effluent, contributing directly to nutrient loading in freshwater and coastal systems.

New Zealand Context

Assimilation capacity: To incorporate a local perspective, nitrogen (N) and phosphorus (P) targets were assessed against New Zealand's environmental assimilation capacity. Assimilation capacity refers to the ability of natural systems, such as soils, waterways, and ecosystems, to absorb, process, and neutralise nutrients without causing ecological harm. This approach means targets consider local conditions and ecological thresholds to prevent exceedance of the country's nutrient carrying capacity.

The Ministry for the Environment has national data from 2016-2020 on river and lake quality from samples across New Zealand, which measures both N & P. The data samples are compared to the default guideline values in the Australian and New Zealand guidelines for fresh and marine water quality (ANZG, 2018), and the percentage of samples which meets the ANZG requirement. Of which, 72% did not meet the ANZG requirement for total nitrogen, and 61% did not meet the requirement for total phosphorus. This means the majority of water bodies have no assimilation capacity remaining i.e., they cannot take higher concentrations in nutrient loading. For CCOs this means the focus must be on reducing nutrient concentrations in discharge.

The Wastewater Environmental Performance Standards (WEPS) 2025 is NZ's new standardised discharge consent framework. It was released to standardise New Zealand's approach to consenting wastewater networks and treatment plants. This is important, as most publicly owned wastewater plants were built 30–40 years ago and are requiring upgrade, and over the next decade 57% of wastewater treatment plant consents will come up for renewal, - 21% have already expired. The new standard includes nutrient concentration limits for wastewater discharge in various receiving environments.

For rivers, the standards apply different requirements based on the level of dilution in the receiving water body, classified as high, moderate, low, or very low dilution. For discharge to land, concentration limits vary based on the assigned land class.

The discharge consent range for concentration of nitrogen in wastewater is 4–35 mg/L. For phosphorus it is 0.5–10 mg/L (WEPS, 2025).

Freshwater Science and Technical Advisory Group

PAN reached out to a number of New Zealand freshwater scientists, including Dr. Mike Joy, Marnie Prickett, Gary Taylor to get their expert input regarding nutrient concentration limits. They referenced the Freshwater Science and Technical Advisory Group's 2019 report to the Minister for the Environment - which - among other indicators for measuring freshwater ecosystem health - recommended local limits for total nitrogen and total phosphorus into freshwater receiving environments.

[1] The International Fertilizer Association estimate that global phosphate (P2O5) fertiliser use is 46.6 million tonnes per year. The mass of elemental phosphorus (P) is approximately 0.436 times the mass of the P2O5. This corresponds to approximately 20 million tonnes as kgP equivalent per year. Refer Cross, L., Gruère, A., de Sousa, J., & Chtioui, H. (2025). Short-term fertilizer outlook 2024–2025. International Fertilizer Association (IFA). https://www.fertilizer.org/wp-content/uploads/2025/02/2024_ifa_short_term_outlook_report.pdf.

Nitrogen & Phosphorus

A Target for Nitrogen and Phosphorus

Many water entities and local councils are already measuring concentrations of total nitrogen and total phosphorus in wastewater discharge, as part of their discharge consent requirements. The concentration limits depend on characteristics of the receiving environment. Total nutrient loading also depends on the size (number of people serviced) and type of treatment undertaken.

This means that a fixed concentration target would not be appropriate; for some i.e., discharges with relatively low nutrient concentration compared to receiving environment assimilation capacity, the upfront investment costs (financial and environmental) would not warrant the return on this investment. Therefore, the recommended target is a % reduction in nutrient loading per litre of wastewater discharge (at the point of discharge) from a baseline year.

Given that N and P flows to wastewater are closely tied to the food system, analysis of the EAT–Lancet Commission's work (Rockström et al., 2025), the global biogeochemical flows Planetary Boundary per Richarson et al. (2023), the new Wastewater Environmental Performance Standards (WEPS) 2025, and expert recommendations on local ecological limits [2], was undertaken to determine appropriate percentage reduction targets considering a top down and bottom up perspective. This included:

- Using a top-down absolute contraction approach to align with the Planetary Boundary per Richarson et al. (2023)
- Scaling the food system to limit to a wastewater share; by disaggregating the share of nutrients that end up in food that is eventually consumed by humans and then ends up in wastewater systems, from total fertiliser application
- A review of local limits based on The Freshwater Science and Technical Advisory Group, 2019 report to the Minister for the Environment

Of the three approaches, the local limits were the most conservative. However, while these are appropriate 'end-point' targets, they do not take into account the transition time practically needed to meet them. The wastewater share of the total food system limit was insufficiently ambitious - as it did not take into account local assimilation capacity. Absolute contraction provides a strong foundation for a transition pathway. However, applying this to a high-performing CCO could result in target reductions that are unfeasible. Likewise, the inverse could result in targets that do not meet the WEPS discharge consent standards. Therefore, absolute contraction was paired with consent standards as upper limits, and local limits as lower limits, to combine the global Planetary Boundary science with local context, with a practical pathways to meet the targets.

<u>Recommended target</u>

Concentration of total **Nitrogen** and **Phosphorus** per litre of discharge is no greater than the most stringent of:

- Wastewater Environmental Performance Standards (WEPS) 2025

OR

- A percentage reduction compared to CCO concentration baselines - determined by the discharge renewal consent year - for all land and freshwater receiving environments to be achieved within 5 years of new consent. See table for % improvement requirements. [2]

Note - reduction targets can be waived for high-performing CCOs if -
A) They are already achieving better than WEPS standard concentrations, AND
B) They can demonstrate that they already achieve the best currently feasible concentrations of N and P

Percentage Reduction from baseline for Nitrogen and Phosphorus Concentrations in Wastewater Discharge

Renewal Consent Year	Improvement on N	Improvement on P
2026	33%	20%
2027	35%	22%
2028	38%	24%
2029	41%	26%
2030	44%	28%
2031	47%	29%
2032	50%	31%
2033	53%	33%
2034	56%	35%
2035	59%	37%

[2] The Freshwater Science and Technical Advisory Group, 2019 report to the Minister for the Environment recommended local limits for total nitrogen and total phosphorus into freshwater receiving environments of ≤1mg N/L, and ≤0.018mg P/L. These recommended limits are based on maximum nutrient concentration levels for ecosystem health. If these levels are achieved, no further reductions are required.

Nitrogen & Phosphorus

Updating targets over time

The KPI targets set out in this document should not be treated as fixed. They are derived from Planetary Boundary science, which is itself an evolving field. As new research of Earth-system thresholds and Planetary Boundary science is refined, the targets should be updated accordingly.

The current targets are also based on trajectories informed by where key environmental indicators are heading today. If global conditions change, whether through accelerated degradation or meaningful recovery, the trajectory and pace of required reductions may need to be recalibrated.

PAN recommends that targets be reviewed at regular intervals i.e., every 2 years, or as the science evolves, so that they remain aligned with the best available science.

Nitrogen & Phosphorus

A step-by-step guide for CCOs

Nitrogen & Phosphorus targets are determined according to the year the CCO joins the programme.

A - Establish Baseline

Document baseline performance: i.e. the concentration of total nitrogen and total phosphorus at the point for each land and freshwater discharge in the baseline year* as per Wastewater Environmental Performance Standards (WEPS) 2025.

*The baseline is for the year prior to renewal consent.

