SETTING WELLINGTON WATER ON A PATHWAY TO NET ZERO EMISSIONS

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ABSTRACT

The water sector is responsible for 5% of global Greenhouse Gas emissions (Thacker et al. 2021), and these emissions must be rapidly reduced over the coming decades if we are to achieve national and global climate change targets. The challenge for the water sector is profound. Emissions result from a wide variety of activities including carbon intensive infrastructure build, energy and chemical use over the operational lifetime of water and wastewater processes, and substantial amounts of biogenic methane and nitrous oxide from wastewater treatment and sludge disposal. An ambitious, planned, collaborative and holistic approach is needed to transition the sector to net zero by 2050.

Wellington Water is committed to playing a leading role in reducing its own emissions and influencing others in the industry to do the same. This paper outlines analysis undertaken by Wellington Water and Mott MacDonald that explores options and pathways to reduce Wellington Water's operational emissions. In line with best practice science-based approaches, reductions of at least 50% by 2030 and net zero by 2050 are explored. This paper shows that such an ambitious pathway is possible but requires immediate action with a particular focus on key emissions hot spots. It proposes a framework of next steps to achieve these aspirations, including the implementation of low-regrets measures now whilst a longer-term integrated net zero plan is developed; embedding whole-life emissions reduction into governance, leadership and decision making; and engaging externally to shape emerging Water Reforms.

The work outlined in this paper is a first for the water sector in New Zealand and draws on international learning from the UK and elsewhere. Multiple emissions pathways are analysed: A Business-As-Usual pathway shows emissions increasing overtime due to population growth; a Moderate Ambition Pathway achieves substantial but insufficient emissions cuts, and a Step-Change Pathway that reduces emissions by almost 90% by 2050 representing a near best case scenario where financial and policy barriers are removed, investment increased and significant technology changes are achieved.

The paper identifies specific opportunities for Wellington Water to reduce wastewater treatment and effluent discharge emissions, reduce then eliminate sludge disposal emissions, eliminate the use of fossil fuel energy and reduce the use and embodied carbon of treatment chemicals. The analysis serves as a model for water companies around New Zealand who wish to embark on a similarly ambitious journey. It can act as a call-to-arms for the water sector to commit to action to help preserve a habitable climate for future life on Earth.

KEYWORDS

Climate change, net zero, Greenhouse gas emissions, operational emissions

PRESENTER PROFILES

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1. INTRODUCTION

In 2019 New Zealand passed legislation to commit the country to reduce emissions from 'long-lived' Greenhouse Gases (including Carbon Dioxide, CO_2, and Nitrous Oxide, N_2O) to net zero by 2050, and from 'short-lived' biogenic methane, CH_4, from agriculture and waste by 24-47% below 2017 levels by 2050. For New Zealand's water sector this means emissions will need to be cut across a wide range of activities including energy and transport use, water treatment, wastewater treatment, effluent discharge and sludge disposal. These reductions will need to happen in context of population growth, market reforms, investment in capital programmes and tightening environmental standards. The challenge for water services providers will be substantial.

This paper presents a summary of work undertaken by Mott MacDonald and Wellington Water in 2022 to explore what an ambitious emissions reduction pathway looks like for Wellington Water. It provides an indication of the extent of ambition and types of measures required to align Wellington Water's activities with Aotearoa New Zealand's climate change commitments. In doing so, it proposes a platform to help guide future decarbonisation strategies, business planning and investment decisions, and it identifies some key technological, policy and financial requirements to unlock ambitious climate action in the water sector.

The scope of this work is 'operational emissions' from drinking water, wastewater and stormwater assets managed by Wellington Water, as well as emissions from downstream assets not in Wellington Water's control but that relate to waste products from Wellington Water's activities (e.g. landfill sludge disposal). Operational emissions are defined here as modules B6 (operational energy use), B7 (operational water use) and B8 (other operational processes) from the PAS2080:2016 Carbon Management Standard (BSI 2016). The scope does not include 'capital emissions' from the renewal or construction of assets, emissions from use-phase maintenance and repair activities, or end-of-life emissions.

Wellington Water manages and operates water services assets on behalf of six client Councils: Greater Wellington Regional Council, Wellington City Council, Porirua City Council, Upper Hutt City Council, Hutt City Council, and South Wairarapa District Council

The study included the following main activities:

- Updating Wellington Water's operational emissions inventory to reflect data from 2020-21, the latest WaterNZ guidelines on biogenic emissions, and the addition of South Wairarapa District Council.
- Identifying and analysing decarbonisation options for each main emissions hotspot, including consideration of timing, deployment potential and impact on emissions. This was informed by input and engagement through workshops with Wellington Water and its client councils.
- Reviewing the current policy, regulatory and industry context driving emissions reduction in the water sector, and identifying implications to consider in setting future emissions targets.
- Developing indicative decarbonisation pathways to 2050 to show the overall level of operational emissions reduction that may be possible and the activities and requirements to achieve this.
- Identifying next steps for the development of a net zero strategy and action plan, identifying key activity areas, risks and stakeholders.

2. WELLINGTON WATER'S 2020-21 EMISSIONS

2.1. METHODOLOGY

2.1.1. EMISSIONS SCOPE AND BOUNDARIES

The scope and boundaries of the 2020-21 operational emissions inventory and subsequent emissions reduction pathway analysis draws on the *GHG Protocol Corporate Accounting and Reporting Standard* ("GHG Protocol") (WRI & WBCSD 2004). It also reflects guidance from the Ministry for the Environment on organisational emissions reporting (MfE 2022), Water New Zealand's Navigating to Net Zero report (WaterNZ 2021a) and Water New Zealand's *Carbon Accounting Guidelines for Wastewater Treatment* (WaterNZ 2022b).

The inventory applies the GHG Protocol's Scope 1, 2 and 3 emissions categories:

- **Scope 1** - direct GHG emissions from sources that are owned or controlled by the organisation. Wellington Water's Scope 1 operational emissions primarily include emissions from the use of fossil fuels for vehicles and heating / drying, and biogenic emissions of CH_4 and N_2O associated with wastewater treatment processes controlled by Wellington Water.

- **Scope 2** - emissions associated with purchased electricity for Wellington Water's operations, such as pumping and running treatment plants.
- **Scope 3** - emissions indirect emissions that are a consequence of an organisation's activities but are from sources not owned or directly controlled by the organisation. Wellington Water's scope 3 operation emissions include emissions associated with purchased chemicals for water treatment and biogenic emissions from sludge disposal at landfill.

