PROGRAMME-WIDE EMISSIONS REDUCTION – A SUSTAINABLE WAY TOWARDS SUSTAINABILITY!

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ABSTRACT

A Victorian water utility, serving over 1 million residents, is currently undertaking a 50-year master planning project to outline their Sewer and Recycled Water Mass Balance Plan (SRWMBP). The plan explores management solutions for recycled water volumes to achieve EPA license compliance and meet the utility's environmental commitments.

Under Victoria's water plan, Water for Victoria, the water sector has committed to achieving net-zero emissions by 2035, becoming the first state in Australia to do so. The sector has also committed to sourcing 100% of its electricity needs from renewables by 2025. For this commitment, water utilities are required to reduce emissions as much as possible and offset the remaining amount. This water utility has taken the initiative to be proactive and factor in Whole of Life Carbon (WoLC) as a decision-making criterion for their master planning project.

For the 50-year master planning project, five different solution packages were developed and assessed for their embodied and operational carbon. Within each solution package, recycled water is transferred to a combination of end uses including existing discharge schemes, new irrigation schemes, and environmental flows. Each solution package requires different infrastructure upgrades to allow for these transfers including pipelines, pump stations, new treatment plant equipment, and bulk water storage.

The operational emissions were assessed using the 2019 Intergovernmental Panel on Climate Change (IPCC) methodology. Compared to the Australian Government's methodology, which is based on the 2006 IPCC methodology, this assessment provided a more defined scope of emissions and allowed for better comparison between the options.

The embodied emissions were assessed using a range of different methods. Where possible, quantities of materials and emissions factors and databases (AusLCI, EPDs) were used to estimate emissions. Following this, rate-based data was used alongside emissions factors. The highest uncertainty came from using proxy data and estimating emissions based on similar projects or processes.

In the assessment, the solution package estimated to have the lowest WoLC emissions focused on the use of recycled water for environmental flows. The emissions for this option were 220,000 tCO_2-e lower than for the highest emitting solution package. In terms of offsetting, we would need to cover a land area of roughly 2000ha with trees for 50 years to sequester the difference in carbon emissions.

The main reasons for lower emissions were:

- Embodied - fewer pipelines and less bulk water storage due to the management of recycled water flow variations.
- Operational - lower N_2O emissions due to reduced discharge emissions with increased quality of the recycled water.

This paper discusses the methodology and outcomes of the carbon assessment and provides practical guidance on the application of the methodologies for future studies. It highlights the scale and challenge of emissions reduction associated with the hard-to-abate sector that is wastewater treatment and the benefits of implementing emissions as a decision-making criterion at the early planning stages of projects. The paper also identifies potential emissions reduction opportunities that can be used within the wider sector.

KEYWORDS

Carbon Assessment, Wastewater Treatment, Greenhouse Gas Emissions, Net Zero Carbon, Sustainability

PRESENTER PROFILE

Alex is a process engineer in Beca's Water team and is passionate about delivering sustainable outcomes within her projects. She utilises her technical knowledge in water and wastewater treatment emissions to help water utilities and councils reduce their emissions.

INTRODUCTION

A Victorian water utility, serving over 1 million residents, is currently undertaking a 50-year masterplanning project to outline their Sewer and Recycled Water Mass Balance Plan (SRWMBP). The plan explores several management solutions for recycled water volumes in the area to achieve Environmental Protection Authority (EPA) license compliance and meet the utility’s environmental duty obligations.

Under Victoria’s water plan, Water for Victoria, the water sector has committed to achieving net-zero emissions by 2035, becoming the first state in Australia to do so. The sector has also committed to sourcing 100% of its electricity needs from renewables by 2025 (Victoria State Government, 2022a).

These targets are formalised in the Statement of Obligations (Emissions Reduction) (Victoria State Government, 2022b). This document states that in reducing their emissions, Corporations shall:

a) prioritise the implementation of actions that avoid or reduce emissions resulting from the Corporations’ operations; and
b) achieve emission reductions efficiently, making full use of the time available to do so.

In reducing their emissions, Corporations shall also:

a) pursue actions and targets at the lowest possible cost, seeking to minimise any impact on water customer bills; and
b) have particular regard to any price impacts on their vulnerable customers.

These priorities highlight the need to measure future carbon emissions as well as find cost-effective ways to reduce them. This water utility has taken the initiative to be proactive and factor in (Whole of Life Carbon) WoLC as a decision-making criterion for their 50-year masterplanning project.

This paper outlines the scope and the methodologies used to estimate WoLC emissions for the solution packages, and the results of the assessment. The paper also highlights potential emissions reduction opportunities and the benefits of introducing WoLC assessments in early decision-making.

Note that the terms greenhouse gas (GHG), carbon emissions, and operational or embodied carbon are often used interchangeably. This paper has presented figures in tonnes of carbon dioxide equivalent (tCO_2-e). Carbon dioxide equivalent accounts for the relative global warming potential of different greenhouse gases in a single equivalent figure.

2 BACKGROUND

This paper focuses on the assessment of the WoLC of nine wastewater treatment plants (WWTPs) in the Victorian state area. The WWTPs currently treat domestic sewage with discharge of effluent (recycled water) to local land, rivers, creeks, or ocean outfalls. The aim of the master planning project is to allow for recycled water from each of the nine WWTPs to be managed in a way that is economical for consumers, beneficial to the environment, and resilient for future populations.

Five different solution packages were developed for the project. Within each solution package, the recycled water from each plant is transferred to a combination of different end-uses including the existing discharge schemes, new irrigation schemes, and supplementing water bodies to achieve environmental flows. The recycled water is conveyed between the areas within the region to maximise end use benefits.

Implementation of irrigation schemes allow for a guaranteed supply of Class C recycled water suitable for irrigation farming to dryland farmers, which improves the region’s drought resilience. Environmental flows are the necessary water flows to allow rivers and creeks to maintain the components, functions, and processes of a resilient aquatic ecosystem.

Several of the solution packages also include the decommissioning of existing schemes and transfer of sewage to other treatment plants. This allows for potentially lower-cost and more reliable centralised treatment of the wastewater.