B - Calculate targets

Use the table below to calculate targets for each discharge; i.e. for a CCO renewing their consent in 2028, the % reduction would be for renewal consent year '2028' corresponding to a 38% reduction for N and 24% reduction for P.+

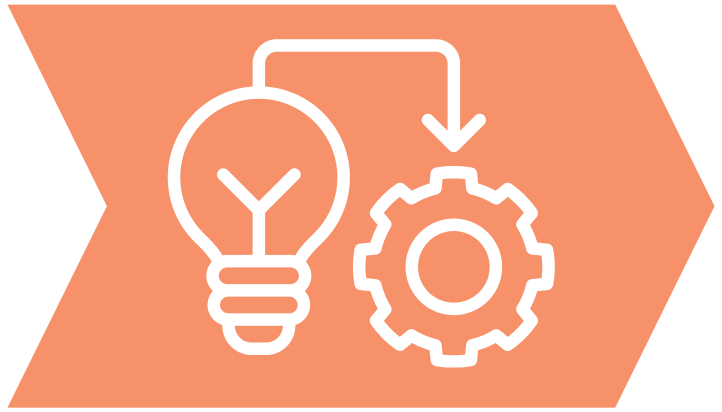
Targets would be calculated as:

- Target N = N_baseline - 0.38*N_baseline
- Target P = P_baseline - 0.24*P_baseline

Compare the calculated targets (Target N, and Target P) to the WEPS discharge requirements for total nitrogen and phosphorus per litre of wastewater discharge. Target concentrations are the most stringent of either the WEPS concentrations, or those calculated (as above).**

+The Freshwater Science and Technical Advisory Group, 2019 report to the Minister for the Environment recommended local limits for total nitrogen and total phosphorus into freshwater receiving environments of ≤1mg N/L, and ≤0.018mg P/L. If these levels are achieved, no further reductions are required.

C - Implementation



Implement intervention(s) to improve N&P performance within 5 years; i.e. if the renewal consent is for 2028, targets need to be reached by 2033.

D - Reporting

Provide documented evidence of performance to LGFA.

Renewal Consent Year	Improvement on N baseline	Improvement on P baseline
2026	33%	20%
2027	35%	22%
2028	38%	24%
2029	41%	26%
2030	44%	28%
2031	47%	29%
2032	50%	31%
2033	53%	33%
2034	56%	35%
2035	59%	37%

**Reduction targets can be waived for high-performing CCOs if-
A) They are already achieving better than WEPS standard concentrations, AND
B) They can demonstrate that they already achieve the best currently feasible concentrations of N and P

Biogenic GHGs

Background

Biogenic greenhouse gases (GHGs) - methane and nitrous oxide emissions - are produced by living organisms through natural biological processes, with agriculture being a major anthropogenic source of both. Wastewater treatment plants also contribute, releasing methane through anaerobic decomposition and nitrous oxide as a byproduct of nutrient removal during treatment.

Global Framing

In 2024 global emissions of methane and nitrous oxide were ~16.3 GtCO2e (United Nations Environment Programme, 2025). ~6.9% of these emissions is from the wastewater sector. Saunois et al, 2020 estimated the global methane emissions produced by wastewater treatment in 2017 was ~34 million tonnes of CH4. The United Nations Environment Programme and Food and Agriculture Organization of the United Nations have estimated that in 2020 total global nitrous oxide emissions produced from wastewater was ~774,000 tonnes N2O (UNEP, 2024).

The UNEP noted that implementing technical solutions to minimise nitrous oxide emissions (for all wastewater in OECD countries and half of wastewater in non-OECD countries), would result in 40 per cent reduction compared to untreated wastewater (UNEP, 2024). However, implementing mitigation strategies - particularly those related to plant operations - require facility level monitoring and analysis to understand when and where N2O and CH4 is produced.

Under the Planetary Boundaries framework, biogenic emissions are captured under 'climate change'. This boundary has been transgressed since the first publication of the Planetary Boundaries in 2009.

New Zealand Context

In New Zealand, Water New Zealand wastewater carbon accounting guidelines use a level or tiered system to estimate emissions from wastewater processes, depending on the level of data accuracy. Level 1 is population based or uses default average data. Level 2 estimates emissions using plant-specific operating data e.g., influent and effluent load, sludge removal information, and general factors. Level 3 is the most accurate, involving comprehensive on-site testing for specific emission factors.

The majority of facilities across New Zealand use Level 1 for emissions reporting. This approach has insufficient granularity to inform mitigation strategies.

Appropriate facility-level mitigation strategies require at least Level 2, but ideally Level 3 measurement and monitoring to identify where and how emissions are produced. However, Level 2 (and Level 3) measurement constitutes a substantial increase in cost and effort to implement. Therefore, while the long-term goal of the SLP is to drive emissions reductions, the preliminary KPI has been established to create a step change in the maturity of emissions measurement, and thus require facilities to establish a robust baseline for subsequent mitigation targets.

A Target for Biogenic GHGs

Recommended target

Level 2 measurement implemented within 2 years of entering the programme.*

Level 3 - facility level measurement implemented by 2040.**

*Greenhouse gas emissions measurement to be in accordance with the most current *Water New Zealand wastewater carbon accounting guidelines*, and future guidance for Level 3 measurement.

**A materiality threshold will be confirmed once the global methodology for Level 3 (Tier 3) measurement has been established. In the interim, the Level 3 measurement will be required for the CCOs largest wastewater treatment plant until global methodology has been established.

Biogenic GHGs

Updating targets over time

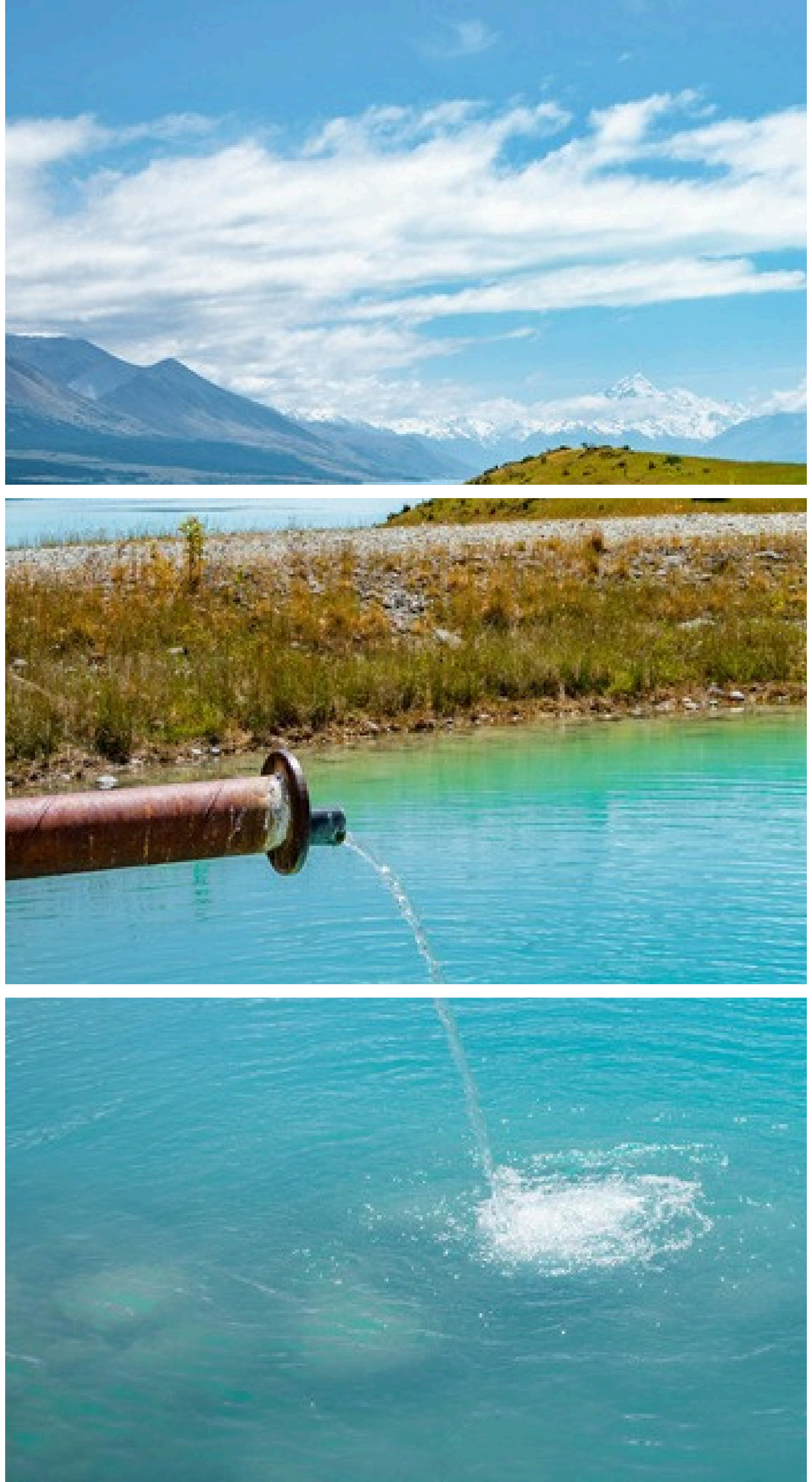
Improving measurement of GHGs is 1) essential for developing appropriate emissions reduction strategies, and 2) is ambitious due to increased burden on entities. However, in the long-term, measurement alone will not continue to be ambitious.