2.1.2. DATA, ASSUMPTIONS AND EMISSIONS FACTORS

Where possible primary activity data for the relevant emissions categories was collected but it was nonetheless necessary to make a number of assumptions to address gaps and provide the necessary detail for calculation purposes. These assumptions were checked through a process of engagement and checking with the technical specialists. The 2020-21 inventory is therefore considered high-level but suitable for providing an overview of Wellington Water's operational emissions and a basis for developing indicative decarbonisation pathways.

Emissions factors were primarily taken from MfE's August 2022 datasets and Water New Zealand guidelines. However where emissions factors specific to New Zealand were not available other sources were used such as the UK Government Department for Environment, Food and Rural Affairs GHG Conversion Factors for Company Reporting (DEFRA 2022) and Infrastructure Sustainability Council's Materials Calculator (Version 1.2 LCI 2016).

2.1.3. APPROACH TO ESTIMATING BIOGENIC EMISSIONS

The approach to including and calculating biogenic emissions associated with water sector activities followed Water New Zealand's *Guidelines for Wastewater Treatment* (WaterNZ 2021b). These guidelines cover anthropogenic biogenic CH_4 and N_2O emissions from municipal wastewater treatment, effluent discharge, sludge disposal. Biogenic emissions from sewer networks, grit and screenings and fossil carbon from petroleum based products in wastewater influent are excluded – this is due to factors such as insufficient data to determine emissions factors at the current time the relative insignificance of grit and screenings as emissions sources, and the degradability of fossil carbon from petroleum based products in wastewater water influent being unknown but assumed to be small.

CH_4 and N_2O emissions are reported in terms of carbon dioxide equivalent (CO_2e). The Water New Zealand guidelines exclude biogenic CO_2 emissions which are derived from organic material and are a part of the Earth's short term carbon cycle.

2.2. SUMMARY OF WELLINGTON WATER'S 2020-21 EMISSIONS

2.2.1. MAIN EMISSIONS HOTSPOTS

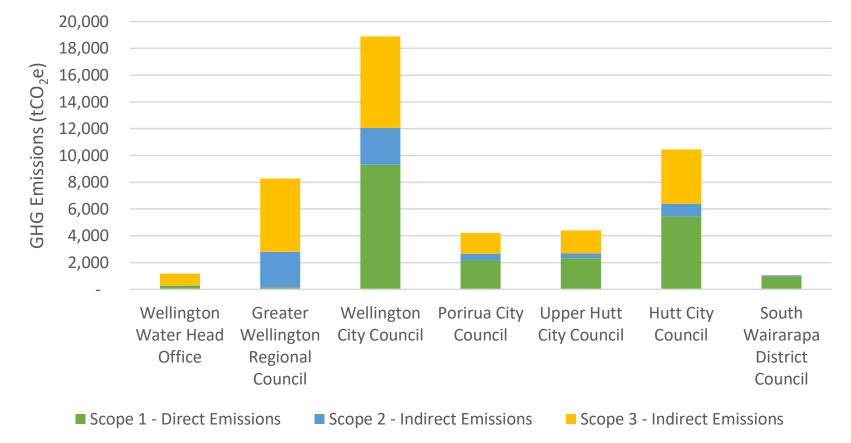
Table 1 summarises the results of the inventory, grouped into the main emissions hotspots. Wellington Water's total operational inventory emissions in 2020-21 were **48,438 tCO_2e**.

Table 1: Emissions hotspots across Wellington Water's GHG inventory

Hotspot	Emissions (tCO_2e)	% of total inventory
Biogenic CH_4 and N_2O, from wastewater treatment	13,552 tCO_2e	28%
Biogenic CH_4 and N_2O, from sludge disposal	12,779 tCO_2e	26%
Electricity use (with T&D losses included)	7,288 tCO_2e (7,957 tCO_2e)	15% (16.4%)
Purchased chemicals	5,768 tCO_2e	12%
Biogenic CH_4 and N_2O, from effluent discharge	3,910 tCO_2e	8%
Natural gas use (with T&D losses included)	2,691 tCO_2e (2,851 tCO_2e)	6% (6.3%)
Fleet vehicles including Alliance partner vehicles	930 tCO_2e	1.9%

2.2.2. EMISSIONS BY COUNCIL

Figure 1: Breakdown of Wellington Water's operational emissions by Council



Commented [UD1]: It think it may be useful to highlight some of the key aspects of the graph that link to the hotspots table above e.g

WCC has the largest population served, over 200,000 people, which is over 50% of the serviced population, a useful link to the pathways that reflect population growth…. also has the largest wwtp in the region moa point….

sludge disposal at the landfills in Greater wellington and Wcc and Hutt City highlights the the indirect emissions...

Of Wellington Water's total operational inventory emissions:

- Almost 40% are associated with Wellington City Council (WCC). Most of these are biogenic wastewater emissions from Moa Point, Karori (Western) and Porirua WWTPs, with a significant contribution also from grid electricity.
- Over 20% are associated with Hutt City Council (HCC). Most of these come from Seaview WWTP and most are biogenic wastewater emissions with a significant contribution also coming from the use of natural gas on site.
- Around 17% are associated with Greater Wellington Regional Council (GWRC). Most come from Te Marua and Wainuiomata WTPs, principally through the

chemicals purchased and used. An additional significant contribution comes from electricity use for GWRC's distribution, collection and treatment systems.
- Around 9% are associated with Upper Hutt City Council (UHCC). Most of these come from Seaview WWTP and most are biogenic wastewater emissions, with a significant contribution also coming from the use of natural gas on site.
- Around 9% are associated with Porirua City Council (PCC). Most of these come from Porirua WWTP and most are biogenic wastewater emissions.
- Around 2% are associated with South Wairarapa District Council (SWDC). Most of these are biogenic emissions from Featherston, Greytown and Martinborough WWTPs. Lack of data was an issue for some SWDC sources.
- Around 2% are associated with Wellington Water Limited (WWL). Most of this comes from fuel used for transport.

3. EMISSIONS REDUCTION OPTIONS

3.1. APPROACH

3.1.1. EMISSIONS MANAGEMENT HIERARCHY

As a general principle, climate change mitigation activities should be prioritised according to an emissions management hierarchy that first reduces the need for emissions generating activities, then replaces inputs or processes with lower emission alternatives, and finally offsets or neutralises residual emissions.

