What does global warming mean for my wastewater treatment plant?

Andrew Springer, Principal Wastewater Treatment Engineer

Contents

ABSTRACT

Global warming is now recognised as occurring and will lead to rising sea levels, changes in weather patterns, more extreme weather events, with potential for droughts, floods and other devastating impacts. Already New Zealand is committed to carbon reduction through the Kyoto agreement and Paris accord, which has resulted in a 2008 carbon trading scheme but levels of emission are increasing. The Climate Change Response (Zero Carbon) Amendment Bill is proposed as a framework for further legislation to drive a change in the thinking and economy of New Zealand and is setting a target of net zero emissions.
Emissions from wastewater treatment plants are greater than water plants due to the high energy requirement for transport and treatment and the emissions of methane and nitrous oxide because of biological activity making up to 33% of all Water Industry emissions. With a Global Warming Potential of 84 x and 284 x carbon dioxide, small quantities of these persistent gases will have a large impact on our carbon footprint.

By understanding the sources of the emissions and how to compare technologies based on carbon footprint combined with reduction in energy, alternative energy sources and reduction in materials in construction the New Zealand Water Industry will be equipped to contribute to our targets.

KEYWORDS

Climate Change, Green House Gas, Methane, Nitrous Oxide, CO2-e, Global Warming, Wastewater, N2O, CH4

PRESENTER PROFILE

Andrew Springer is the Technical Principal Wastewater Engineer for WSP Opus New Zealand, responsible for providing value solutions and expert advice to clients in all areas of wastewater treatment across New Zealand. He is an innovator in technology having created a low energy SAF in 2006, and an advocate for sustainable thinking in the water sector.

He has 30 years' experience in the water sector in the United Kingdom and New Zealand having been an environmental scientist, operator, asset manager, and process engineering contractor before becoming a designer and consultant. This gives him a practical experience of delivery from need identification, option development, detailed design and commissioning.

While Process Team Leader in Anglian Water, he championed carbon reduction with some innovative processes such as the UK's first full scale IFAS plant coupled with ultrahigh efficiency aeration and achieved in a 5-year period over 30% reduction in embodied carbon, and 20% reduction in capital costs.

His personal vision is "To improve the environment every day".

1 Introduction

The global community has recognised that Global warming will occur unless changes are made to the activities of mankind. The Intergovernmental Party on Climate Change (IPCC), (2019) predict with medium confidence a global mean sea level change of 0.26 to 0.77m because of 1.5oC rise in global temperature compared to before the industrial revolution. A 5% likelihood is given to a sea level rise of 1.5 m.

The Ministry for the Environment (MfE, 2018) predict extreme rainfall will increase across New Zealand with an associated rising flood risk. Other predictions include melting icecaps, increase in extreme weather events, droughts, changes to weather systems with impacts of people, wildlife and ecosystems across the globe. The consequence to our coastal communities will cost billions of dollars.

- Scope 1 Gas emissions including Methane, Nitrous Oxide
- Scope 2 Energy and Chemical associated with generation and infrastructure to deliver
- Scope 3 Embodied Carbon associated with construction of assets.

All infrastructure has an impact on the greenhouse gas emissions whether in the production of materials for construction, maintenance, transport, electricity for lighting, or in the moving and treating of large volumes of water. However, the Scope 1 fugitive emissions are largely associated with wastewater, waste management and agriculture. Wastewater is recognised as a significant source of greenhouse emissions.

The IPCC recognise that carbon dioxide produced directly from a treatment system is a biogenic source, and this is not accounted for in the international systems. This is attributed to the food we eat is directly or indirectly a result of plant uptake of carbon dioxide from the atmosphere. We eat this food, and burn the energy, and leave a waste, which in a natural cycle is returned to the atmosphere for repeated uptake by plants. This biogenic cycle is in equilibrium.

However, there are many other contributions from the wastewater systems that are not considered natural. These include the emission of Scope 1 gases such as nitrous oxide and methane, and the use of fossil fuels for transport, or energy for pumping and treatment. Carbon associated with the construction must also be considered as part of the whole life thinking.

2 New Zealand's Commitments

In 1997 under the United Nations Framework Convention on Climate Change (UNFCCC) the Kyoto protocol was adopted setting internationally recognised commitments to reduce greenhouse gas emissions by member states.