Each solution package requires different infrastructure upgrades to allow for these transfers and end uses, including pipelines, pump stations, new treatment plant equipment, and bulk water storage.

The five solution packages developed by the water utility are summarised below:

- Solution Package R5: This solution package is characterised by upgrades of the treatment plants to produce water volumes necessary to achieve environmental flows.
- Solution Package R5A: This solution package is largely the same as R5, however, varies in the recycled water volumes distributed to different areas within the region.

- Solution Package R6 (Reference case): This solution package is defined as the agricultural scheme. The treatment plants do not undergo any significant long-term upgrades, but the local areas have major irrigation schemes implemented.
- Solution Package R7: This solution package focuses on the transfer of recycled water to efficiently utilise land available within the region. Several treatment plants undergo upgrades to achieve higher recycled water qualities as required by the different discharge schemes.
- Solution Package R8: This solution package looks to decommission several existing treatment and discharge schemes and transfer the sewage to a larger centralised treatment plant.

3 SCOPE OF GHG EMISSIONS

The scope for the WoLC assessment includes both operational and embodied carbon emissions over a 50-year design horizon. **Error! Reference source not found.** outlines the emissions sources included and excluded in the assessment, and relevant methodologies which are discussed further in Section 4.

Table 1: Summary of Emissions Sources and Methodologies

Emissions	Definition	Inclusions	Exclusions	Method
Embodied carbon emissions	Emissions associated with materials and construction of the project reported as tCO_2-e.	Embodied emissions in materials and construction-related emissions for major items only (pipelines, storage tanks, major plant structure and equipment). Critical replacements over the design life where required.	Items insignificant to the assessment outcome and/or lacking suitable emissions factors.	ISCA materials calculator EPDs from suppliers Rates from previous assessments Aus LCI database
Operational carbon emissions	Emissions associated with the operation of the project reported as tCO_2-e/input time period or project design life.	Energy / electricity consumption. Wastewater process emissions (CH_4 + N_2O) associated with treatment and discharge of sewage generated within the boundaries of the utility.	Emissions in the sewer network. Emissions from the trucking and disposal of biosolids.* Anthropogenic biogenic CO_2 emissions.** Chemical use.	IPCC methodology

* Biosolids are assumed to be consistent between all scenarios due to their complexity.

**Anthropogenic biogenic CO_2 emissions are typically excluded from carbon accounting methodologies.

This assessment includes GHG emissions within each of the defined scopes (1, 2, and 3) of the GHG protocol (World Business Council for Sustainable Development and World Resources Institute, 2011).

- Scope 1 emissions are those that come from operations that are owned or controlled by the reporting company. This can include nitrous oxide (N_2O) and methane (CH_4) emissions from wastewater treatment and discharge, and fugitive emissions from onsite flaring, anaerobic digestion, and composting.
- Scope 2 emissions are those that result from purchased electricity or other heating/cooling mechanisms by the organisation.
- Scope 3 emissions are all other indirect emissions that arise as a result of the organisation's activities but are from sources not owned or controlled by the company. For example, N_2O and CH_4 emissions from the treatment of wastewater at a plant not owned by the organisation, or the production of purchased materials for construction.

In general, net-zero targets within the water industry only apply to Scope 1 and Scope 2 emissions, and this is the case for the Victorian Water Statement of Obligations (emissions reductions). Whilst organisations can choose to adhere to the minimum reporting requirements, the assessment and inclusion of Scope 3 emissions can allow for greater potential emissions reductions to be realised.

4 METHODOLOGIES

4.1 OPERATIONAL EMISSIONS

4.1.1 METHODOLOGY SELECTION

The operational carbon emissions were initially assessed using the National Greenhouse and Energy Reporting (NGER) regulations (Australian Government, 2023). This methodology was found to have several limitations which led to a lack of differentiability between the options assessed. The main limitations are:

- N_2O emissions do not differentiate by treatment type, the same emissions factor is utilised for ponds, centralised aerobic treatment, and other types; and
- CH_4 emissions are assumed to be 0 for centralised aerobic treatment due to a MCF of 0.

Due to these limitations, the emissions were reassessed using the 2019 Intergovernmental Panel on Climate Change (IPCC) methodology (IPCC, 2019) which is discussed in this paper.

4.1.2 DESIGN BASIS

To establish a design basis for the operational emissions, several inputs were required including the population projections, and the flows and loads for each of the nine treatment plants. Population projections were supplied by the utility and used to calculate per capita influent loading for nitrogen (N) and chemical oxygen demand (COD). The future influent and effluent plant flows were taken from Source Integrated Modelling System (SOURCE) calculations. SOURCE is Australia's national hydrological modelling platform. The effluent flows were then categorised into disposal to land, or disposal to freshwater, estuarine, and marine waters to calculate discharge emissions. The following inputs from the nine existing wastewater treatment plants' operational data were provided by the utility:

- Effluent N concentration (mg/L)
- Effluent COD concentration (mg/L)
- Primary sludge volume (ML)

- Primary sludge volatile suspended solids (VSS) (mg/L)
- Waste activated sludge volume (ML)
- Waste activated sludge VSS (mg/L)
- Sludge transferred to landfill (t)
- Sludge transferred to other (t)
- Sludge transferred VSS (weight%)
- Biogas captured for combustion (Nm^3)
- Biogas flared (Nm^3)
- Biogas transferred out of the plant (Nm^3)
- CH_4 concentration in biogas (%)
- Electricity use (kWh/year)

In general, if operational data is not available or the treatment plants are not previously existing, values from literature can be utilised based on the type and level of treatment.

4.1.2 EMISSIONS CALCULATIONS

4.1.2.1 Process and Discharge Emissions

The current operational emissions for each plant were calculated using the inputs from the design basis alongside the methodologies in Volumes 4 and 5 of the IPCC guidelines (IPCC, 2019).

The future operational emissions were calculated using the SOURCE modelling flow projections and it was assumed that the effluent quality (N and COD) remained constant until a plant upgrade occurred. In years where upgrades occurred, the effluent quality was adjusted appropriately for the end use requirements or based on the typical level of treatment for the process. For example, where treatment plants were upgraded to produce environmental flows, the assumed effluent N and COD concentrations were each 0.3 mg/L in alignment with the discharge requirements.