The emissions reduction options considered for Wellington Water fall into the following categories which broadly reflect the emission management hierarchy:

- *Reduce* potable water demand, water leakages, wastewater infiltration and improve water catchment management (leading to reduced demand on Water Treatment Plants [WTPs] and Wastewater Treatment Plants [WWTPs]).
- *Reduce* energy / fuel demand and chemical usage through efficiency and optimisation.
- *Replace* fossil fuels, e.g. through electrification (based on renewable sources) and/or other clean fuels.
- *Reduce* emissions from the wastewater treatment process (including sludge and final effluent) through treatment plant optimisations.
- *Reduce* emissions from the wastewater treatment process (including sludge and final effluent) via installing new technology options on treatment plants.
- *Offset / neutralise* residual emissions – outside the scope of this work.

3.1.2. IDENTIFYING AND ASSESSING INTERVENTIONS

In total over 50 emissions reduction interventions were considered. These were identified through a collaborative approach between Mott MacDonald's and Wellington Water's technical experts, along with reference to external sources (WaterNZ 2021a, WaterUK 2020, Anglian Water 2021, IWA 2022).

Individual interventions were grouped together according to the five intervention categories above and considered in terms of their impact on the main emissions categories identified in the GHG inventory. A high-level scoping was carried out to estimate technical feasibility and theoretical levels of deployment and emissions reduction, and these estimates were subject to a process of challenge and validation through engagement with Wellington Water's technical experts.

For each intervention we identified two sets of deployment and emissions reduction figures, corresponding to the pathways set out in Section 4:

- A "typical" delivery environment (aligned with the Moderate Effort pathway) - where interventions are delivered in line with typical industry procedures and limited by standard financial restrictions, procurement and delivery processes.
- A "best-case" scenario (aligned with the Step-change pathway) - where timelines were reduced and financial restrictions were removed to gain an understanding of maximum possible reductions under optimal conditions.

3.1.3. UNCERTAINTIES AND ASSUMPTIONS

There is inherently a high degree of uncertainty in assessing the potential of decarbonisation interventions over a period of decades. For example, mirroring the current uncertainty around the level of biogenic emissions from wastewater processes, the development of solutions for reducing these emissions is also uncertain. A number of process emission interventions are at an early stage and need to be scaled and demonstrated before they can be rolled out widely. WaterUK (2020) has estimated the uncertainty related to the water sector's ability to reduce process emissions at around 30% of total process emissions.

The analysis addresses this in two ways. First, to provide transparency, interventions were allocated as High, Medium or Low confidence. Second, the emissions reduction potential of some interventions was considered in groups that include a number of potential technologies or approaches, so that if one or two solutions within a group fail to realise their full potential or are not ultimately applicable to Wellington Water's operation, others may prove effective. For example, there are multiple potential solutions to improve nitrification and denitrification in wastewater treatment processes (e.g. Dissolved Oxygen (DO) control, carbon control, pH control or increasing recycle rates) and these are grouped together under a single intervention group.

3.2. SUMMARY OF EMISSIONS REDUCTION OPTIONS

Table 2: Summary of emissions reduction interventions mapped against the main emissions categories impacted.

Intervention category	Main emissions categories impacted	Description / Summary
Reduce water demand and	Treatment Chemicals	Reducing water demand, water leakages, wastewater infiltration and improve water catchment management, resulting in cascading impacts on

Intervention category	Main emissions categories impacted	Description / Summary
improve water catchment management	Wastewater treatment CH_4 emissions Wastewater treatment N_2O emissions	emissions throughout the water service value chain, e.g. reduced need for treatment chemicals and reduced volumes into wastewater treatment. Driven by behavioural changes from end-users throughout the catchment and distribution network and by using technology to reduce leakage. Types of interventions considered include: • Widespread customer metering alongside customer engagement to drive water use reduction. • Leakage and infiltration reduction by focussing on good practice leakage and water loss management and on improving storm management and aging infrastructure.
Reduce energy / fuel demand and chemical usage through efficiency and optimisation	Fleet Vehicles Power Treatment Chemicals	Reducing demand for energy / fuel and other inputs (e.g. chemicals) through data analytics, better maintenance and equipment replacement. Types of interventions considered include: • Improve data capture on all aspects of the operation of the company so that emission sources within Wellington Water can be further understood. Following this, potential activities for emissions reduction of material emissions can be recognised. This could include identifying seasonal variations in chemical use at water treatment through sampling. • Use of monitoring and smart control systems to drive optimum operation. This ranges from power optimisation by using optimum pumping arrangements to replacing poor performing equipment.
Replace fossil fuels	Contract Fleet Fleet Vehicles Gas consumption Power Rental Vehicles Stationary Fuel	Reduce reliance on fossil fuels for energy (including electricity, process heat and transport fuels). We assume that New Zealand's electricity grid will be fully decarbonised by 2035 and this is reflected in the 2050 pathways, including BAU. Types of interventions considered include: • Electrification of process heating systems and fleet vehicles. • Purchase of certified 'green' grid electricity • Increased onsite renewables generation and storage • Use of biofuels for medium to large vehicles • Capture of biogas from sludge processing to produce useful low-carbon energy products. For example, Combined Heat and Power and hydrogen or methane for use onsite or exported to the grid. Green Power Purchase Agreements and onsite renewables have the potential to reduce electricity emissions ahead of the decarbonisation of New Zealand's grid and may also deliver other financial and non-financial benefits.
Reduce emissions from wastewater treatment through process optimisations	Final effluent discharge CH_4 Final effluent discharge N_2O Sludge Processing Wastewater treatment CH_4 emissions Wastewater treatment N_2O emissions	The knowledge of process emissions is still developing and as such data gathering is expected to help the water sector as a whole improve understanding of process emissions and possible areas of optimisation. Optimising of the treatment process will range from reducing generation of N_2O and CH_4 to ensuring optimum capture of produced gases. Types of interventions considered include: • Gather data on actual emissions from existing treatment works, such as by using N_2O probes in tanks, so that wastewater treatment processes can be further understood, the emission more accurately assessed and process optimisation achieved to reduce emissions. • Use of data analytics and digital twins. The use of digital twins and soft sensors to proactively manage treatment processes could reduce process emissions from N_2O by between 40% and 65%. • Chemical additive use to minimise the generation of N_2O. • Improving capture rate of off-gas and investing in capital works that support this (such as covering tanks, gas capture improvements).