It is recommended that future iterations of this SLL consider including a requirement to set a reduction target that:

- is aligned with the Planetary Accounting limit for biogenic emissions [3], and
- considers feasibility of emission reduction opportunities.

The KPI requires Level 3 (Tier 3) measurement for *a representative portion of the wastewater processes.* A materiality threshold for the *representative portion* should be confirmed well before 2030 i.e., in the next review of the SLL, in two-years time. Ideally, the threshold will be informed by a global methodology for Level 3 (Tier 3) measurement. However, confirming the threshold should not be held up by delayed publication of the future methodology.

[3] The Intergovernmental Panel on Climate Change have published a series of '1.5°C aligned pathways' for limiting global temperature rise to 1.5°C above pre-industrial levels. These pathways consider various mechanisms to meet reduction scenarios e.g., energy demand, sustainable lifestyles and consumption habits, population growth, and varying degrees on reliance on technological vs nature-based solutions for carbon dioxide removal. Planetary Accounting uses the IPCC1.5 °C 'P2' pathway targets for 2100, being a sustainability-oriented scenario with low population growth, low consumption, high energy efficiency, and minimal reliance on Bioenergy with Carbon Capture and Storage (BECCS).



Biogenic GHGs

A step-by-step guide for CCOs

Level 2 measurement requires plant influent and effluent load data and sludge removal information, which are processed into emissions estimates using default emissions factors. This summary is taken from the WaterNZ Carbon Accounting Guidelines for Wastewater Treatment for Level 2 measurement. Please refer to that reference for further detail.

A - Prepare & Collect

Decide whether to use biochemical oxygen demand (BOD), or chemical oxygen demand (COD) *Note - you must not mix BOD/COD in your calculations*

Calibrate flow meters (within ±5% accuracy)

B - Collect

Collect samples for:

- Influent composition
  - 24-hour composite sampling (ideally flow weighted)
- Effluent composition
  - Measurements must be of total nitrogen (not TKN)
- Flow
  - Totalised daily flows from real-time totalisers

C - Calculate

Calculate loads and emissions using emissions factors:

- Total Organics in Wastewater
- Total Nitrogen
- Emissions - Wastewater Treatment (Methane)
- Emissions - Wastewater Treatment (Nitrous Oxide)
- Emissions - Discharge
- Emissions - Sludge
- **Total Emissions**

Within 2-years of entering programme.

D - Measure

Generate a plant-specific emissions factor through on-site testing.

Use this and data collected under Level 2 measurement to recalculate **total emissions**.

By 2040

Water Efficiency

Background

Water is essential to all life, economies, and ecosystems, yet freshwater supplies face growing pressure from population growth and climate change altered precipitation patterns. Agriculture accounts for the largest share of global water use, followed by industry and municipalities (United Nations, 2024). Groundwater aquifers, which supply nearly half the world's drinking water, are being depleted faster than they can naturally recharge in many regions (United Nations, 2024). Managing water sustainably means not only using less, but using it more wisely: reducing waste, improving infrastructure, recycling treated water, and aligning demand with what ecosystems can reliably provide.

Global Framing

The Planetary Boundary for Freshwater Use has been defined for sustainable water management to limit 'blue' water consumption i.e., water extracted from surface water (rivers, lakes) and groundwater, in order to protect environmental flows. The global boundary for Freshwater Use is 2,800 km^3 / year and considers gross water consumption (Steffen et al., 2015), (Rockström et al., 2025). Current global blue water withdrawals are circa 4,000 km^3 / year. The majority (~69%) of this water is used for agriculture (mainly irrigation) (Rockström et al., 2025). The remainder is from domestic (12%) and industrial use (19%) (Food and Agriculture Organization of the United Nations. (n.d.)).

New Zealand Context

While New Zealand is often perceived as a water-abundant country, this perception obscures a growing vulnerability to water scarcity that is already being felt. Drought is increasingly frequent and severe across New Zealand, with 70 percent of monitored climate stations recording extreme dryness between 2013 and 2022 (Stats NZ, 2023). In 2024, some areas experienced over 200 days of rainfall deficit (Environmental Health Indicators NZ, n.d.), and drought was formally declared as a medium-scale adverse event across multiple regions including Canterbury, Otago, Wellington, Taranaki, and Northland (Inland Revenue NZ, 2023).

Auckland provides a particularly stark illustration of this vulnerability. The 2019–2020 drought was the most extreme in modern records, with the city receiving only 60 percent of its normal rainfall between November 2019 and May 2020 (Watercare, 2020a). Storage dam levels fell to as low as 42.5 percent and mandatory water restrictions were imposed for the first time in over 25 years (Watercare, 2020b). The crisis led to the construction of a new water treatment plant at Tuakau. Even with this new infrastructure, water restrictions remained in place for 17 months (Watercare, 2020b).

Ageing water infrastructure resulting in leaks along water pipeline networks compounds the challenge. Water inefficiencies are not just a water problem. Higher water consumption and losses demands more energy, chemicals, and infrastructure capacity to treat and distribute water, causing increased operational costs and environmental pressure. Increasing water usage directly correlates to a higher volume of wastewater that requires treatment, as most residential and industrial water enters sewage systems after use. In this context, water use efficiency is not merely an operational improvement — it is a fundamental requirement for the long-term resilience and sustainability of the water sector.

Water Efficiency

A Target for Water Efficiency

Most water abstracted in New Zealand is for irrigation. The regional councils and unitary authorities are responsible for setting the allocation limits and granting consents for water takes, and is therefore is outside of the CCOs remit. For consistency across all CCOs, water that is not supplied on the drinking water network e.g., water used for irrigation, is excluded from the target.

Top down and bottom-up approaches were used to establish the target for water efficiency. Year-on-year global reductions rates needed to align with the Planetary Boundaries limit by 2050 were determined, based on linear reduction over 25 years (2025–2050).

An end-point efficiency target was then derived from the 2050 budget by disaggegating the total Planetary Boundary by end-use (agriculture, industrial, domestic) according to Rockström et al. (2025) coupled with New Zealand specific benchmarks. This resulted in an end-point of water provision of 190L/capita/day - including household and non-household use.

As water is an essential service and basic need, bottom up approaches were used to determine a) the minimum water supply needed to meet basic needs and b) feasibility:

- Minimum water requirements for domestic needs as per Stewart-Koster et al., (2023) Living within the safe and just Earth system boundaries for blue water is 100L/capita/day.
- Global best practice in water efficiency for developed nations is ~128L/capita/day (based on EU average from Te Waihanga New Zealand Infrastructure Commission (2024)).

i.e. an end-point in reductions towards ~190L/capita/day is both reasonable and feasible in the long term, and provides allowance for non-household use, therefore this end point was selected.

This target is intended to provide Water CCOs flexibility to employ initiatives supporting reductions on both supply and demand side depending on their own social and regional characteristics, and seasonal / temporal constraints i.e., capital works programmes to address and manage leaks, vs behaviour change / social campaigns.