The Paris Agreement was adopted on December 2015 with 196 nations making commitments to reduction in global carbon emissions. The key objective is to make effort to maintain global temperature to 1.5oC above preindustrial levels to minimise the impact of climate change. New Zealand committed to reducing our net carbon emissions by 30MtCO2-e below our 2005 level by 2030. (MfE 2016).

MfE (2018) report that over 2021 to 2030 New Zealand's emissions will be higher than the budget of 601 Mt CO_2-e with a current forecast of 804MtCO_2-e with current policies. However, to meet this target substantial carbon trading is required by major generators and users of energy and fuels. Most of this trading is related to short term carbon capture with forestry locally or purchasing carbon credits from overseas.

Currently at Parliament is the Proposed Climate Change Response (Zero Carbon) Amendment Bill. This is an amendment to the 2002 Climate Change Response Act and will ensure all key climate legislation is within one act. This bill will achieve four key things.

- Set new Greenhouse Gas emissions target to
  - Reduce all greenhouse gases to net zero by 2050
  - Reduce emissions of biogenic methane within the range of 24-47% below 2017 levels by 2050, including 10% reduction by 2030.
- Set a series of emissions budgets to act as stepping stones towards long term targets
- Require the Government to develop and implement policies for climate change adaptation and mitigation
- Establish an independent Climate Change Commission to provide expert advice and monitoring to keep on track.

With this framework in place, it's no longer a question of IF but when our industry must do something different. The wastewater assets we build now will be in use for 50 years. Consider that the selection of technology now, if not the best for carbon footprint, will require expensive replacement before the end of its asset life, making economic sense to do the best possible now.

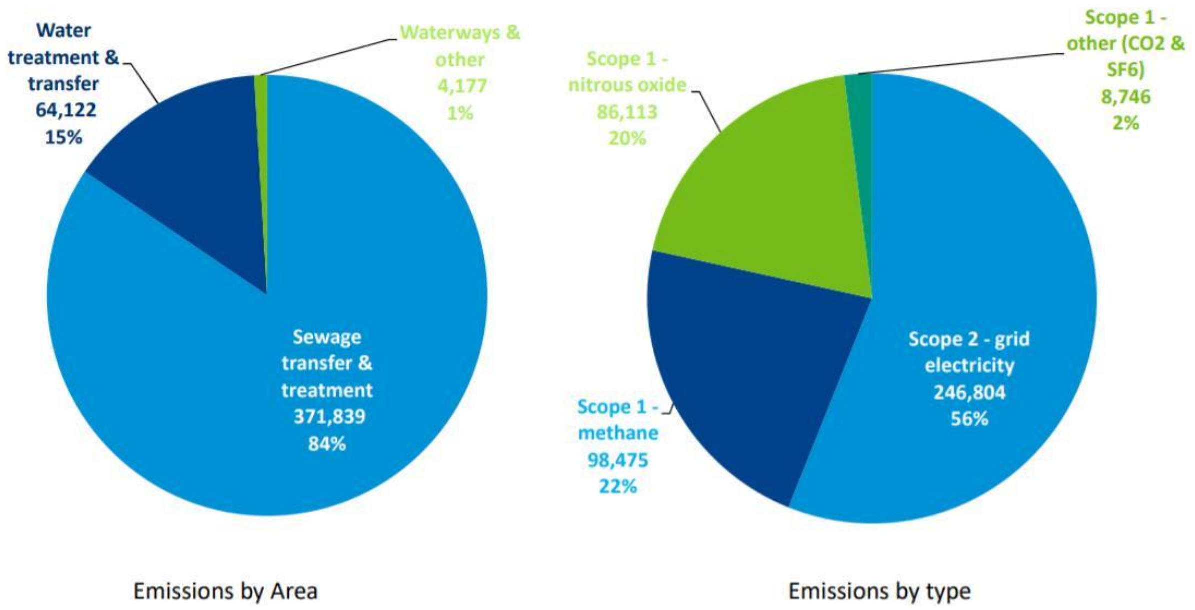
3 Current Global Approaches

In 2005, OFWAT, the UK water regulator requested all water and sewerage companies to assess and report on their carbon footprint. The leading organisations set out to convert thinking and practices to low carbon as standard, with results of over 30% reduction in embodied carbon (Scope 3), over 20% reduction in operational carbon (Scope 2) The benefit is a cost reduction of over 20%.