Intervention category	Main emissions categories impacted	Description / Summary
Reduce wastewater processes emissions via installing new technology options on wastewater treatment plants	Gas consumption Sludge Processing WW Treatment N_2O	Using new technologies, particularly in sludge treatment, for the reduction of process emissions and the generation of biogas, has the potential to reduce process emissions. Across Wellington Water's value chain there is currently limited sludge treatment prior to disposal. Types of interventions considered include: • Moving to advanced digestion processes and undertaking post sludge treatment processing. • Increasing the yield of biogas and reducing the remaining emission potential of sludge post treatment. • Conversion of biosolids to char or gasification of biosolids. This could result in sludge having no further decomposition potential, removing potential residual emissions from sludge. Furthermore, the move towards a circular economy would encourage the use of this inert sludge for useful purposes such as soil conditioner rather landfill.

4. EMISSIONS REDUCTION PATHWAYS

4.1. DEFINING THE PATHWAYS

Three 2050 emissions pathways were developed. Each uses the 2020-21 inventory as a baseline and then assumes deployment of the interventions described in Section 3 with varying degrees of ambition and effectiveness.

Overall levels of emissions reduction were quantified and compared to a benchmark net-zero trajectory of a 50% cut in GHG emissions by 2030 and net zero by 2050 – in line with the Science-Based Targets Initiative's Net Zero Corporate Standard (SBTi 2022). Net-zero is defined as "a state of balance between anthropogenic emissions and anthropogenic removals", with the SBTi Net Zero Standard making clear that organisations should aim to halve their emissions by 2030 and make deep emissions cuts of at least 90% before 2050 – in order to align with 1.5^{O}C global emissions pathways and the temperature goals of the Paris agreement. Unlike New Zealand's national emissions reduction framework, the SBTi approach does not differentiate between long-lived and short-lived GHG emissions.

The three pathways to 2050 can be summarised as:

- **Business-As-Usual (BAU)**. In this reference pathway emissions are projected into the future based on anticipated population growth rates and taking into account known changes to operations within Wellington Water (e.g. due to already committed investments) and anticipated wider changes at the national level (such as grid decarbonisation). However no further changes or emissions reduction measures were assumed to be implemented.
- **Moderate Effort**. This pathway assumes that Wellington Water continues its current delivery and procurement processes and timelines, but with a greater focus on investment which reduces operational emissions. The pathway uses interventions which are deemed to be technologically developed and

illustrates the impact of a 'typical' delivery and deployment scenario considered by industry experts to be achievable by current standards.

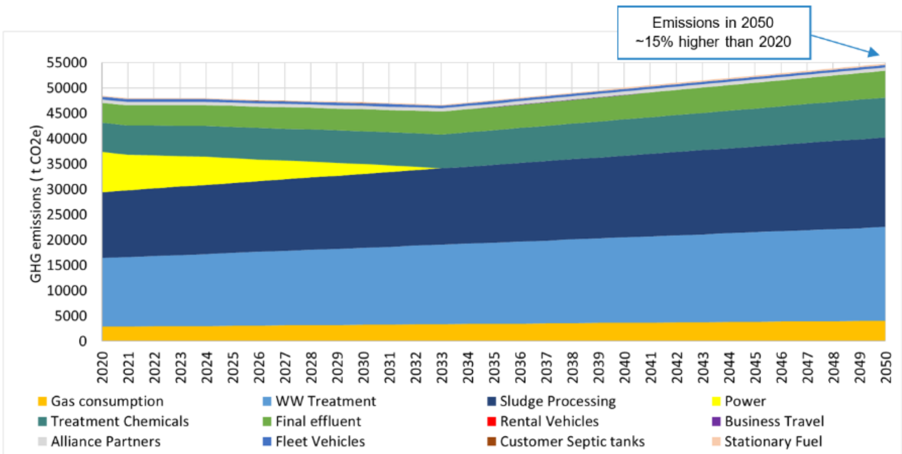
- **Step-change**. This pathway is considered to be an ambitious, near best case scenario where financial and policy barriers are removed, investment is substantially increased and significant technology and industrial changes are achieved. It assumes that Wellington Water pursues emissions reduction as a priority and that the wider infrastructure sector (including the international water sector) invests to develop emissions reduction technologies which are currently in pilot scale for use industry wide.

It should be noted that within all pathways a straight-line deployment of interventions has been assumed between the defined start year and full deployment year. In practice interventions are likely to result in non-linear emissions reductions (for example, a project may take time to be built and then reductions would be immediate). The approach used here is considered appropriate for the purpose of creating indicative long-term pathways.

4.2. BUSINESS-AS-USUAL PATHWAY

Taking account of projected population growth alone results in a projected increase of emissions of around 35% by 2050, compared to 2020. Once grid decarbonisation and other planned interventions are considered (principally a reduction in final effluent emissions in the Martinborough and Greytown regions), the BAU pathway results in total GHG emissions (long-lived gases and biogenic methane) declining slightly between 2020 and 2033, then increasing so that by 2050 total emissions are over 10% higher than 2020. See Figure 2.

Figure 2: BAU pathway total GHG emissions 2020-2050



The following assumptions underpin the BAU pathway:

- Population growth continues across the Wellington Water area though to 2050 and this leads to a proportionate increase across all emissions categories.
- Grid electricity is zero emission by 2035, broadly reflecting the Government's aspiration for 100% renewable energy by 2030 (whilst allowing an extra 5 years for this to be achieved).
- Wellington Water projects that have agreed funding are taken into account but not projects for which funding is not yet secured.

4.3. MODERATE EFFORT PATHWAY

In the Moderate Effort pathway, total GHG emissions (long-lived gases and biogenic methane) decline by around 45% between 2020 and 2037, driven by reductions in grid electricity, natural gas, sludge processing and wastewater treatment emissions. From 2037 emissions increase again - due to population growth alongside financial barriers and diminishing returns on technology investment, stalling further progress so that by 2050 emissions are only around 40% lower than 2020 - see Figure 3. This pathway would not achieve the illustrative SBTi aligned trajectory of a 50% cut by 2030 and net zero by 2050.