Quantities of COD, VSS, and N in sludge and quantities of biogas produced from the treatment plants were assumed to increase in proportion to the population in each area.

The key emissions factors utilised from the 2019 IPCC guidelines are outlined below, and provide an indication of the main emissions sources:

- Treatment plant emissions are 0.016 kgN_2O-N/kgN for centralised aerobic treatment systems and 0 kg N_2O-N/kgN for pond-based systems.
- Discharge emissions to an aquatic environment (freshwater, estuarine and marine discharge) are 0.005 kgN_2O-N/kgN in the effluent.
- Discharge emissions to land (direct and indirect) are 0.01425 kgN_2O-N/kgN in the effluent.
- The maximum CH_4 producing capacity for wastewater is 0.25 kgCH_4/kgCOD.
- A methane correction factor (MCF) of 0.03 is utilised for centralised aerobic treatment, 0.8 for anaerobic reactors, 0.2 for anaerobic shallow lagoons and facultative lagoons, and 0.8 for anaerobic deep lagoons.

One centralised treatment plant was located outside the scope boundaries of the water utility. To account for Scope 3 emissions, the volume of sewage from the utility treated at this plant was calculated. An emissions factor per ML supplied by the plant operators was utilised and these emissions are later referred to as the 'CTP' emissions.

4.1.2.1 Electricity Emissions

The electricity use for each treatment plant was assumed to increase in proportion to the wastewater treated. The pumping electricity for flow transfers was calculated using the elevation difference between areas and the pumping distances (lengths of pipe) with a friction factor applied.

For plant upgrades, values for electricity consumption in kWh/m^3 of wastewater treated were used from Table 17-3 in Wastewater Engineering: Treatment and Resource Recovery (Metcalf & Eddy Inc., et al, 2013). The electricity consumption for each of the relevant processes is shown in Table 2 for reference.

Table 2: Electricity Consumption for Plant Equipment

Process	Range (kWh/m^3)	Value taken (kWh/m^3)
Activated sludge with nitrification/denitrification	0.23	0.23
Membrane bioreactor	0.5-1.0	0.75
Tertiary filtration	0.03-0.08	0.05
UV disinfection	0.01-0.05	0.03
Microfiltration/Ultrafiltration	0.2-0.3	0.25
Reverse osmosis	0.5-0.65	0.55

Victorian water utilities have been legislated to use 100% renewable electricity by 2025. To account for this change, the Victorian grid emissions factor was utilised until 2025 followed by an emissions factor of 0.05 kgCO_2-e/kWh from 2026 till 2070. This is based on renewable electricity modelling done by the New Zealand Climate Change Commission (He Pou a Rangi, 2021). This modelling is applicable in the Australian context as it is based on renewable electricity and not the local grid. In general, country-specific or renewable energy-based electricity emissions factors should be utilised.

4.2 EMBODIED EMISSIONS

4.2.1 DESIGN BASIS

This assessment included the embodied emissions associated with the major capital works that were different between the solution packages. Capital works that were consistent between all packages were excluded on the basis that they would not change the relative assessment outcome. All of the assets are assumed to have a design life out to the design horizon year of 2070; hence no critical replacements were required.

The information provided was at a concept design level and is summarised below:

- **Pipelines** –diameter in mm and length in km, no material selection.
- **Storage** – capacity in ML, no dimensions.

- **Pump stations** – capacity in L/s, no pumping head.
- **New treatment plants or treatment plant upgrades** – capacity in ML/d, type of treatment.
- **Irrigation infrastructure** – area supplied in ha.

Given the high-level inputs, the embodied carbon emissions assessment was carried out using a range of different methods all with varying degrees of uncertainty. Where possible, quantities of materials and emissions factors from databases (such as AusLCI and EPDs) were used to estimate emissions as this provides the highest accuracy. If quantities of material or emission factors were not available, the next best method was using rate-based data, i.e., the number of hours excavating per m^3 of material, which is used alongside emissions factors. The highest uncertainty came from using proxy data and estimating emissions based on similar projects or processes. All these methods can be seen to be used below and the assumptions used to mitigate uncertainty are outlined.

4.2.2 PIPELINES

The emissions associated with the pipelines were estimated using a pipeline emissions calculator developed by Beca Ltd. The calculator estimates the material emissions by accounting for the pipe diameter and material and then utilises appropriate standards and environmental product declarations (EPDs) made available by suppliers. The construction emissions associated with installation are also estimated by using standard installation specifications for the Victorian context. The key assumptions are outlined below:

- As there were no materials selected, typical materials relative to the size of the pipeline were assumed. Pipelines with a diameter less than 450mm were assumed to be high-density polyethylene (HDPE). Pipelines with diameters between 450-650mm were assumed to be glass-reinforced plastic (GRP). Pipelines with diameters 650mm and above were assumed to be mild-steel cement lined (MSCL).
- All pipes were assumed to have a pressure rating of PN16 unless a higher-pressure rating was deemed necessary in pumping calculations.
- An average pipe cover of 0.9m was assumed for each pipeline.
- All the pipelines were assumed to be installed through field terrain, this was due to the region being largely agricultural.
- Where the pipeline diameters did not match standard supplier sizes, the next largest diameter was used instead.

The following limitations were identified and should be noted when using similar methodologies on carbon assessments:

- The process used to make HDPE pipe is energy intensive. As the emissions associated with electricity use in Australia decrease, the emissions factor for HDPE pipes may also decrease meaning that pipelines built later have lower associated emissions.
- Pipe emission factors vary across different suppliers. The EPD utilised should be, where possible, from a supplier typically selected by the water utility or council.
- Installation standards for pipelines vary between states and countries, and local standards should be utilised.

4.2.3 STORAGE

Emissions associated with the construction of storage lagoons were estimated using excavation rates and diesel use for excavators.