The BBC reported on 2 May 2019 that "UK can cut emissions to nearly zero by 2050" following a statement from The Committee on Climate Change, that maintains this can be done at no added cost from previous estimates, a position supported by our Ministry for Environment (MfE).

In the state of Victoria, the Climate Change Act, 2017 has been passed to lower carbon emissions, the first state in Australia to do so. This has set a goal to be carbon neutral by 2050. However, stretch targets have been set in the water sector to reduce current emissions by 50% by 2025 and net zero by 2030. This has made the water organisations in the state to take stock of their carbon footprint. Figures from Melbourne Water show 42% of their Scope 1 and Scope 2 emissions are Scope 1 arising solely from wastewater treatment.

Figure 1: Split of Melbourne Water's GHG emissions Source Melbourne Water (MW 2018)



Melbourne Water (2018) Plans include transition to a zero-emissions vehicle fleet within 10 years; Capturing methane rich biogas by covering anaerobic lagoons and generating renewable energy; by generating hydroelectricity through the water transfer system; Capturing global expertise to reduce emissions.

Watercare (Watercare 2015) figures for carbon emissions show a similar picture with 43% of all Scope 1 and Scope 2 emissions due to wastewater fugitive gases and 33% of total emissions.

Figure 2: Watercare Energy and Greenhouse Gas Emissions (Watercare 2015)

Type Emissions	tCO2-e/yr.	% of Total Emissions
Scope 1	12,003	32.8 %
Scope 2	15,529	42.4%
Scope 3	9,090	24.8%

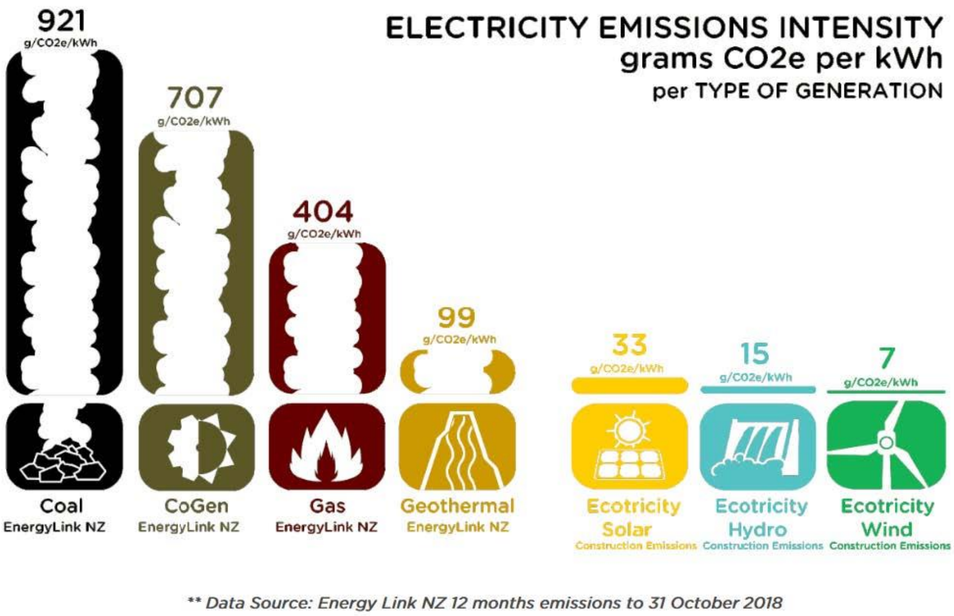
Several NZ councils have declared a climate crisis and are voluntarily stepping towards reduction in their carbon footprint. These steps include sourcing energy from certified carbon neutral providers, lowering electricity usage and consideration of carbon in infrastructure.

Watercare have now launched a 40:20:20 approach to reduce emissions by 40% in construction (Scope 3), 20% reduction in cost, 20% less safety incidents. NZTA require carbon footprint reporting for all projects to drive behaviour in construction.
It must be considered that overseas large reductions in total emissions are being achieved by change in energy source.

For comparison a plant in Victoria using Anthracite coal as a fuel at over 1 kgCO2-e/kwh as energy source can achieve a 96% reduction in carbon footprint by conversion to solar sources. Statistics for 2018 (Energylink,2019) show the average energy footprint in New

Zealand is 0.11kg CO2-e/kwh as 90% of all energy in New Zealand is renewable. The same conversion to solar on a site will reduce the carbon emissions by 70%, and reduce operating costs.