Figure 3: Moderate Effort pathway total GHG emissions 2020-2050

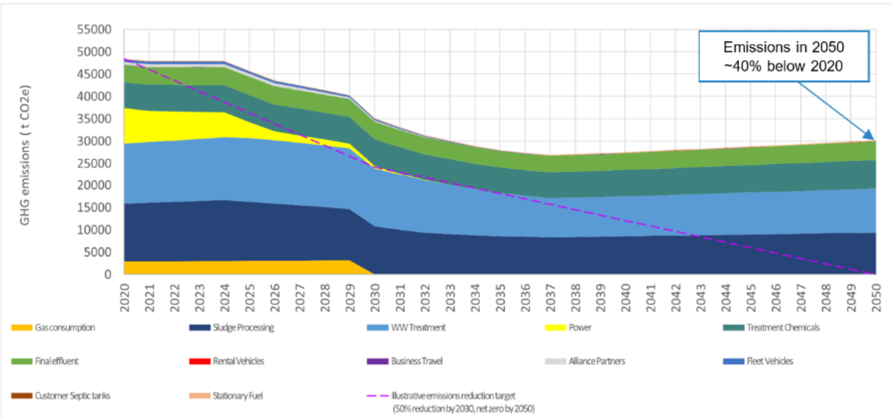


Table 3 below describes the broad level of emissions reduction achieved within each emissions category and summarises the main interventions assumed to deliver this change. The percentage reduction numbers are measured against the BAU pathway (unless otherwise stated) and given to the nearest 5%. They are derived from the underlying spreadsheet model and informed by expert judgement. They should be considered indicative only.

Table 3: Drivers and scale of emissions reduction for Moderate Effort pathway.

Emissions category	Aggregate reduction	Description of relevant interventions in Moderate Effort pathway
Wastewater Treatment N_2O	~55% reduction vs BAU by 2040. Gradual increase in emissions to 2026 from population growth, and again from 2040 after full implementation of interventions.	Key driver to reducing N_2O emissions is to reduce/prevent production in the first place. Interventions which promote the complete nitrification and denitrification in the treatment process will contribute to this. We assume: • Interventions to gather data, using digital twins and optimising the treatment works (such as by targeting DO or using chemical additives) will deliver a ~25% reduction. • Where nutrient removal is not required as part of treatment options it could also be considered to prevent the nitrification and denitrification process. • Additional or alternative treatment processes such and membrane aerated biofilm reactor (MABR) will further reduce emission by ~10%. • Remaining N_2O produced within the treatment works is managed through increased level of off-gas stripping within the treatment works for capture and destruction. Reducing emissions by ~15%. • Reduction of flows to the treatment works providing opportunities for process efficiencies through reduced nutrient dilution. • Network improvements contribute to lower infiltration and leakage rates and customer demand reductions reduce the waste flows – delivering a ~5% reduction.
Wastewater Treatment CH_4	~15% reduction vs BAU by 2040. However from 2040 to 2050 there is a subsequent slight increase due to population growth.	CH_4 is produced when wastewater remains in anerobic conditions. Interventions here reduce the generation of CH_4 in the treatment works. • Intervention to gather data, using digital twins and optimising the treatment works deliver an ~10% reduction. This is lower than N_2O reductions as most processes in Wellington Water's asset base are aerobic and optimisation potential is more limited. • Alternative processes to capture and destroy generated CH_4 from the treatment processes reduce emissions by <5%. These processes have potential to address emissions from both N_2O and CH_4 and may provide greater emissions reductions that expressed here, It is currently lower than N_2O reductions as processes are already targetting aerobic conditions and a number of processes are already covered and sent to bio filters for organics removal. • Reduction of flows to the treatment works providing opportunities for process efficiencies through reduced nutrient dilution. • Network improvements contribute to lower infiltration rates and customer demand reductions reduce the waste flows. Delivering ~5% reduction to emissions.
Final effluent discharge N_2O	~25% reduction vs BAU by 2037. Some increases are observed following 2037 due to population growth.	Emissions from final effluent are caused by nitrogen that remains within the final effluent which is dischagred from treatment works. Optimising the treatment processes for complete nitrification and denitrification will result in nitrogen within wastewater being reduced. This is anticipated to include data gathering, digital twin development and actions such as DO and pH control. This results in a reduction of ~30%.
Final effluent discharge CH4	~15% reduction vs BAU by 2037 - due to optimisation of treatment processes for aerobic conditions. Increases are observed following 2037 due to population growth.	Emissions from final effluent are caused by organic matter which has not been treated as part of the treatment process entering anerobic conditions within the natural environment and decomposing. To reduce the organic matter remaining in the final effluent the treatment processes can be optimised towards aerobic conditions and general organic matter removal. This is anticipated to include data gathering and digital twin development. This results in an ~10% reduction of emissions, lower than N_2O reduction as most Wellington Water processes are aerobic and optimisation potential is considred to be more limited. There are limited opportunities to deploy these interventions across the Wellington Water so that population effects ultimately exceed reductions.
Customer septic tanks N_2O	Anticipated to increase by ~35% in 2050 vs 2020	Details of anticipated growth for Lake Ferry were not available and as such the average population growth across the Wellington Water area (37%) was used. The increase of population is anticipated to increase use of septic