Recommended Target

Reduction in gross water consumption per capita across the network (includes withdrawals and losses) of at least 7% reduction per 5-year period (average of 1.4% per year) from a three-year average baseline immediately prior to entering the programme [4]. Gross water consumption includes water abstracted for household use, commercial use, and water losses. It includes water supplied to rural properties.

The 5-year timeframe to meet reductions allows for step-wise change, i.e., pipe upgrades to reduce losses in the system, and protects against a potential scenario where unforeseen circumstances cause higher water consumption i.e., fires or emergency events requiring water from the network.

The % reduction applies to all water supplied on the drinking water network, regardless of the end-use. This on the basis that reporting the volume of non-residential water used per Taumata Arowai requirements (2025b) includes all water used for non-residential properties, rural and agricultural uses, and outdoor areas i.e., it is a combined value, and does not distinguish between the different uses.

Updating the Water Efficiency target over time

As climate change intensifies the frequency and severity of droughts, and population growth places increasing demand on finite freshwater resources, improving water efficiency is critical to building resilience against growing water scarcity. Therefore, PAN recommends this target is reviewed at regular intervals i.e., every 2 years, or as the Planetary Boundaries framework evolves, so that it remains aligned with the best available science and considers changes in environmental and societal pressures.

Currently, the target excludes water that is not supplied on the drinking water network i.e., non-potable water used for irrigation. It is recommended that future iterations of this SLL consider including a requirement for non-potable water, where this falls within the CCO remit. Future iterations should also consider the use of recycled water.

[4] To a base level no less than 190L water per person per day. This level is based on Rockström et al. (2025) coupled with New Zealand specific water consumption benchmarks, global best practice water efficiency, and minimum water requirements for domestic needs as per Stewart-Koster et al., (2023) Living within the safe and just Earth system boundaries for blue water.

Water Efficiency

A step-by-step guide for CCOs

The Water Efficiency target is determined according to the year the CCO joins the programme.

A - Establish Baseline

Document baseline performance of gross water consumption per capita as an average across 3-years prior to entering the programme.

The relevant Taumata Arowai reporting metrics and reference codes are:

- *Water supplied to the drinking water network (D-EH4)*, and
- *Total population served by the drinking water network (D-EH3).*

Gross water consumption per capita calculated as: *water supplied (D-EH4)* divided by *population served (D-EH3).*

For a CCO joining in year 2028, this would be calculated as:
Water Efficiency_baseline = (D-EH4/D-EH3 in year 2025 + D-EH4/D-EH3 in year 2026 + D-EH4/D-EH3 in year 2027) / 3

B - Calculate targets

Calculate the water efficiency reduction target, (7% reduction per 5-year period) for each 5-year time horizon.

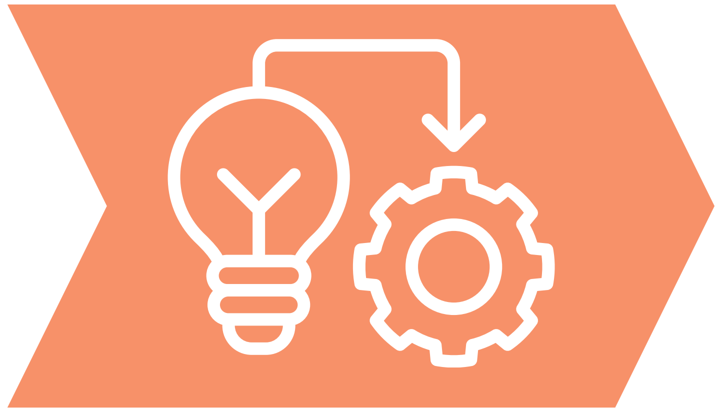
For a CCO joining in 2028 the target in 2033, would be calculated as:

Target Water Efficiency (2033) = Water Efficiency_baseline - 0.07*Water Efficiency_baseline.

For a CCO joining in 2028 the targets in subsequent 5-year periods (i.e., 2038, then 2043, and so on and so forth) are calculated as follows:

Target Water Efficiency (2038) = Target Water Efficiency (2033) - 0.07*Target Water Efficiency (2033).

C - Implementation



Implement intervention(s) to improve water efficiency performance for the 5-year time horizons; i.e. for a CCO joining in 2028, targets need to be reached by 2033,

Additional Taumata Arowai reporting metrics and reference codes that are relevant when exploring improvement pathways for implementation include:

- Non-residential water use (D-EH7)
- Median Residential Water Consumption (D-RE4)
- Estimated Total Water Network Loss (D-RE1)

D - Reporting

Provide documented evidence of performance to LGFA.

Embodied Carbon

Background

Carbon dioxide and other greenhouse gas emissions from human activities are the primary driver of rising global temperatures. Embodied carbon refers to the total greenhouse gas emissions generated through the life cycle of a product (e.g. cement or steel), from raw material extraction, manufacturing, transportation, construction, maintenance, and end-of-life disposal of building materials.

Global Framing

The built environment is responsible for approximately 37%–42% of annual global carbon emissions, comprising both operational emissions (27%) from energy use and embodied carbon (15%) from construction materials like steel and cement (UNEP, 2023). With total global emissions reaching 57.7 GtCO2e (UNEP, 2025) in 2024, the built environment's contribution is substantial — and growing as infrastructure investment increases worldwide.

The Planetary Boundary for climate change measures the balance between incoming and outgoing energy at the Earth's surface. Rising atmospheric CO_2 and greenhouse gases trap more radiation, driving higher global temperatures and shifting climate patterns. To set its carbon reduction targets, PAN draws on this Planetary Boundary framework alongside 1.5°C-aligned pathways developed by the Intergovernmental Panel on Climate Change (IPCC). The 1.5°C-aligned (P2) pathway means that global emissions must reduce to 50% by 2030 (from 2020 levels), reach net-zero by 2055 (commonly referred to as 'net-zero 2050), and -12GtCO2e by end of the century.

New Zealand Context

DIA estimates New Zealand will need to invest between NZ$120 billion and NZ$185 billion over the next 30 years (DIA, 2021) on water infrastructure. In the nearer-term (over next 10-years), this is forecast as ~$47.9b, including $17b on drinking water infrastructure, and $22.5b on wastewater infrastructure. Infrastructure spending at this scale carries a significant embodied carbon footprint — the emissions associated with manufacturing, transporting, and installing materials such as concrete, steel, and pipework.

Despite this, it is not yet common practice for water entities to measure and report on carbon emissions from capital works (either for forward planning, or actuals from construction). Of the 13 councils that LGFA and PAN spoke to, only 2 reported they had completed carbon assessments for capital works projects.

A Target for Embodied Carbon

The ultimate goal of this KPI is to reduce embodied carbon associated with capital works. However, given the scale of planned investment in water infrastructure, and that quantifying embodied emissions of projects is not yet standard practice across the sector, the preliminary target is for entities to measure GHG emissions related to capital works.

This target is intended to capture measurement of embodied emissions in materials, as well as fossil fuels used in construction, as both are significant. For example, in Watercare's 2020 carbon emissions baseline for their capital works programme 50% of the emissions are from materials. A further 40% is associated with excavation, backfill and reinstatement i.e., construction plant used for pipeline networks (Watercare, 2023). Therefore, there are potential opportunities to reduce emissions from reviewing material selection and construction technique.

Recommended Target

Measure prospective emissions from the CCOs forward capital works programme for at least 80% of anticipated spend in a 3-5 year period, starting from one year after joining the programme. [5]

The embodied carbon emissions baseline should be estimated using a prospective life-cycle assessment (LCA) approach, consistent with the principles and framework of ISO 14040 / ISO 14044. Recognised industry methodologies such as the NZGBC Embodied Carbon Methodology or MBIE Whole-of-Life Embodied Carbon Assessment - Technical Methodology may be used where consistent with ISO 14040/44 principles, noting these these will need to be adapted for water infrastructure.

The embodied emissions assessment should be subject to independent review or validation consistent with ISO 14064-3 or equivalent.

Forward-looking estimates must include documented assumptions, data sources, and methodological limitations.