Figure 3: Electricity Emissions by source in NZ, Source Energy Link NZ.



4 Wastewater Emissions

4.1 Scope 1 Emissions

The main emissions included in the accounting of Scope 1 emissions are presented below. These can be directly measured on site but require analytical equipment and mass balance calculations. There is considerable variation so continuous monitoring would be required, making this an expensive means of measurement.

To reduce costs, it is recommended that type plants are assessed across NZ and these used for future determinations.

Figure 4: CO2 Equivalence and occurrence of Scope 1 Emissions in Wastewater Plants (IPCC, 2014)

Gas	Source on WWTP	20-year CO_2-e	100-year CO_2-e
CO_2	All Processes	1	1
CH_4	Sewers, Septic Tanks, Sludge Tanks, Digestion, Sludge Disposal, Anaerobic Ponds	28	84
N_2O	Denitrification – Anoxic Zones, aeration zones, irrigation, tertiary treatment, wetlands	265	264
CF_4	Refrigerant, industrial Processes – Minimal on WWTP	6630	4880

The figures above from IPCC (2014) show that due to the persistence of both methane and nitrous oxide in the atmosphere, there is a high equivalence to carbon dioxide as global warming impact and small quantities make a large impact.

The IPCC (2006) provide an overview level mechanism for approximating the emissions from wastewater based on population, incoming carbon and nitrogen. This is intended as a national benchmarking tool, but can be adopted as a bench mark for each treatment plant in the absence of other data.

As methane and nitrous oxide are a direct result of bacterial activity, it must be noted that for a true footprint it is necessary to monitor plants over a variety of seasonal conditions as bacterial activity will change with temperature and flow rates. It is considered that a national assessment of different treatment plants can be undertaken, as recommended by IPCC, to consider differences in demographics, climate and water usage.

The source and controls of Scope 1 emissions are discussed below.

4.2 Scope 2 Emissions

By comparison to Scope 1, these can be easily measured and have a direct tangible incentive to be reduced as a reduction in direct operational costs arise.

Energy savings can be achieved by use of alternative power sources, such as replacing diesel power with electricity for portable pumps or use of solar or wind to supplement daily peak demand will result in a carbon reduction.

Energy efficiency measures such as optimising pump curves and operation, use of ultra high efficiency aeration and optimisation of controls will lower usage, but due to the nature of the systems and the need to prevent environmental harm from poor quality discharge there is a need on most sites for 24 hr a day pumping and treatment.

4.3 Scope 3 Emissions

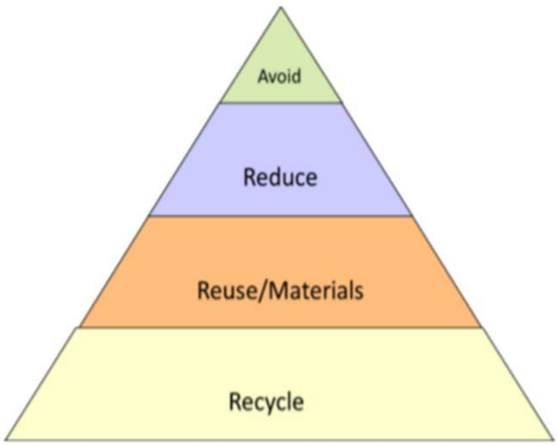
Embodied carbon is the carbon required in the production of the asset. Ideally this figure should include an estimate of the demolition of the asset, and use of recycling of materials at the end of life. Also included in transport elements of operation.

Most embodied carbon calculations available including the NZTA, ISCA, UK Environment Agency and many other calculator tools use a bill of quantities approach.

This enables a project to be quantified during construction as transport and quantities are known. It must be noted that an off the shelf carbon calculator is not one size fits all. If you consider the case of cement manufacture, with 110 kw being required for 1 tonne of cement production (VDZ 2017). In the UK (at 0.45 kgCO2-e/kwh) that is a carbon footprint of 49.5 kg CO2-e/t cement for energy.

Whereas for the same cement in New Zealand, the carbon footprint is 12.1 kg CO2-e/t cement for the energy as the average carbon footprint of power is 0.11 kgCO2-e/kwh. Transportation and the carbon footprint of the embodied cement infrastructure should also be added to this value so local sourced materials will have a lower carbon footprint. The source of the materials used is important, and responsible suppliers will be able to tell you the carbon footprint of their product.