- Excavators are assumed to have an average excavation rate of 25 m^3/h in hard ground (Methvin, 2023)
- Excavators use 5.1 kL of diesel per month (based on 300 hours of operation) (Caterpillar, 2017)

The diesel emissions factor should be based on the location of the assessment, and the excavation rate adjusted for ground conditions, if possible.

4.2.4 PUMP STATIONS

The estimation of embodied carbon emissions from pumps and pump stations utilised an average factor for tCO_2-e/L/s. This rate-based value was estimated using data available from five embodied carbon assessments for new pump stations completed by Beca Ltd. The pump stations ranged in size from 275 L/s to 1300 L/s and therefore there is some uncertainty in using this rate-based value for smaller pump stations (<275 L/s). In general, this is a suitable approach as pump fabrication, pipework, and valve sizes are based on flow rate.

4.2.5 TREATMENT PLANTS

The details of treatment upgrades for the plants in the assessment were broad and similar for the different upgrade options mainly including membrane bioreactors (MBR), reverse osmosis (RO), membrane filtration (MF), ultra-filtration (UF) and ultraviolet (UV) disinfection either appended to the existing plant or replacing the current treatment. Due to calculation complexities, it was decided to not apply different emissions factors to different types of treatment plants. Capital cost was also not utilised as a proxy for embodied carbon, as the different treatment options could vary greatly in capital expenditure whilst requiring similar capital works.

The assessment of embodied carbon for the different treatment plant upgrades was completed using aggregated emissions rates for tCO_2-e/MLD based on previous assessments.

Beca Ltd utilised benchmarking for tCO_2-e/MLD from previously completed embodied carbon assessments. The benchmarking data showed that tCO_2-e/MLD significantly decreased with an increase in plant size. This follows a similar pattern to the capital cost of WWTPs, where capital cost/MLD decreases with an increase in plant capacity. Fifteen different embodied carbon assessments were used to generate a rate-based curve, which included either new treatment plants or major upgrades to an existing treatment plant. The type of treatment plants included were not limited to those specified in the solution packages. The rate-based curve was then used to estimate tCO_2-e/MLD for the various capacities of treatment plant upgrades required in the solution packages. The fifteen plants ranged in size from 0.1 MLD to 171 MLD and therefore covered the scope of the solution package upgrades (2-60 MLD).

Whilst the benchmarking assessments were done in the New Zealand context; it was assumed that differences between the Australian and New Zealand emissions factors would similarly impact each solution package and hence the treatment plant emissions factors used were suitable for a comparative assessment.

4.2.6 IRRIGATION INFRASTRUCTURE

The emissions factors for the irrigation infrastructure were obtained from the Australian Lifecycle Inventory (Aus LCI) database initiative. All of the irrigation systems were assumed to be Centre Pivots and used an emissions factor based on hectares (ha) irrigated.

5 RESULTS

5.1 OPERATIONAL CARBON

The results of the operational carbon assessment for each solution package are shown in Figure 1 below. Scope 1 and Scope 2 emissions are shown in plain colour whilst Scope 3 emissions resulting from sewage treated at the centralised treatment plant are shown with pattern.

Figure 1: Total operational emissions from 2021-2070 for each solution package

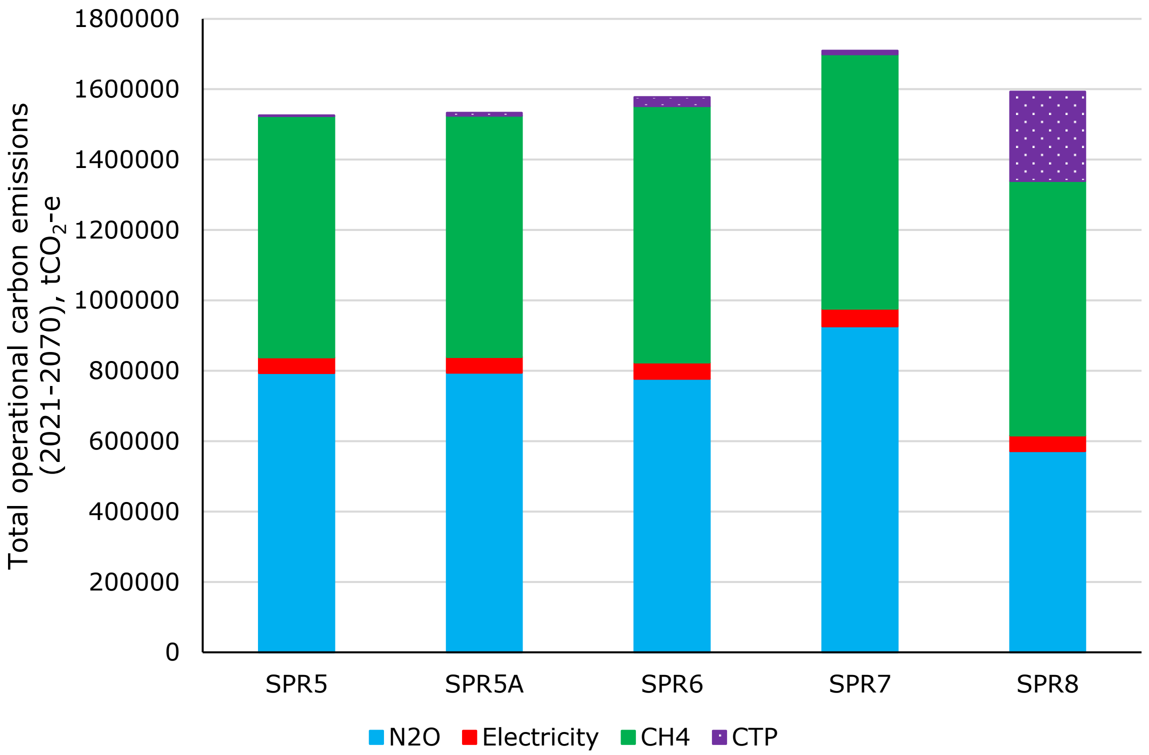


Figure 1 shows that the electricity emissions were comparatively small due to the introduction of 100% renewable electricity in 2025. The key differences between the solution packages were N_2O emissions and CTP emissions.