[5] PAN recommends future iterations of the SLLs shift the materiality threshold to an '80% by impact threshold'.

Embodied Carbon

Updating the Embodied Carbon Target

Whilst this KPI is currently focused on measurement, it is recommended that the data and insights gathered from this measurement are then used to develop reduction targets and roadmaps.

When establishing a future reduction target, it will be important to take into consideration that some actions taken to improve one KPI may positively or negatively affect another. For example, repairing leaks along the network would increase embodied carbon emissions, but subsequently reduce gross water consumption. As such, rather than setting a fixed reduction target, PAN recommends the next review of the SLL consider implementing a requirement to robustly demonstrate capital work have a net environmental return on investment. For example, carbon impact ≤ environmental benefit. This could be completed using Planetary Accounting, or any other framework that enables science-based management of environmental trade-offs (i.e., providing a comparison between water, waste, carbon, etc).

As maturity of embodied carbon measurement improves, the materiality threshold should evolve in step. PAN recommends that future iterations of the SLLs shift the materiality threshold from ‘at least 80% of anticipated spend’ (per year) to an ‘80% by impact threshold’ to better capture what drives outcomes, not just where capital is allocated.

PAN recommends CCOs choosing this KPI integrate it into programme and project level decision-making:

- At a programme level, alongside financial, service delivery, and risk information when planning and prioritising capital investment, so that carbon being spent through the programme is delivering genuine improvements to water service outcomes. Capital carbon data can be used to build a clear picture of the ‘carbon hotspots’ i.e., where carbon is concentrated within the capital works programme by asset type, material, and project phase - for further investigation, scenario testing, and reduction planning.
- At a project level, to compare options during design, challenge material selections, and evaluate whether the proposed scope is the most efficient way to achieve the required outcome.

Embodied Carbon

A step-by-step guide for CCOs

This KPI is to advance the measurement of capital carbon emissions from the CCOs forward capital works programme, 3-5 years after joining the programme, for at least 80% of anticipated spend over that period.

A - Prepare & Collect

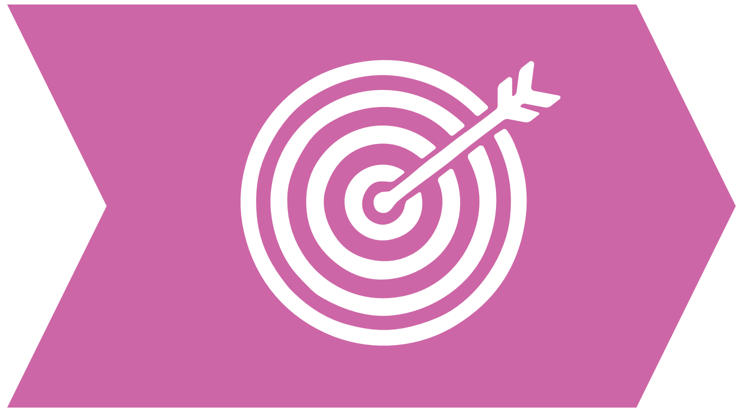
Using Water Services Delivery Plans, existing asset management plans and/or capital works programmes as a basis, collate a list of all upcoming capital works projects with their associated spend over the next 3-5 years.

Identify capital works projects to be assessed which represent at least 80% of anticipated spend for each upcoming year.

CCOs can do this by determining 80% of the overall annual capital spend, and then summing the capital spend of the projects (starting from highest budget to lowest) until the 80% value is reached.

For the purpose of this KPI, minor works such as maintenance, non-infrastructure projects (e.g. IT systems), and consultancy services are excluded.

B - Collect Data

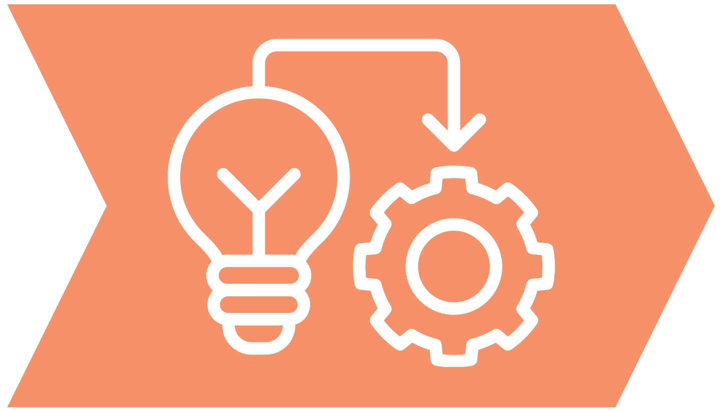


Collect data for the prospective capital works carbon assessment - the baseline. This includes information related to the materials used on the projects. Reference documents could include:

- Bill of quantities or pricing schedules.
- For renewals – historical bill of quantities for similar project
- Where information isn't available – similar historical projects or high-level estimates

The baseline should be estimated using a prospective LCA approach, consistent with the principles and framework of ISO 14040 / ISO 14044 (or equivalent recognised LCA methodology such as the NZGBC Embodied Carbon Methodology or MBIE Whole-of-Life Embodied Carbon Assessment - Technical Methodology, adapted where required for water infrastructure). WaterNZ has also published guidance to support industry understanding of key concepts and steps to reduce emissions. Refer to *Understanding Embodied Carbon in the Water Sector - Advancing our journey to net zero*.

C - Calculate Baseline



Calculate embodied emissions from production of materials, transport, and construction stages in the LCA. This includes emissions from:

- Manufacturing materials (including raw material supply, transport, and processing)
- Transport of materials (and waste) to/from site
- Construction activities i.e., fuel use for plant and equipment, and disposal of waste
- Emissions from land use change

There are many carbon assessment tools and software solutions on the market which have databases of these emissions factors built in. Moata Carbon Portal is one. However, CCOs may opt to use other software providers or develop in-house spreadsheets to estimate carbon emissions from capital works projects.

Provide documented evidence of the capital carbon emissions baseline to LGFA.

D - Reporting

Water CCOs are required to provide progress updates to LGFA on whether emission reduction opportunities have been achieved, with supporting evidence.

Although not mandatory for this KPI, it is recommended that Water CCOs use the carbon baseline to develop emission reduction targets, with a roadmap and action plan for how emissions will be reduced over the forward programme. Setting targets will support CCOs to identify potential opportunities to reduce emissions, and test scenarios to develop a roadmap for achieving the targets. The roadmap would be able to inform the action plan. This should be reviewed regularly and updated as required i.e., as the forward works programme is updated, so too should the action plan.

References

Cross, L., Gruère, A., de Sousa, J., & Chtioui, H. (2025). Short-term fertilizer outlook 2024–2025. International Fertilizer Association (IFA). https://www.fertilizer.org/wp-content/uploads/2025/02/2024_ifa_short_term_outlook_report.pdf.

Department of Internal Affairs (2021) National Evidence Base. Wellington, NZ: Department of Internal Affairs. Available at: https://www.dia.govt.nz/Water-services-reform-national-evidence-base.