Emissions category	Aggregate reduction	Description of relevant interventions in Moderate Effort pathway
	due to population growth in the Lake Ferry catchment.	tanks and associated emissions. No interventions are proposed for the reduction of these emission.
Customer septic tanks CH_4	As above	As above
Sludge Processing	~45% reduction vs BAU by 2037. After this there is a gradual increase in emissions caused by population growth	The majority of emissions in this category are caused by decaying organic matter that is sent to landfill. By reducing the decay of the sludge it reduces the emissions: • Treatment of sluge prior to discharge to landfil along with the use of generated biogas for useful products at the largest WWT plants in Wellington Water (including Moa Point) is assumed to provide a ~30% reduction overall. • Where sludge treatment is not deployed at WWTP an additional intervention is proposed to install systems for increasing the capture of dissolved gases and preventing aerobic conditions in sludge storage tanks at the remaining plants. This would contribute ~5% reduction in emissions. • Optimisation of sludge processes (enabled by data analytics) provides 10% reduction to account for process changes increasing sludge yield.
Treatment Chemicals	~15% reduction vs BAU by 2035. Increases are observed following 2035 due to population growth with overall emissions in 2050 ~15% higher than in 2020.	Treatment chemicals are predominantly used within potable water treatment processes and as such interventions have focused on the reduction in use of these chemcials: In Step-change further interventions to use alternative chemicals are considered. • The predominant reduction ~10% is delivered through a range of operational efficiencies and targeted maintenance (e.g. seasonal dosing, more efficient operation of mixers etc.). • A reduction in water demand and treatment works output would also reduce the treatment chemicals required. This is achieved through leakage reductions from targeted infrastructure renewals and by increasing metering across the network. These two solutions provide a <5% reduction. • A reduction of ~5% is assumed due to long term engagement and outreach to improve the catchment water quality, particularly in more rural catchments. This intervention is deployed over 20 years.
Fleet Vehicles owned and managed by Wellington Water	100% reduction by 2038.	The elimination of emissions from fleet vehicles is based on the procurement of emission free vehicles as the existing operational fleet comes to the end of its life. • Assumes fleet replacement aligned with typical operational life of fleet. • Assumed the procurement of light EVs and either EVs or biodiesel for medium and heavy vehicles. • Replacement of medium and heavy vehicles delayed until 2030 to allow for additional development of technology for these types of vehicles.
Rental Vehicles	100% reduction by 2032	Assumes only emission free vehicles being used for rental whether EV or biofuels. Could be applied immediately for light vehicles but an extended timeline of 7 years has been applied for medium and heavy vehicles.
Alliance Partner	As above	As above
Gas consumption	100% reduction by 2030	Gas consumption is used at Seaview WWTP and upgrades are required to the current system in the next 5-7 years. Following the implementation of sludge processes described elsewhere the sludge systems would no loner require the use of gas for drying and could be removed.
Power	100% reduction in emissions by 2033	The decarbonisation of the grid means the BAU pathway demonstrates a complete elimination of emissions from power by 2035. The interventions included in Moderate Effort and Stepchange pathways are intended to demonstrate strategies to achieve this decarbonisation more rapidly:

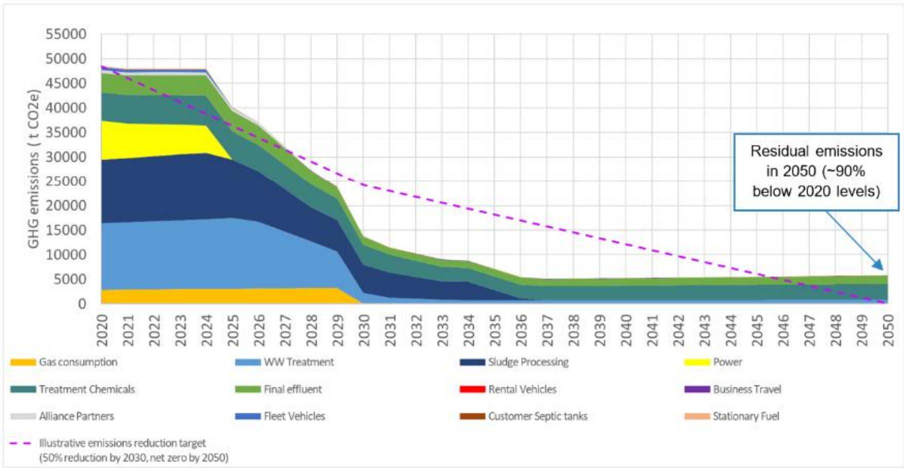
Emissions category	Aggregate reduction	Description of relevant interventions in Moderate Effort pathway
		• A reduction can be achieved ~50% via a certified green PPA. • The development of solar power for energy generation is assumed to provide a further ~50% reduction in emissions • Reductions in electricity demand through efficiency and optimisation.
Business Travel	Business travel is expected to rise by ~15% by 2050 compared to 2020.	An increase in staff required to maintain operational function of Wellington Water is assumed in line with wider population inceases, in turn resulting in increased business travel. No interventions are proposed for the reduction of this emission.
Stationary Fuel	~25% reduction vs BAU by 2026.	It is anticipated that fossil fuels for generators can be reduced by the use of Hydrotreated Vegetable Oil (HVO). The age of generators will determine if they are suitable HVO. We assume only minimal conversion here.

4.4. STEP-CHANGE PATHWAY

In the Step-change pathway, total GHG emissions (long-lived gases and biogenic methane) decline by just under 90% between 2020 and 2036 with very gradual increases thereafter - see Figure 4. This pathway suggests that ambitious action can reduce emissions below the illustrative emissions reduction trajectory of a 50% cut by 2030 and get close to zero gross emissions before 2050.

The residual emissions by 2050 in this pathway are associated essential treatment operations, of which the largest contributor is treatment chemicals which are unlikely to be totally eliminated. There may however be potential for reductions beyond those assumed here if chemical producers implement changes within their own operations – these have not been considered at this stage. The other significant emissions are from methane process emissions in the treatment process and final effluent. Again, further reductions may be possible in the future through optimisation and as new treatment approaches are developed.

Figure 4: Step-Change pathway total GHG emissions 2020-2050



The main interventions required to achieve the Step-change pathway are set out in Table 4. The percentage reduction numbers are measured against the BAU pathway (unless otherwise stated) and given to the nearest 5%. They are derived from the underlying spreadsheet model and informed by expert judgement. They should be considered indicative only.

Table 4: Drivers and scale of emissions reduction for Step-change pathway.