SPR7 had the highest N_2O emissions. This was due to plant upgrades to centralised aerobic treatment (EF of 0.016 kgN_2O-N/kgN) with more recycled water discharging to land (EF of 0.01425 kgN_2O-N/kgN) than to aquatic environments (EF of 0.005 kgN_2O-N/kgN) compared to SPR5 and SPR5A.

SPR6 had the lowest N_2O emissions due to retaining pond-based systems (EF of 0 kg N_2O-N/kgN), however, this resulted in higher CH_4 emissions (MCF of 0.8 or 0.2).

5.2 EMBODIED CARBON

The results of the embodied carbon assessment for each solution package are shown in Figure 2 below. Irrigation embodied emissions were insignificant and hence not shown.

Figure 2: Total embodied emissions from 2021-2070 for each solution package

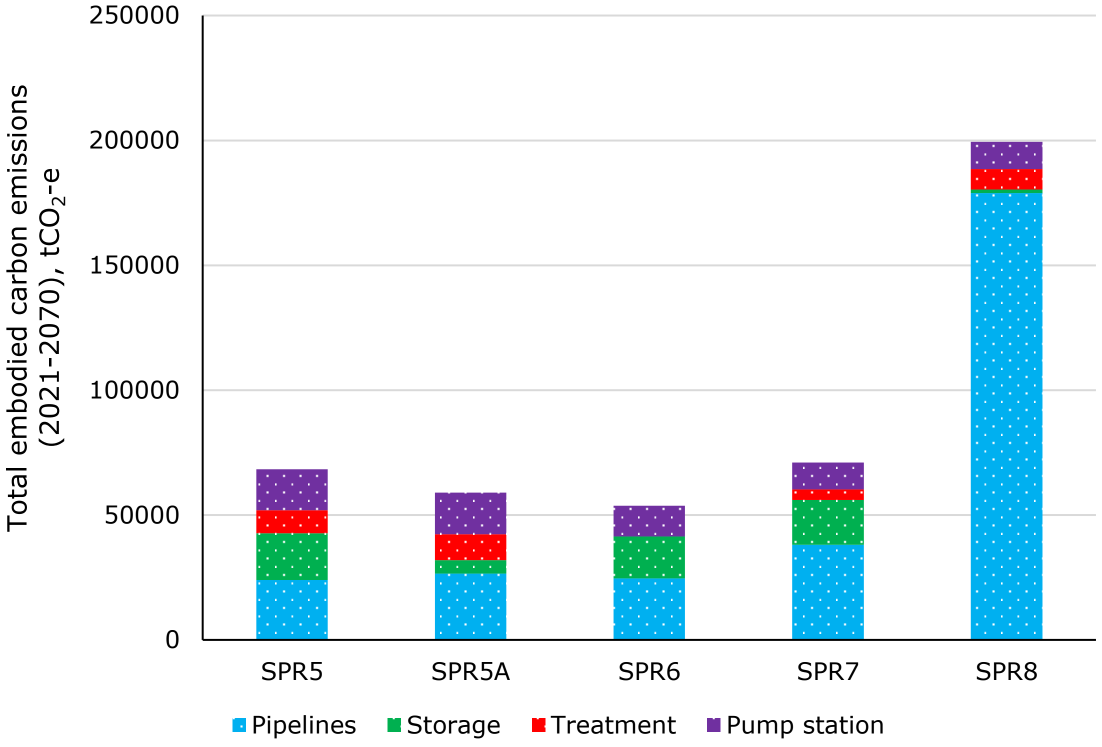


Figure 2 shows that the main contributors of embodied emissions across the solution packages are pipelines and storage.

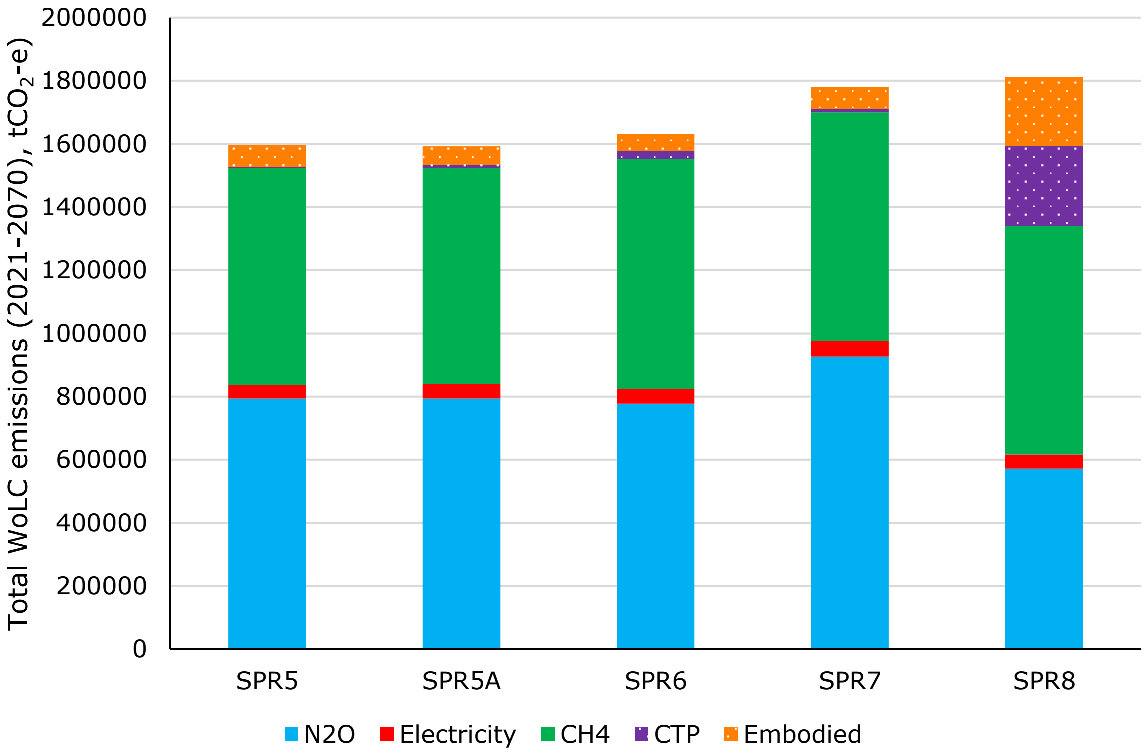
SPR8's embodied emissions were significantly higher than the other solution packages, mainly due to the large pipelines required to transfer sewage from the decommissioned treatment plants to the CTP. Two of the largest pipelines (2000mm and 2700mm diameter) were assumed to be MSCL pipelines, however, typically MSCL pipeline suppliers have a nominal diameter limited to 1750mm and the emissions intensity data was extrapolated to fit for the purpose of the assessment.