Food and Agriculture Organization of the United Nations. (n.d.). Water use. AQUASTAT - FAO's Global Information System on Water and Agriculture. https://www.fao.org/aquastat/en/overview/methodology/water-use

Environmental Health Intelligence NZ (n.d.) Drought and rainfall https://ehinz.ac.nz/indicators/climate-change/rainfall-and-drought-our-changing-climate/

GHD, Beca, & Boffa Miskell. (2020). The New Zealand Wastewater Sector. Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/wastewater-sector-report.pdf

Inland Revenue NZ (March 2024). Drought Declared Across Parts of New Zealand https://www.ird.govt.nz/updates/news-folder/2024/drought-declared-across-parts-of-nz

IPCC. (2019). 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories (E. Calvo Buendia, K. Tanabe, A. Kranjc, J. Baasansuren, M. Fukuda, S. Ngarize, A. Osako, Y. Pyrozhenko, P. Shermanau, & S. Federici, Eds.). IPCC. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

Meyer, K., & Newman, P. (2020). Planetary accounting: Quantifying how to live within planetary limits at different scales of human activity. Springer. https://doi.org/10.1007/978-981-15-1443-2

Ministry for the Environment. (2025). Measuring emissions guide: 2025. https://environment.govt.nz/publications/measuring-emissions-guide-2025/

NIWA (2020) Auckland's drought most extreme in modern times https://niwa.co.nz/news/aucklands-drought-most-extreme-modern-times

Singhal. N., et al. (2023) Mitigating nitrous oxide emissions from wastewater treatment systems. https://www.waternz.org.nz/Story?Action=View&Story_id=2148

Saunois, M., Stavert, A. R., Poulter, B., Bousquet, P., Canadell, J. G., Jackson, R. B., Raymond, P. A., Dlugokencky, E. J., Houweling, S., Patra, P. K., Ciais, P., Arora, V. K., Bastviken, D., Bergamaschi, P., Blake, D. R., Brailsford, G., Bruhwiler, L., Carlson, K. M., Carrol, M., Castaldi, S., Chandra, N., Crevoisier, C., Crill, P. M., Covey, K., Curry, C. L., Etiope, G., Frankenberg, C., Gedney, N., Hegglin, M. I., Höglund-Isaksson, L., Hugelius, G., Ishizawa, M., Ito, A., Janssens-Maenhout, G., Jensen, K. M., Joos, F., Kleinen, T., Krummel, P. B., Langenfelds, R. L., Laruelle, G. G., Liu, L., Machida, T., Maksyutov, S., McDonald, K. C., McNorton, J., Miller, P. A., Melton, J. R., Morino, I., Müller, J., Murguia-Flores, F., Naik, V., Niwa, Y., Noce, S., O'Doherty, S., Parker, R. J., Peng, C., Peng, S., Peters, G. P., Prigent, C., Prinn, R., Ramonet, M., Regnier, P., Riley, W. J., Rosentreter, J. A., Segers, A., Simpson, I. J., Shi, H., Smith, S. J., Steele, L. P., Thornton, B. F., Tian, H., Tohjima, Y., Tubiello, F. N., Tsuruta, A., Viovy, N., Voulgarakis, A., Weber, T. S., van Weele, M., van der Werf, G. R., Weiss, R. F., Worthy, D., Wunch, D., Yin, Y., Yoshida, Y., Zhang, W., Zhang, Z., Zhao, Y., Zheng, B., Zhu, Q., Zhu, Q., and Zhuang, Q.: The Global Methane Budget 2000–2017, Earth Syst. Sci. Data, 12, 1561–1623, https://doi.org/10.5194/essd-12-1561-2020, 2020.

StatsNZ (2023) Drought. https://www.stats.govt.nz/indicators/drought/

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223), Article 1259855. https://doi.org/10.1126/science.1259855

Stewart-Koster, B., Bunn, S.E., Green, P. et al. Living within the safe and just Earth system boundaries for blue water. Nat Sustain 7, 53–63 (2024). https://doi.org/10.1038/s41893-023-01247-w

Taumata Arowai. (2025a). Network environmental performance report 2023/24. https://www.taumataarowai.govt.nz/assets/Uploads/Network-Performance/Network-Environmental-Performance-Report-2023_24.pdf

Taumata Arowai. (2025b). Network environmental performance measures and guide 2025. https://www.taumataarowai.govt.nz/assets/Uploads/Network-Performance/Environmental-Performance-Measures-and-Guide-2025.pdf

References

Te Waihanga New Zealand Infrastructure Commission. (2024). Valuing water: Sustainable water services and the role of volumetric charging. New Zealand Infrastructure Commission/Te Waihanga. https://media.umbraco.io/te-waihanga-30-year-strategy/i4djtc0t/valuing-water-sustainable-water-services-and-the-role-of-volumetric-chargingv3.pdf

Tinholt, R. (2019). The value of biosolids in New Zealand: An industry assessment. Paper presented at the WaterNZ Conference 2019.

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., Petri, S., Porkka, M., Rahmstorf, S., Schaphoff, S., Thonicke, K., Tobian, A., Virkki, V., Weber, L., & Rockström, J. (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9(37), Article eadh2458. https://doi.org/10.1126/sciadv.adh2458

Rockström, Johan et al. (2025) The EAT–Lancet Commission on healthy, sustainable, and just food systems. The Lancet, Volume 406, Issue 10512, 1625 - 1700 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01201-2/abstract

Statistics New Zealand. (2020, August 23). National population estimates: At 30 June 2020. https://www.stats.govt.nz/information-releases/national-population-estimates-at-30-june-2020/

United Nations Environment Programme and Food and Agriculture Organization of the United Nations. 2024. Global Nitrous Oxide Assessment. Nairobi. https://doi.org/10.59117/20.500.11822/46562

United Nations Environment Programme (2025). Emissions Gap Report 2025: Off target – Continued collective inaction puts global temperature goal at risk [Olhoff, A., chief editor; Lamb, W.; Kuramochi, T.; Rogelj, J.; den Elzen, M.; Christensen, J.; Fransen, T.; Pathak, M.; Tong, D. (eds)]. Nairobi. https://doi.org/10.59117/20.500.11822/48854.

United Nations (2024), The United Nations World Water Development Report 2024: Water for Prosperity and Peace. UNESCO, Paris. https://unesdoc.unesco.org/ark:/48223/pf0000388948/PDF/388948eng.pdf.multi

Watercare Services Limited. (2018). Funding plan 2018 to 2028. https://wslpwstoreprd.blob.core.windows.net/kentico-media-libraries-prod/watercarepublicweb/media/watercare-media-library/reports-and-publications/funding-plan-2018-2028.pdf

Watercare (2020) Auckland's residential water restrictions to be adjusted for summer https://www.watercare.co.nz/home/about-us/latest-news-and-media/auckland-s-residential-water-restrictions-to-be-adjusted-for-summer

Watercare (2021). Timeline of the drought response https://ourauckland.aucklandcouncil.govt.nz/media/ichn12q4/4-1210-watercare-drought-timeline7.pdf

Watercare (2023). Watercare climate change summary 2023. https://promising-sparkle-d7f0c0cfc9.media.strapiapp.com/greenhouse_gas_online_supplement_2023_92f9133eaa.pdf

Water New Zealand (2021). Carbon accounting guidelines for wastewater treatment: CH4 and N2O. V1.1.

Water New Zealand (2025). Understanding Embodied Carbon in the Water Sector - Advancing our journey to net zero. https://www.waternz.org.nz/Article?Action=View&Article_id=3091

Water Services (Wastewater Environmental Performance Standards) Regulations 2025 (SL 2025/258). https://www.legislation.govt.nz/secondary-legislation/pco-drafted/2025/258/en/latest

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., ... & Wood, A. (2019). Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447-492. DOI: 10.1016/S0140-6736(18)31788-4

Appendices

Appendix A - Long List of KPI Recommendations

This mapping process has been used to establish a long-list of KPIs as shown in the table below.

The results of the Planetary Accounting Assessment highlighted that phosphorus, nitrogen, biogenic greenhouse gases, water use, and carbon+ (in bold) are the most material environmental impacts within the New Zealand water sector. To drive meaningful improvement across the sector, these KPIs were selected to take forward as part of the SLLP, with a target established for the four most material impact categories.