Figure 5: Sustainable Hierarchy (Springer,2016)



The greatest way to reduce our embodied carbon is to build nothing. If we must do something, then we can do less, or reuse existing assets. If we must build, then consider alternative materials and what we build. As Example, if we need to build a tank, we could make this tank of 250mm thick concrete. If we were to use precast sections, of 90 mm, then we can use less material. The use of alternative cement mixes and fillers is developing to further reduce the carbon footprint.

Sustainable thinking is long term thinking. The whole of life needs to be considered. In short term thinking the lowest capital cost and at times the lowest carbon can be seen. However, to be sustainable in delivery, the whole life of the asset must be considered. Including the end of life. Is the asset recyclable?

As an example, a steel tank is required. The carbon footprint of a mild steel tank is approx. 70% of the stainless-steel tank. Over 40 years, in a wastewater application, the mild steel tank will be replaced, so doubling the overall carbon footprint. Hence a single stainless-steel tank offers the lowest carbon footprint.

The mild steel tank, due to corrosion has little material for recycling. An NPV calculation will also support the longer-term choice. Leading global sustainable organisations are reporting up to 40% reduction in embodied carbon and a saving of 20% in capital delivery cost in the water industry. Watercare have now implemented these into their 40/20/20 vision to reduce embodied carbon, reduce cost and improve safety.

5 Methane

5.1 Network Methane

A gravity sewer with free air space will not produce methane due to air entrainment preventing the conditions necessary for the anaerobic bacteria to thrive.

In a sewer with substantial depth, or surcharged where oxygen is not available, the bacteria associated with wastewater will convert organic matter using alternative chemicals to enable respiration.

These may be in sediments in pump stations and pipes, or as a biofilm layer coating all surfaces. As a result, once oxygen is depleted, nitrates will be reduced, then sulphates to sulphide, giving rise to hydrogen sulphide and sulphurous acid that are both nuisance and damaging to assets. In accumulated materials, or where long retention time mains are used, further reduction occurs to produce methane.

By adopting an approach to prevent the formation of H2S in the wastewater network, then methane can be prevented. IPCC guidelines (2006) indicate that in an anaerobic sewer 0.24 to 0.48 kgCH4 can be produced per kg of BOD.

Measures that remove sulphide such as ferric addition, although cheaper to run than some alternatives, will still permit the conditions that lead to methane formation and if considering the whole carbon life of the asset, should be avoided with preference for redox management such as nitrate addition or magnesium hydroxide.

Emissions Factor = Bo. X MCF

Bo	Max methane Production , typically 0.6 kg CH_4/kg BOD
MCF	Methane Correction Factor, typically 0.5, but in the range of 0.4 to 0.8

EF = 0.6 x 0.4 to 0.6 to 0.8 = 0.24 to 0.48

Applying this as example

Volume	500 m^3/d
BOD	250 mg/l 125 kg/d

Applying EF
BOD load x EF

Low range	0.24 x 125 kg/d	30 kg CH_4/d
Hi Range	0.48 x 125 kg/d	60 kgCH_4/d

Using carbon equivalence of Methane of 84 x CO2-e

Low range	2,520 kgCO_2-e/d	919 tCO_2-e/yr
Hi range	5,040 kgCO_2-e/d	1840 tCO_2-e/yr

5.2 Treatment Methane

Methane is generated in many locations in the wastewater treatment plant.

- Inlet works - Variable, Release from return liquors or network production

- Septic Tank- High, sludge layer is anaerobic
- Primary tanks- None should be produced if sludge levels are low.
- Anoxic Zone of ASP- None should be produced if sludge levels are low.
- Anaerobic Zone of ASP (BNR) – low, as the conditions of aerobic/anaerobic sludge recycle do not favour methanogenic bacteria.
- Anaerobic ponds- Very high
- Covered Anaerobic Ponds – Very high, but may be captured and used as fuel to generate energy. Offsets emissions
- Sludge tanks – None if fresh sludge is maintained
- Anaerobic digestion – High but largely captured
- Sludge Dewatering – High as soluble Methane is released to atmosphere
- Sludge Storage – High, bacterial activity continues
- Anaerobic sludge liquors – High
- Aerobic process downstream of anaerobic system – High as soluble methane is air stripped.
- Digested Sludge to land – High, bacterial activity continues
- Landfill – High

Methane is saturated to 24.9 mg/l at 20oC in water. This means that methane emissions may be recorded from aerobic processes as the soluble methane comes out of solution, particularly if air stripping occurs. (Zhan, 2018)

To assist in assessment of the sources and potential generation of Methane, the IPCC guidelines (2006 & 2019) identified the emissions factor for different conditions.