SPR6 had the lowest embodied carbon emissions as no major plant upgrades were required with all recycled water being irrigated.

5.3 WHOLE OF LIFE CARBON

The results of the WoLC assessment for each solution package are shown in Figure 3 below.

Figure 3: Total WoLC emissions from 2021-2070 for each solution package



From Figure 3 it can be seen that whilst SPR8 had the lowest Scope 1 and Scope 2 emissions (shown in plain), it had the highest Scope 3 (shown in pattern) and WoLC emissions (total). This highlights the importance of assessing all three GHG protocol scopes within carbon assessments, particularly when using the results for decision making.

These results also show that whilst centralised treatment is generalised to be more efficient and lower carbon emitting, the embodied carbon associated with achieving this can outweigh the operational benefits over a project lifetime.

Overall, there did not appear to be a significant difference in WoLC emissions between each of the solution packages. However, due to the scale of the emissions within the wastewater sector there was a difference of over 220,000 tCO_2-e between SPR8 and SPR5A.

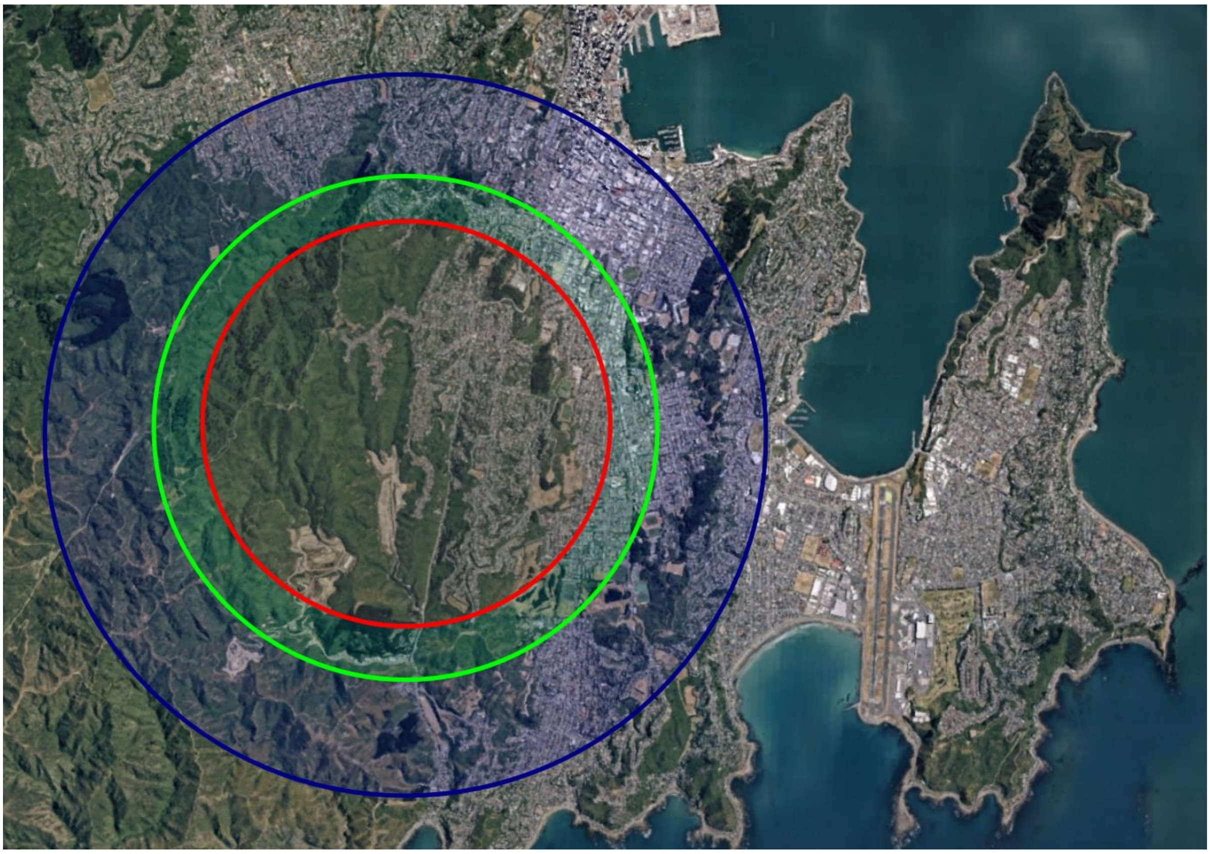
5.4 OFFSETTING REQUIREMENTS

Potential offsetting requirements were investigated to understand the scale of the carbon emissions. This included looking at pasture, cropping, and forest sequestration. The Australian Emissions Reduction Plan (Australian Government, 2021) sets out the potential for soil organic carbon sequestration by both pasture and cropping land use. The region was found to lie in the rainfall zone of 600-900 mm and therefore had the potential to offset 2.5 and 1.25 ACCUs (1 tonne of carbon) per ha for pasture and cropping, respectively. Alternatively, OzFlux

(Beringer, J et al., 2016) found that every ha of Australia's temperate forests absorbs 3.9 tonnes of carbon in a year.

To show the potential additional requirements, the land area required to offset the 220,000 tCO_2-e difference between SPR5A and SPR8 is shown in Figure 4 in relation to Wellington City in New Zealand.

Figure 4: Land area offsetting requirements for forests (red), pasture (green) and cropping (blue) assuming sequestration occurs over the 50-year period.