Emissions category	Aggregate reduction	Description of relevant interventions in Step-change pathway
Wastewater Treatment N_2O	100% reduction by 2030.	As with Moderate Effort we assume interventions which promote the complete nitrification and denitrification in the treatment process: • Interventions to gather data, use of digital twins to optimise treatment works such as DO control or chemical additives are delivered across Wellington Water's whole operation (more widely than in Moderate Effort), delivering an 80% reduction (vs 30% in Moderate Effort) • Additional or alternative treatment processes such as MABR will further reduce emissions and increased off-gas stripping and destruction for management of generated emissions is anticipated to fully reduce the emissions to zero. While emissions are resolved using the above the opportunity to reduce flows at wastewater treatment works has also been considered. Network improvements contribute to lower infiltration and leakage rates and customer demand reductions reduce the waste flows. Delivering ~15% reduction - higher than in Moderate Effort due to the assumed increased investment expected to reduce leakage and infiltration and increased water demand reduction from customers.
Wastewater Treatment CH_4	~80% reduction vs BAU 2035. Slight increase after 2035 due to population growth.	Methane is produced when wastewater remains in anerobic conditions and as such interventions are targeted to reduce the generation of methane. • Interventions to gather data, using digital twins and optimising the treatment works will deliver ~50% reduction (vs ~10% in Moderate Effort due to the increased deployment of the interventions across Wellington Water's assets and an increased focus on improvement technologies globally). • Alternative processes to capture and destroy generated methane from the treatment processes reduced the emissions by ~15% (vs <5% in Moderate Effort due to the increased deployment of the interventions across Wellington Water and an increased focus on improvement technologies globally). • Reduction of flows to the treatment works providing opportunities for process efficiencies through reduced nutrient dilution • Network improvements contribute to lower infiltration rates and customer demand reductions reduce the waste flows. Delivering ~15% reduction to emissions (vs 5% in Moderate Effort due to the increased investment expected to reduce leakage and infiltration and increase water demand reduction from customers).
Final effluent discharge N_2O	~80% reduction vs BAU by early 2030s. Some increases following 2031 due to population growth.	Emissions from final effluent are caused by nitrogen that remains within the final effluent which is discharged from treatment works. Optimising the treatment processes for complete nitrification and denitrification will result in nitrogen within wastewater being reduced. This is anticipated to include data gathering, digital twin development and actions such as DO and pH control. This results in a reduction of 80% of emissions (vs ~30% in Moderate Effort pathway due to the increased deployment of the interventions across Wellington Water and an increased focus on improvement technologies globally).
Final effluent discharge CH_4	~50% reduction vs BAU by early 2030s.	Emissions from final effluent are caused by organic matter which has not been treated entering anerobic conditions within the natural environment and decomposing.

Emissions category	Aggregate reduction	Description of relevant interventions in Step-change pathway
	Some increases following 2031 due to population growth.	To reduce the organic matter remaining in the final effluent there is optimisation of the treatment processes towards aerobic conditions and general organic matter removal. This is anticipated to include data gathering, digital twin development. This results in an ~45% reduction of emissions (vs ~10% in Moderate Effort pathway due to the increased deployment of the interventions across Wellington Water and an increased focus on improvement technologies globally).
Customer septic tanks N_2O	As per Moderate Effort	As per Moderate Effort
Customer septic tanks CH_4	As per Moderate Effort	As per Moderate Effort
Sludge Processing	Deployment of interventions begins at 2024 and achieves 100% reduction by 2037. The majority of this (55%) is due to sludge treatment and biogas use.	The majority of emissions in this category are caused by decaying organic matter that is sent to landfill. By reducing the decay of the sludge it reduces the emissions: • Treatment of sludge prior to beneficial use or disposal combined with the capture and processing of the generated biogas for either CHP or commerical uses (for example exporting to the grid) is anticipated to provide a ~55% reduction of emissions (vs 30% in Moderate Effort pathway to reflect greater deployment of sludge treatment and the use of the generated biogas). • Treated sludge still contains some organic matter which is able to decay. An additional intervention included in Step-change converts biosolids to char or gasifies the biosolids which would eliminate remaining decomposition. This is assumed to provide a ~45% reduction in emissions, however this technology is not fully developed and as such is not deployed here until 2035. • Optimisation of sludge processes (enabled by data analytics) provides a 20% reduction (vs 10% in Moderate Effort) to account for process changes which would increase biogas yield .
Treatment Chemicals	~60% reduction vs BAU by 2035 Increases are observed following 2035 due to population growth.	Treatment chemicals are predominantly used within potable water treatment processes and as such interventions have focused on the reduction in use of these chemcials. • A ~20% cut is delivered through operational efficiencies and targeted maintenance (vs 10% in Moderate Effort to account for greater ambition to operate efficiently). • A reduction in the water demand and treatment works deployable output would also reduce the treatment chemicals required. This is achieved through leakage reductions increasing metering. These two solutions provide a ~10% reduction (vs <5% in Moderate Effort to reflect greater investment in network replacement and a bigger reduction in demand from metered customers with higher water charges). • An adaptation in the operating philosophy of potable water treatment works towards processes which minimise contributions to emissions is anticipated to deliver a reduction of 15% - by reducing chemical use, switching to alternative lower embodied emission chemicals, and targeting greater mixing. This is considered in Step-change only as it could contribute to higher operational costs and maintenance due to increased mixing and operational interventions. • A further reduction of ~20% is assumed due to long term engagement and outreach in order to improve the catchment water quality particularly in more rural catchments (vs ~5% in Moderate Effort). This intervention is anticipated to be deployed over 10 years and signifies a shift in investment to encourage catchment improvement.
Fleet Vehicles owned and	100% reduction by 2025	Step-change assumes all fleet vehicles go emissions free within the next few years, so that by 2025 all vehicles are either electric or on biodiesel:

Emissions category	Aggregate reduction	Description of relevant interventions in Step-change pathway
managed by Wellington Water		• Light vehicles are assumed to switch to EVs ahead of the end of the current fleet's natural life (and ahead of Moderate Effort) • Medium and heavy vehicles are assumed to be retrofitted to run on biodiesel in the short term and replaced by electric vehicles from 2030. These interventions assume a sustainable, low emissions supply of biodiesel
Rental Vehicles	100% reduction by 2027	Assumes only emission free vehicles being used for rental whether EV or biofuels. This is applied immediately for light vehicles and by 2027 years for medium and heavy vehicles (quicker than Moderate Effort).
Alliance Partner	As above	As above.
Gas consumption	100% reduction by 2030	Gas consumption is purely used at Seaview WWTP. Upgrades are required to the current system in the next 5-7 years. Following the implementation of sludge processes described elsewhere the sludge systems would no loner require the use of gas for drying and could be removed.
Power	100% reduction by 2025 (ahead of Moderate Effort)	The decarbonisation of the grid means the BAU pathway result in the elimination of emissions from electricity by 2035. The interventions included in Moderate Effort and Step-change pathways are intended to demonstrate strategies for WWL to achieve this decarbonisation more rapidly: • A significant reduction can be achieved (~95%) via a certified green PPA (more than in Moderate Effort). • It is possible that a substantial proportion of Wellington Water's power demand could be met through on-site renewables with supporting storage technologies. Whilst this may not be needed if the Green PPA route is pursued, onsite renewables may be financially attractive in their own right and offer the potential for other co-benefits. • Reduction in electricity demand through efficiency and optimisation.
Business Travel	As per Moderate Effort	As per Moderate Effort
Stationary Fuel	~80% reduction vs BAU by 2025	It is anticipated that fossil fuel use for generators can be reduced by the use of HVO. The age of generators will determine if they are suitable for use with HVO. Stepchange assumes a higher proportion of generators are suitable for conversion of fuel or that aged generators would be replaced with suitable equipment.