EF = B x MCF

EF Emissions Factor

B Proportion of BOD that can be converted to Methane, Default is 0.6 $kgCH_4/kgBOD$

MCF Methane Correction Factor, considering proportion of maximum likely to be seen.

This has been summarised by Dennehy and Zhan (2019) in the following figure.

Figure 6: IPCC Methane Emission Factors, from Dennehy and Zhan (2019)

Type of Treatment Systems and Discharge Pathways	Comments	MCF	Range
Untreated systems			
Sea, river and lake discharge	Anaerobic conditions can exist with high organic loadings.	0.1	0–0.2
Stagnant sewer	Open and warm.	0.5	0.4–0.8
Fast flowing sewer (open or closed)	Insignificant CH_4 emission from pump stations, etc.	0	0
Treated systems			
Well managed centralized, aerobic system	CH_4 can be emitted from clarifiers and other zones where anaerobic conditions are present.	0	0–0.1
Poorly centralized, overloaded aerobic system	Overloaded.	0.3	0.2–0.4
Anaerobic digesters for sludge management	If no CH_4 recovery.	0.8	0.8–1.0
Anaerobic treatment system	If no CH_4 recovery.	0.8	0.8–1.0
Anaerobic shallow lagoon (depth < 2 metres)	Expert judgement is required.	0.2	0–0.3
Anaerobic deep lagoon (depth > 2 metres)		0.8	0.8–1.0
Septic tank	Half of BOD_5 settles in anaerobic conditions.	0.5	0.5
Latrine in dry climate, and for a small family (3–5 persons)	Groundwater table lower than latrine.	0.1	0.05–0.15
Latrine in dry climate, and for communal use (many users)	Groundwater table lower than latrine.	0.5	0.4–0.6
Latrine in wet climate	Use flush water and, groundwater table higher than latrine.	0.7	0.7–1.0
Latrine with regular removal of sediment	Sediment removal for fertilizer.	0.1	0.1

To apply nationally, the number of different sources can be estimated, with an estimate of likely emissions. To demonstrate, MfE (2018) estimates put the number of septic tanks in New Zealand at over 270,000. If each serves 2.5 people, at 60g/hd BOD/d, that is a total BOD load of 40,500 kg/d. Based on the emissions factors above for septic tanks, Bo = 0.6, MCF=0.5

We can estimate the methane produced across the country.

Load x EF = CH4
40,500 x 0.6 x 0.5 =12,150 kgCH4 /d= 1020 tCO2-e/d = 372,300 tCO2-e/yr.

Although a small proportion of the national carbon footprint, septic tanks and on-site treatment systems have an appreciable carbon footprint. This highlights that even on-site treatment systems need to evolve to reduce carbon footprint.

5.3 Methane Reduction

By managing the treatment system to minimise odour production, anaerobic conditions can be prevented in unwanted places, therefore minimising methane emissions. This can include;

- Maintain low levels of primary sludge
- Regular desludging of septic tanks
- Annual cleaning of sludge tanks and wet wells
- Air mixing of sludges to keep fresh and mixed.
- Maintenance of gas covers and biogas systems on anaerobic processes
- Consider alternative sludge processes that do not produce Methane, such as aerobic digestion, solar drying, gasification.
- Capture of methane. Methane can be used in CHP engines or site boilers. This is a substitute for electricity or natural gas so are converted to zero rated biogenic source carbon dioxide. However, care of the system is essential as estimates are up to 10% of methane may be emitted in exhaust of a poor gas engine or boiler.

5.4 Nitrous Oxide

Nitrous Oxide has the carbon dioxide equivalence of x 264, and is a long term persistent gas in the atmosphere making it a gas of great concern. Nitrous Oxide does not form in anaerobic conditions but is a direct result of partial nitrification or denitrification. This means that nitrous oxide is formed in the treatment system and not the networks.