6 EMISSIONS REDUCTION OPPORTUNITIES

In the WoLC assessment, several carbon hotspots were identified through the assessment results and the use of guidelines and carbon accounting methods. Potential emissions reduction opportunities for each of these hotspots are outlined below. Implementing these reduction strategies alongside a lower emissions solution package could allow for the progression of the Victorian water sector towards their net zero target with less offsetting required. As a next step in the assessment, it would be valuable to identify which solution package has the highest potential for reductions.

6.1 OPERATIONAL CARBON HOTSPOTS

The operational carbon hotspots and their potential reduction opportunities are given in Table 3 below.

Table 3: Operational Carbon Hotspots and Reduction Opportunities

Carbon Hotspot	Reduction Opportunities
N_2O	
N_2O emissions from aerobic treatment process	1. Optimise reactor operation (Dissolved oxygen (DO) set point) with consideration of energy use and process N_2O emissions and consent compliance. Change in the DO set point has the ability to promote nitrite shunt or simultaneous nitrification denitrification, resulting in a reduction of N_2O emissions. 2. Operating the process with a high solids retention time can maintain low ammonia and nitrate concentration, also minimising N_2O emissions
CH_4	
CH_4 emissions from shallow anaerobic lagoon systems	Anaerobic lagoons have a MCF of 0.2, which is due to the CH_4 produced during anaerobic decomposition of the wastewater or sludge. This can be mitigated by: 1. Covering the anaerobic lagoons and capturing the CH_4 gas produced. This could then be used to generate biogas. 2. Upgrading the treatment method to managed aerobic treatment which has a lower MCF of 0.03. 3. Upgrading the sludge treatment method to anaerobic digestion. Whilst the anaerobic digestion treatment process has a MCF of 0.8, accounting for the CH_4 produced during digestion allows for CH_4 emissions to be closer to 0. In several of the solution packages in this assessment, anaerobic shallow lagoon systems are retained. In general, the embodied carbon alongside potential increases in N_2O emissions should be considered and the lowest carbon emitting option over the design life should be implemented.
CH_4 emissions from anaerobic digestion	Steps that can be taken to reduce CH_4 emissions from plants with anaerobic digesters include: 1. Improving the quality of the storage system. For example, using digesters with fixed roofs rather than floating roofs. 2. Full utilisation of the biogas. 3. Improving the efficiency of the flare. These additions would all allow for reduced CH_4 emissions when using anaerobic digestion. Full utilisation of the biogas would also provide other benefits to the plants such as offsetting plant electricity use which is discussed further below.
Electricity	
High plant electricity	Several of the treatment plants in this assessment were identified to have higher electricity use in comparison to other similar plants

Carbon Hotspot	Reduction Opportunities
	(e.g., pond based systems). This may be due to a combination of energy inefficiencies throughout the plants. Energy efficiency measures that can be introduced to reduce use are: 1. For aeration - blower energy efficiency should be investigated. Blower energy use can be reduced by reducing aeration, using higher efficiency diffusers or better process control to reduce over aerating. 2. Using energy efficient pumping. This can include the introduction of Variable Speed Drives (VSDs). 3. Review UV disinfection systems to match performance rather than theory to reduce electricity use. UV can be using significantly more energy than required due to theoretical doses, and tuning can improve this.
All plant electricity	In several of the solution package upgrades there is the introduction of managed aerobic treatment systems including MBR, UF and RO which are all highly energy intensive processes. The effect of this increase in electricity use can be reduced by the introduction of anaerobic digestion. Currently, a portion of biogas produced by the wastewater treatment plants is flared. Full utilisation of the biogas could significantly reduce dependence on grid electricity. Note this may be more economical and feasible for larger plants compared with smaller plants.
Biosolids	
Biosolids emissions	The biosolids emissions are not included within the scope of this assessment. However, there may be significant emissions associated with the trucking of these. Majority of the nine WWTPs do not have onsite sludge treatment methods resulting in significant volumes of sludge being trucked away. Implementation of onsite anaerobic digestion or alternative sludge treatment methods would reduce volumes of sludge and contaminants found in the sludge. In general, the embodied carbon for implementing sludge treatment methods alongside operational emissions should be considered and the lowest carbon emitting option over the design life should be implemented.

6.2 EMBODIED CARBON HOTSPOTS

The embodied carbon hotspots and their potential reduction opportunities are given in Table 4 below.

Table 4: Embodied Carbon Hotspots and Reduction Opportunities

Carbon Hotspot	Reduction Opportunities
Assets	
Pipelines	Use lower carbon pipeline materials such as GRP, where possible. Using the pipeline calculator, the supply emissions for 1 km of DN450 PN16 GRP pipe vs PN16 PE pipe were compared. The emissions associated with the PE pipe were 158 tCO_2-e compared to 44 tCO_2-e for the GRP pipe. This is a reduction of over 70%. Where possible, considering cost and other factors such as thrust blocks which have not been accounted for in the pipeline calculator, GRP could be used in place of other pipe materials.
Treatment Plants and Pump Stations - Concrete	One of the main emissions sources from building new or upgrading treatment facilities is the concrete from buildings, reactors, and other structures. In the Australian Emissions Reduction Plan, it is highlighted that Australia is well placed to develop a low emissions cement industry, one of the key ingredients in concrete. Typical concrete mixes should be replaced with lower emissions alternatives. Holcim has developed EcoPact, a low carbon concrete range which can reduce the embodied carbon of infrastructure projects by 30 to 60% (Holcim, 2021). There is also a patent pending for GreenCem which is a powdered admixture – compliant with AS1478 – that allows increased fly ash and slag in a concrete mix without compromising on concrete performance. Emissions reductions of up to 70% can be achieved by replacing general purpose concrete with GreenCem's mix of 40% Fly ash and 40% Slag (GreenCem, 2023).
Treatment Plants and Pump Stations - Steel	Another significant embodied emissions contributor to water infrastructure is steel. Whilst companies have not advertised lower emissions steel options yet, the Australian government has highlighted their investment in low emissions technologies for steel production in the Emissions Reduction Plan. Modelling suggests that in adopting new technologies, by 2050 emissions from steel production could fall by over a third even as production increases by about two thirds (Australian Government, 2021). In general, building assets at a later date could mean there is an opportunity for new technologies to be developed which may have lower emissions intensities compared to existing technology. This would result in more emissions reductions in the long term.
Construction	
Pipeline installation emissions	The pipelines across the solution packages are assumed be installed as open trench through field terrain. Whilst open trench installation through field emits lower emissions than installation through road or footpath, the assessment indicated that installation through field can make up to 10% of the total pipeline emissions.