KPI	Related Activities	Relevance to Water CCO Activities	Data Measurement Required
Carbon+	Operations Capital Works	Carbon dioxide and fossil-based greenhouse gas emissions from operations (e.g., diesel and petrol vehicles) and capital projects (e.g., production of concrete, and other materials).	• Use of fossil fuels e.g., L diesel, L petrol, MJ gas, or km driven, hours of generator use etc. • Electricity usage (kWh) for each source, e.g., NZ grid, solar, etc. • Waste treatment (incineration) • Bill of materials from capital works. • Land use change: Deforestation/ Afforestation.
Biogenic GHGs	Operations	Greenhouse gases produced from wastewater treatment processes and disposal.	• Emissions from wastewater treatment (currently mostly estimated via volumes treated and industry factors) and disposal (currently estimated from tonnage of biosolids and industry factors).
Nitrogen, N Footprint Phosphorus, P Footprint or Eutrophication Potential*	Operations	Nitrogen in wastewater discharge. Phosphorus in wastewater discharge.	• N & P measured in wastewater discharge.
Water Efficiency	Operations	Extraction, delivery and treatment of potable water.	• Ideally CCOs would measure water use (per capita) and losses via direct metering. However, currently, most councils are estimating water use via demographic information and total network monitoring • Water losses are mostly measured via night flow monitoring.
Water Scarcity Impact	Operations	Accounts for local impacts on water bodies/water supply i.e., considers regional variations of water supply, temporal variations in water supply, etc.	• Gross water consumption / withdrawals.
Biodiversity	Operations Capital Works	Land use and land-use change from capital works. Pollutants in untreated discharge.	• Area of land used, and by type e.g., urban land, native bush (i.e., blue-green stormwater networks). • Land-use change from capital works (deforestation / afforestation). • Pollutants / contaminants measured in wastewater discharge. Pollutant monitoring in stormwater discharge is typically undertaken by regional councils, however will be relevant to CCOs who are choosing to include SW management e.g., QLDC.
Waste	Operations Capital Works	Waste captured through wastewater treatment, and generated by capital works.	• Waste captured from wastewater screenings, imperishable waste generated in operations. • Construction and demolition waste generated in capital works.

Metrics that have been grouped include:

- Water quality - release of pollutants to waterways is captured under biodiversity and waste.
- Air quality - the use of fossil fuels is captured carbon+.
- Forestland - land use change is captured under biodiversity.
- Ozone - as not considered material for water CCO activities.

Appendix B - Assumptions

<table>
<tr><th>Category</th><th>Methodology Process</th><th>Description</th></tr>
<tr><td rowspan="3">Drinking Water</td><td>Treatment Mix</td><td>To develop a New Zealand specific dataset which models the treatment of drinking water, public information was reviewed to determine typically used treatment types. No comprehensive national stocktake of drinking water treatment types is currently available. To address this data gap, a desktop review was undertaken to identify the primary water sources (groundwater vs. surface water) and associated treatment types across a sample of councils. This approach provides an indicative overview to inform assumptions, acknowledging that it is based on publicly available information and may not fully capture site-specific variations. Based on this assessment, the estimated proportional distribution of treatment types across total treated drinking water volume in New Zealand is as follows:
• A – Conventional Surface-Water Multi-Barrier (48% of NZ treated volume)
• B – Membrane Multi-Barrier (26% of NZ treated volume)
• C – Groundwater w/ UV and/or Filtration + Cl (15% of NZ treated volume)
• D – Groundwater w/ Chlorine Treatment Only (10% of NZ treated volume)</td></tr>
<tr><td>Ecoinvent Datasets</td><td>Surface water treatment datasets used:
• Conventional treatment: conventional treatment includes coagulation and decantation, filtration and disinfection. Ecoinvent Dataset: ‘tap water production, conventional treatment’
• Conventional with biological treatment: conventional with biological filtration treatment includes coagulation and decantation, biological filtration and disinfection. Ecoinvent Dataset: ‘tap water production, conventional with biological treatment’
• Direct filtration treatment: direct filtration treatment includes sand filtration and disinfection. Dataset: ‘tap water production, direct filtration treatment’
• Microstrainer treatment: microstrainer treatment includes intake pumping, microfiltration through stainless steel strainers and disinfection. Ecoinvent Dataset: ‘tap water production, microstrainer treatment’

Ground water treatment datasets used:
• Underground water with chemical treatment: Water is pumped from aquifer, chemically enhanced (e.g. corosion inhibitor, ph, chloration, etc.) and pressurized for distribution. Ecoinvent Dataset: ‘tap water production, underground water with chemical treatment’
• Underground water with disinfectant: Underground water pumping and disinfection using chlorine. Ecoinvent Dataset: ‘tap water production, underground water with disinfection’
• Underground water without treatment: Underground water without further treatments. Water is pumped from aquifer and pressurized for distribution. Ecoinvent Dataset: ‘tap water production, underground water without treatment’</td></tr>
<tr><td>Dataset Adaptations</td><td>To develop a New Zealand–specific dataset for modelling drinking water treatment, the following key steps were undertaken:
• Exclusion of infrastructure impacts: Capital infrastructure components were removed to ensure the dataset reflects operational impacts only.
• Localisation of energy inputs: All electricity inputs were adjusted to reflect the New Zealand grid mix.
• Derivation of representative baseline: Results from multiple geographies were averaged to establish a generalised baseline for tap water treatment, which was then adapted to the New Zealand context.</td></tr>
</table>

Assumptions cont.

Category	Methodology Process	Description
Wastewater	Treatment	In 2020 MfE engaged a joint consultant team of GHD, Beca and Boffa Miskell to provide a series of reports that describe the wastewater sector in New Zealand including details on current and emerging issues for wastewater management. This stocktake of NZ's wastewater sector provides information on number and types of treatment plants across NZ, the capacity of these plants, and details of effectiveness of treatment. As per the report, wastewater treatment in New Zealand involves three key stages: Primary Treatment, Secondary Treatment, and Disposal of biosolids, non-biological waste, and the treated wastewater. Reference: *Beca, GHD, & Boffa Miskell. (2020). The New Zealand wastewater sector. Prepared for the Ministry for the Environment.*
	Datasets	The following datasets and assumptions were applied to represent wastewater and biosolids treatment processes: • Primary treatment: Modelled using the Ecoinvent dataset "treatment of wastewater, average, wastewater treatment." • Secondary treatment: Modelled thermal drying, which corresponds to 13% of NZ's sludge produced based on findings from 'Tinholt (2019), The Value of Biosolids in New Zealand – An Industry Assessment.'. This was modelled using Ecoinvent datasets "*drying, sewage sludge* | *raw sewage sludge*" • Biosolids disposal: Model assumed to comprise 70% landfill and 30% land application (landfarming), split based on '*Tinholt (2019), The Value of Biosolids in New Zealand – An Industry Assessment.'* This was modelled using Ecoinvent datasets: *'treatment of sewage sludge, 75% water, WWT, WW, average, sanitary landfill'*, *'treatment of sewage sludge, 97% water, WWT, WW, average, landfarming'*. • WaterNZ Conference 2019. These proportions were modelled using the Ecoinvent datasets "*treatment of sewage sludge, 75% water, WWT, WW, average, sanitary landfill*" and "*treatment of sewage sludge, 97% water, WWT, WW, average, landfarming*'.
	Dataset Adaptations	To develop a New Zealand–specific dataset for modelling wastewater treatment, the following key steps were undertaken: • Exclusion of infrastructure impacts: Capital infrastructure components were removed to ensure the dataset reflects operational impacts only. • Localisation of energy inputs: All electricity inputs were adjusted to reflect the New Zealand grid mix. • Derivation of representative baseline: Results from multiple geographies were averaged to establish a generalised baseline for tap water treatment, which was then adapted to the New Zealand context. • Changed dinitrogen monoxide emitted in treatment processes from fossil based (carbon+) to non-fossil (biogenic GHGs) in alignment with Planetary Accounting • Updated nitrate and phosphate emissions factors to reflect the mid-point of the TIN and TIP range in Table 8 in The New Zealand Wastewater Sector (GHD, Beca and Boffa Miskell, 2020) • Updated the dinitrogen monoxide (nitrous oxide) emissions factors as per the 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC, 2019)

Appendix C - Results: Average Per Person, Per Day

Results of the Planetary Accounting Assessment on a daily per capita basis are shown below. This assumes:

- NZ Population in 2024: 5,356,700
- Volume Drinking Water: 722,629,000 m3 / year. 560,629,000 m3 / year accounting for losses
- Volume Wastewater Treated: 547,500,000 m3 / year
- Volume Drinking Water Per Person: 134 m3 / year, ~370 L / day (including losses)
- Volume Wastewater Treated Per Person: 102 m3 / year, ~280 L day