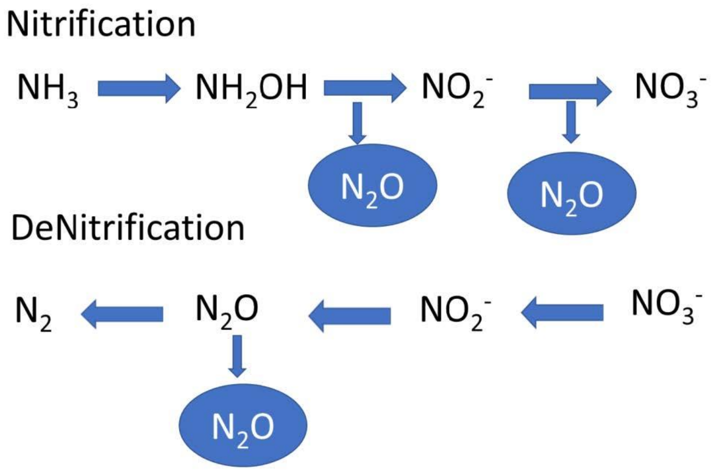
The IPCC guidelines give values for nitrous oxide emissions, but these are for national estimates where there is no developed infrastructure and a high degree of treatment. The IPCC recommend that national values are measured and used that reflect the infrastructure and demographics of the population.

Biogas used in boilers and power generation will contain some nitrous oxide, and must be accounted for in IPCC accounting. Poor combustion of methane in these processes should also be considered as methane emissions.

Nitrous Oxide production pathways are shown below. The production of nitrite is a direct result of nitration (oxidation of NH3 to NO2). N2O is reported to be produced as an alternative metabolic pathway if there is a build up of nitrite, or insufficient oxygen to convert nitrite to nitrate. Ammonia Oxidising Bacteria are reported to be able to denitrify if oxygen is insufficient. This process will occur within the aerobic phase of treatment. This can occur in an activated sludge plant with < 2 mg/l DO.

At lower DO concentrations the floc structure allows for low DO processes within the floc, so denitrification can occur in the process. This simultaneous nitrification and denitrification will reduce energy emissions, but is off set by higher N2O emissions. Wang et al (2016) demonstrated that when higher aeration rates were applied to their reactor they could manipulate conditions to give lower nitrous oxide emissions because of greater DO concentration in the floc and higher DO set point.

Figure 7: Metabolic pathways for N_2O production.



The second mechanism is when partial denitrification occurs. The metabolism is dictated by the presence of nitrite and carbon.

High carbon availability gives denitrification in anoxic conditions, giving largely nitrogen gas, such as in an anoxic zone of an activated sludge plant. In this condition there is sufficient carbon to drive reduction of nitrate to nitrite then to nitrogen with little nitrous oxide formation.

However, when carbon is limited, the metabolic pathway to reduce nitrite can be changed to produce nitrous oxide. There are many processes where low carbon conditions and denitrification will occur and these have a high potential to produce N2O.

This condition can occur in the following locations on the wastewater plant;

- Second Anoxic zone in BNR unless carbon dosed
- SBR reactor
- Passive Denitrification Process
- Wood Chip Filter
- Wetland
- Irrigation Field

The mechanism in the irrigation field is more complex as the soil bacteria can also degrade solids and convert ammonia to nitrite and nitrate, enabling both pathways to occur in the soil. For secondary treated effluents, nitrogen is largely in the form of nitrate whereas for a pond effluent the nitrogen will be as ammonia or solids related nitrogen which can be oxidised to nitrate in the soil which is subsequently denitrified.

Literature presents different values depending on the nature of the waste, water content of soil and pH. Nosalewicz et al (2005) report for grassland 3.7 to 7.8% of applied N is emitted as N2O.

Pfeifer-Meister et al (2018) report 30% of Denitrification occurring was N2O in their control grassland, with 50% in their control wetland. Zaman et al report that with the addition of nitrate to their study N2O emissions increased to 25% of applied N for wetland and 5.7% for pasture soil. A similar process occurs in tertiary wetlands, and may occur in the environment if nitrogen rich waters are discharged to stream.

In New Zealand with an increase in discharge to irrigation and a drive for reduction in ammonia and total nitrogen which leading to more nitrates, we can see that the enhancement of treatment will increase the emission of nitrous oxide. Consideration must be given to adding carbon sources to denitrifying processes where it is lacking to reduce nitrous oxide production.

Figure 8: Published N2O emissions by process.