Carbon Hotspot	Reduction Opportunities
	Using alternative trenchless techniques such as horizontal directional drilling or pipe jacking/thrusting can significantly reduce backfill requirements and reduce the installation emissions. Reuse of cut material onsite or other means of non-imported fill should be utilised where possible.
Storage	The construction of storage makes up a significant amount of the embodied emissions across the solution packages. For the purpose of this assessment the cut from the storage was assumed to be beneficially reused or stored onsite and trucking emissions were excluded. It should be noted that these trucking emissions could be a major carbon hotspot and to keep this reduction opportunity, the cut could be used for landscaping or for bunds on the storage system. The excavator was assumed to be diesel operation. Employing the use of electric mobile equipment could be investigated to reduce emissions associated with diesel use. Liebherr have developed two electric excavators for mine and quarry use, and it is likely more companies will introduce electric construction equipment (Equipment Journal, 2021).

RECOMMENDATIONS

The methodologies and assumptions used in this paper can be applied across the water industry to develop other WoLC assessments. However, the following recommendations should be considered:

- The operational carbon assessment ustilised the IPCC guidelines. These are internationally recognised guidelines and were found to be more suitable for a comparative assessment than the Australian Government’s NGER guidelines.
- The Water NZ Carbon Accounting Guidelines for Wastewater Treatment (Water New Zealand, 2021) align with and refer to the IPCC guidelines, with a number of additions relevant to the New Zealand context. The Water NZ guidelines should be used when completing New Zealand based carbon assessments.
- The principles for future operational emissions estimating are applicable for any assessment location, however, only suitable when considering domestic wastewater flows.
- For embodied emissions calculations, it is recommended that the principles in this assessment are utilised with project-specific information substituted where possible. For example, suitable pipeline materials, suppliers, pressure ratings, ground conditions for excavation of storage lagoons, and productivity rates of equipment. This information could be developed with input from contractors to provide more accurate emissions estimates.

It was noted in this paper that net zero targets within the water industry generally only apply to Scope 1 and Scope 2 emissions. However, the results from the assessment highlight the importance of the inclusion of all three GHG protocol scopes within carbon assessments, especially when the assessments are informing decision-making. For example, if only Scope 1 and 2 emissions were assessed then SPR8 would have been identified as the lowest emissions solution package in comparison to the other solution packages. However, SPR8 was estimated to have the highest Scope 3 emissions and hence highest comparative WoLC emissions. The measurement and management of Scope 3 emissions can enable water utilities to understand the full emissions profile of their assets which aids decision-making but also enables greater impact in their emissions reduction activities.

CONCLUSIONS

There are significant benefits in implementing WoLC assessments at the early planning stages of a project to estimate future carbon emissions and inform decision-making, given suitable methodologies and reasonable assumptions are used. In summary:

- WoLC assessments provide an indication of the scale of emissions required to abate over the project lifetime if a utility or council is adhering to net zero or emissions reduction targets.
- They allow for the identification of current and potential future carbon hotspots and hence relevant reduction emissions strategies that can be put in place ahead of time.
- There is a high level of uncertainty in the assessments due to the design information available and current limitations in estimating carbon emissions. However, implementing quantitative comparative carbon estimations into decision making at the early planning phase allows for the highest reduction potential which is demonstrated in Figure 5 below (World Business Council for Sustainable Development, 2021).

Figure 5: Carbon reduction potential at each phase of a project

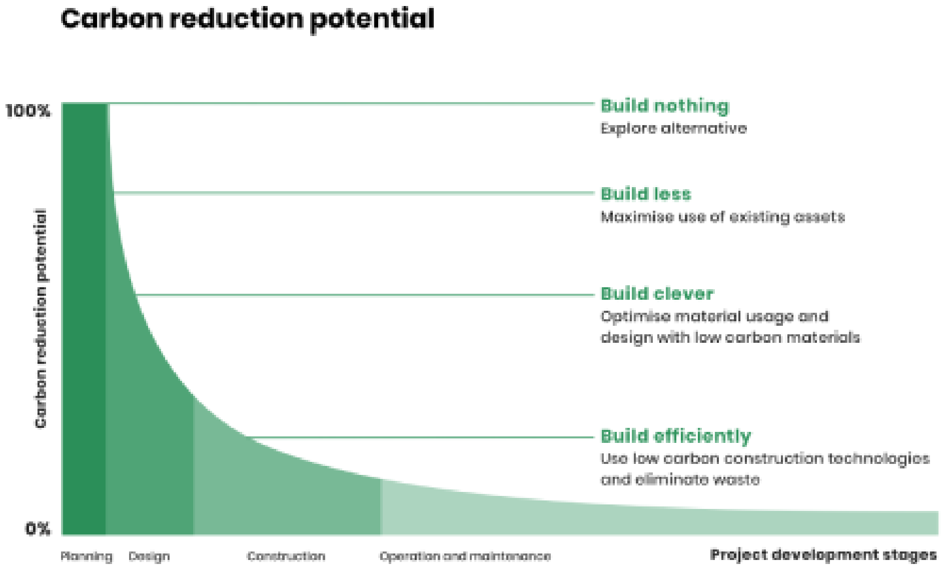


Figure 5 shows that our ability to impact on carbon reduction decreases the later phase of design we are in. Although it may be easier to complete a carbon assessment when the project is more defined, this paper demonstrates that an assessment and decision in the planning stages has the potential to save over 220,000 tCO_2-e.

One of the most important takeaways from this paper is that we can't manage what we don't measure. Completing carbon assessments brings awareness to the scale of emissions brought about by our activities and places us in a better position to understand potential emissions reduction.

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