4.5. EXTERNAL REQUIREMENTS TO UNLOCK AMBITION

The Step-change pathway and to a lesser extent the Moderate Effort pathway both assume that a number of policy, financial and technological barriers can be overcome whilst other enablers are also put in place. These barriers and enablers can be seen as external requirements for unlocking Wellington Water's decarbonisation potential – summarised in Table 5.

Wellington Water, its asset owners and its potential successor entity can (and should) wield influence over these external requirements through collaboration, leadership and external engagement, but this influence may be limited and will vary depending on the issue at hand.

Table 5: External requirements for unlocking ambitious reductions.

External requirement	Comment
Successful innovation and demonstration of emerging technologies such as biochar from sludge.	This may be largely driven from outside of New Zealand but Wellington Water's asset owners and Aotearoa's other water services providers can support these wider efforts and will need to consider the deployment of these technologies and approaches in their own local contexts. A collaborative approach to the re-use of treated biosolids could also be beneficial.
Investment	Councils are currently able to borrow from banks, issue local bonds or access finance through the Local Government Funding Agency (LGFA) - with a debt ceiling limit set in consultation with citizens and within the boundaries set by the Office of the Auditor General. The water sector reforms may support greater investment through better access to funding, and this may be required for ambitious pathways as they may have higher upfront investment requirements.
Requirement to deliver ambitious emissions reduction	Depending on the investment costs associated with ambitious emissions reduction, it may be challenging to generate sufficient public and political support. A greater level of requirement for water sector asset owners and managers to cut emissions, along with increased pressure from the investment and financial sector for climate risk disclosure and mitigation, could help address this risk.
Better knowledge and data	Knowledge gathering and sharing with other entities both within and outside of New Zealand, particularly on process emissions, will be key to unlocking industry decarbonisation potential.
Supply chain capacity	Supply chains will need to be able to scale up to meet the required demand for low carbon technologies, products and services in the water sector, yet supply chains are currently under strain. Long-term certainty, capacity building and incentivisation will be required to build and sustain supply chain capabilities.
Grid decarbonisation	A substantial proportion of Wellington Water's emissions cuts are driven by the decarbonisation of electricity supply (which in turn supports decarbonisation in other areas that can switch to electricity). The Government aims to reach 100% renewables by 2030 and we have assumed 2035 in our pathways. Failure to achieve this would undermine wider decarbonisation efforts.
EV technologies and infrastructure	Electric vehicles are now being deployed at increasing scale globally, with costs decreasing. New Zealand's transport sector will need to act in a coordinated and proactive fashion for EV infrastructure to be rolled out and to enable rapid EV uptake.
Biofuel sustainability	Deploying biofuels at scale to replace fossil fuels should only happen where high sustainability standards can be met and verified. Biofuels are only likely to play a small role, if any, in Wellington Water's decarbonisation strategy (e.g. HVO for generators), but where they are used there is a need for biofuel supply chains to embed these standards whilst scaling up supply.

5. DELIVERING A NET-ZERO EMISSIONS PATHWAY

Whilst the analysis set our above indicates that an ambitious emissions reduction pathway is possible for Wellington Water, further steps will be needed to realise this ambition.

The following framework of next steps provides an overview of some of the key activities likely to be required:

- **Develop and implement a fully-fledged, integrated net zero strategy.** The analysis presented here provides an important step towards a net zero strategy. This can now be developed into a fully-fledged, ambitious and flexible net zero strategy that is underpinned by council and senior leadership buy-in, further analysis of the interventions outlined above, and engagement with Iwi partners and stakeholders. It must be accompanied by a commitment to sustained investment and collaboration into the future.

- **Implement low regrets measures now**. There are a number of low-regrets measures that can be implemented in the near-term and that do not need to wait for a net zero strategy or for Water Reform to be progressed. These measures are likely to deliver emissions reductions at low overall cost and/or reflect investments needed to support wider economic changes. Examples include improving water catchment quality, implementing energy and water efficiency measures and taking advantage of asset replacement cycles to switch from fossil fuels to other sources such as electricity.
- **Seek to embed climate change as a priority in Water Reform**. Given the planned reforms to New Zealand's water sector it will be essential that climate change and emissions reduction are established as priority areas for the new successor entity. There is an opportunity to build on this analysis and for a collaborative and ambitious approach to emissions reduction.
- **Embed emissions reduction into leadership, governance and processes**. Wellington Water has already made progress towards embedding emissions reduction into its governance, for example its future capital works programme. There is now an opportunity to take this further through action to embed whole-life carbon management into the culture, leadership, governance and project delivery processes of Wellington Water, its asset owners and potential successor entity.

6. CONCLUSIONS

The analysis set out here indicates that ambitious levels of GHG emissions reduction are possible across Wellington Water's asset base and operations. Without action, population growth is likely to push emissions up over the coming decades as demand for water services increases. However with action now, gross emissions of both biogenic methane and long-lived GHGs can be reduced by more than 50% by 2030 and almost 90% by 2050, broadly in line with the Science Based Target Initiative's general requirements for alignment with the Paris Agreement temperature goals.

However, achieving this level of emissions reduction - and delivering the types of interventions assumed in our Step-change pathway – is unlikely to be possible without concerted coordinated effort across industry and government over a sustained period of time. This is especially the case for those activities that rely on progress being made in areas that are largely outside of Wellington Water's direct control, such as technology development and grid decarbonisation.

The case for New Zealand's water sector to take an ambitious approach to climate change is growing ever stronger. New Zealand's evolving legislative and policy framework, alongside growing expectations from the financial sector and broader society, means that a business-as-usual approach is no longer a sensible option. By taking steps to deliver deep cuts in emissions this decade, New Zealand's water sector will reduce its exposure to future risks and be in a position to realise the benefits that climate action can offer.

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