PA Metric	Unit	Drinking Water Treatment	Primary Treatment	Secondary Treatment	Biosolids disposal	Total WWT Results	Total	Total as % daily per capita budget, 2030
Air Pollution	kg PM2.5-Eq	0.00008	0.00005	0.00000	0.00001	0.00006	**0.00015**	**1%**
Biodiversity	species.yr	2.0E-10	1.2E-09	1.7E-11	1.5E-09	2.8E-09	**3.0E-09**	**2%**
Biogenic GHGs	kg CO2-Eq	0.00009	0.035	0.000	0.355	0.390	**0.390**	**17%**
Carbon+	kg CO2-Eq	0.043	0.025	0.004	0.021	0.050	**0.093**	**2%**
Deforestation	m2	3.1E-06	1.7E-06	2.8E-08	8.2E-08	1.8E-06	**5.0E-06**	**0.2%**
Nitrogen	kg N-Eq	0.000006	0.0073	0.0000	0.0001	0.0074	**0.0074**	**16%**
Ozone	kg CFC-11-Eq	5.2E-10	3.7E-10	3.4E-11	2.1E-10	6.1E-10	**1.1E-09**	**0%**
Phosphorus	kg P-Eq	0.000026	0.0016	0.000001	0.0002	0.0018	**0.0019**	**40%**
Waste	kg waste	0.0038	0.0036	0.0001	0.0008	0.0046	**0.0083**	**0.4%**
Water Use	m3	0.370	-0.280	0.000005	-0.00001	-0.280	**0.090**	**3%**

Average Percentage Daily Limit ~8%

Results - New Zealand

Results of the Planetary Accounting assessment ((for total volume of water and wastewater treated) are shown below. This assumes:

- NZ Population 2024: 5,356,700
- Volume Drinking Water: 722,629,000 m3 / year. 560,629,000 m3 / year accounting for losses
- Volume Wastewater Treated: 547,500,000 m3 / year

PA Metric	Unit	Drinking Water Treatment	Primary Treatment	Secondary Treatment	Biosolids disposal	Total WWT Results	Total
Air Pollution	kg PM2.5-Eq	162,333	91,017	4,883	26,580	122,480	**284,813**
Biodiversity	species.yr	<1	2	<1	3	5	**6**
Biogenic GHGs	kg CO2-Eq	172,825	68,750,725	12,140	694,567,800	763,330,665	**763,503,490**
Carbon+	kg CO2-Eq	83,492,964	49,404,454	7,248,784	41,268,079	97,921,317	**181,414,282**
Deforestation	m2	6,150	3,362	55	161	3,577	**9,727**
Nitrogen	kg N-Eq	11,156	14,262,283	371	120,162	14,382,816	**14,393,972**
Ozone	kg CFC-11-Eq	1	1	<1	<1	1	**2**
Phosphorus	kg P-Eq	50,227	3,151,369	1,533	434,481	3,587,383	**3,637,610**
Waste	kg waste	7,356,985	7,135,229	238,958	1,579,710	8,953,897	**16,310,883**
Water Use	m3	723,374,312	- 546,629,138	10,298	- 17,988	- 546,636,828	**176,737,484**

Sensitivity Results - Upper Bound (N2O, N, P)

Results of the sensitivity analysis (upper bound) on a daily per capita basis are shown below. This assumes

- Phosphorus and nitrogen concentration in wastewater discharge (as PO25, and nitrate) based on the upper bound of TIN and TIP values in Table 8 in *The New Zealand Wastewater Sector* (GHD, Beca and Boffa Miskell, 2020)
- Factors for methane based on upper bound of Table 6.3 for Centralised, aerobic treatment plant and Anaerobic digester for sludge in the *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories* (IPCC, 2019)
- Factors for nitrous oxide based on upper bound of Table 6.8A for Centralised, aerobic treatment plant, as per the 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC, 2019)

PA Metric	Unit	Drinking Water Treatment	Primary Treatment	Secondary Treatment	Biosolids disposal	Total WWT Results	Total	Total as % daily per capita budget, 2030
Air Pollution	kg PM2.5-Eq	0.00008	0.00004	0.00000	0.00001	0.00006	**0.00014**	**1%**
Biodiversity	species.yr	2.0E-10	1.6E-09	1.7E-11	1.5E-09	3.2E-09	**3.4E-09**	**2%**
Biogenic GHGs	kg CO2-Eq	0.00009	0.092	0.000	0.355	0.448	**0.448**	**19%**
Carbon+	kg CO2-Eq	0.043	0.025	0.004	0.021	0.050	**0.093**	**2%**
Deforestation	m2	3.1E-06	1.7E-06	2.8E-08	8.2E-08	1.8E-06	**5.0E-06**	**0.2%**
Nitrogen	kg N-Eq	0.000006	0.0092	0.0000	0.0001	0.0092	**0.0093**	**19%**
Ozone	kg CFC-11-Eq	5.2E-10	3.7E-10	3.4E-11	2.1E-10	6.1E-10	**1.1E-09**	**0.02%**
Phosphorus	kg P-Eq	0.000026	0.0022	0.000001	0.0002	0.0024	**0.0024**	**52%**
Waste	kg waste	0.0038	0.0036	0.0001	0.0008	0.0046	**0.0083**	**0.4%**
Water Use	m3	0.370	-0.280	0.000005	-0.00001	-0.280	**0.090**	**3%**

Average Percentage Daily Limit ~10%

Sensitivity Results - Lower Bound (N2O, N, P)

Results of the sensitivity analysis (lower bound) on a daily per capita basis are shown below. This assumes

- Phosphorus and nitrogen concentration in wastewater discharge (as PO25, and nitrate) based on the lower bound of TIN and TIP values in Table 8 of *The New Zealand Wastewater Sector* (GHD, Beca and Boffa Miskell, 2020)
- Factors for methane based on lower bound of Table 6.3 for Centralised, aerobic treatment plant and Anaerobic digester for sludge, as per the 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC, 2019)
- Factors for nitrous oxide based on lower bound of Table 6.8A for Centralised, aerobic treatment plant, as per the 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC, 2019)

PA Metric	Unit	Drinking Water Treatment	Primary Treatment	Secondary Treatment	Biosolids disposal	Total WWT Results	Total	Total as % daily per capita budget, 2030
Air Pollution	kg PM2.5-Eq	0.00008	0.00004	0.00000	0.00001	0.00006	**0.00014**	**1%**
Biodiversity	species.yr	2.0E-10	9.2E-10	1.7E-11	1.5E-09	2.5E-09	**2.7E-09**	**1%**
Biogenic GHGs	kg CO2-Eq	0.00009	0.004	0.000	0.355	0.359	**0.359**	**15%**
Carbon+	kg CO2-Eq	0.043	0.025	0.004	0.021	0.050	**0.093**	**2%**
Deforestation	m2	3.1E-06	1.7E-06	2.8E-08	8.2E-08	1.8E-06	**5.0E-06**	**0.2%**
Nitrogen	kg N-Eq	0.000006	0.0058	0.0000	0.0001	0.0059	**0.0059**	**12%**
Ozone	kg CFC-11-Eq	5.2E-10	3.7E-10	3.4E-11	2.1E-10	6.1E-10	**1.1E-09**	**0.02%**
Phosphorus	kg P-Eq	0.000026	0.0012	0.000001	0.0002	0.0014	**0.0014**	**31%**
Waste	kg waste	0.0038	0.0036	0.0001	0.0008	0.0046	**0.0083**	**0.4%**
Water Use	m3	0.370	-0.280	0.000005	-0.00001	-0.280	**0.090**	**3%**

Average Percentage Daily Limit ~7%


LGFA
New Zealand Local
Government Funding Agency
Te Pūtea Kāwanatanga ā-rohe
the
planetary
accounting
network