Process	Author	Nitrous Oxide % of N applied
ASP Various	Foley 2011 Law et al (2016)	0.01 to 1.5% 0.001 to 2.59%
Anoxic-aerobic	Sun et al (2013)	1.95%
SBR	Sun et al (2013) Wang et al (2016)	6.52% 2.3%- 10.1 % (Hi DO-Lo DO)
Wetland	Pfeifer-Meister et al (2018) Zaman et al (2018)	50% 25%
Irrigation Field	Pfeifer-Meister et al (2018) Zaman et al (2018)	30% 5.7%
Sim. N/DN	Schneider et al (2013)	2.9%
Annamox	Law et al (2012)	5.1-6.6 %

5.5 How to reduce Nitrous Oxide

In summary, nitrous oxide emissions are highest when low DO conditions occur in nitrification as anoxic conditions form in the floc, a build up of nitrite occurs or low carbon denitrification occur. Selection of process, optimisation of control, such as maintaining 2 mg/l DO or more and avoidance of nitrate rich discharges will substantially reduce nitrous oxide emissions.

There are several technologies that use biological processes to short cut the nitrification and denitrification pathways such as simultaneous nitrification/denitrification. These do lower Scope 2 emission by reducing the energy required for providing oxygen, but literature also shows that as the process leads to an accumulation of nitrite then nitrous oxide increases. Schneider et al (2013) found in this condition 4 times the N2O was produced than in a full nitrifying system. These processes are reported to have higher nitrous oxide, and if they are to be used, the carbon footprint of the process should be compared to the conventional full nitrification/denitrification process before adopting the technology.

Studies of pure culture annamox bacteria found very low N2O emissions as they utilise a different metabolic pathway that does not produce nitrous oxide, but real plants, with a mixture of bacteria showed the same impact as low oxygen and partial denitrification conditions. Van Hulle at al (2012) report that larger granular floc can increase N2O production, as result of the low oxygen conditions within the floc.

Low energy treatment systems such as tertiary woodchip filters and wetlands also should be assessed for carbon footprint before adopting as a suitable solution as the nitrous oxide release may be substantial. Consideration to carbon dosed tertiary nitrogen systems should be made as a lower N2O option.

6 Example of Carbon in Decision Making

To demonstrate a comparison of two treatment options for a small works upgrade.

A wastewater treatment plant treats an average flow of 1500 m3/d, with an incoming BOD of 250 mg/l, Two options for pre-treatment are considered. Anaerobic Pond to remove 50% of BOD, or an Aerated Pond to remove 50 % of BOD.

Option1 Anaerobic Pond
Option2 Aerobic Pond

Figure 9: Comparison of treatment options – anaerobic and aerobic pond.

	Option 1 Anaerobic	Option 2 Aerobic
BOD load	375 kg/d	375 kg/d
Removal	187.5 kg/d	187.5 kg/d
Methane kg/BOD removed	0.6	0
Methane Produced	112.5 kg CH_4/d	0
Oxygen Required	0	2.3x BOD = 431.25 kg/d
kgO_2/kwh		1 kg/kwh
Power required	0	431.25 kwh/d
Annual Power	0	157,406 kwh
CO_2-e/yr	3,449 tCO_2-e/yr	17.3 tCO_2-e/yr
Whole Life CO_2-e/40 years	137,960 tCO_2-e	692 tCO_2-e

For this calculation Methane is based on 84 x CO2-e (IPCC) and energy is 0.11kgCO2-e/kwh. Clearly by considering the carbon footprint of the two options, there is a substantial GHG impact from the anaerobic system, although this will have a lower operational cost.

6.1 NZ Emissions Trading Scheme

The Climate Change Response (Emissions Trading) Amendment Act 2008 introduced New Zealand to carbon trading to encourage behaviours to lower carbon footprint. This is only applicable to large organisations and intensive users of energy. Currently farming and local authorities do not require to participate. (source Wikipedia 2019).

To assist in driving behaviour there is a system of carbon trading units. 1 unit is equivalent of 1 tCO2-e, and is initially valued at $25/unit. Although not mandatory for local authorities, as relatively low emitters, this serves as a future bench mark cost of carbon for decision making. With time the number of units available will be reduced, to drive behaviours.

In the State of Victoria, carbon users looking to the future are using up to $50/unit.

So, for option 1 above

Power	Zero		
Carbon Units	3,433 t CO2-e/yr.	3,433 units	$85,825/yr.

For Option 2 above

Power	136,875 kwh/yr. at $0.45/kwh	$61,593/yr.
Carbon Units	Zero	

For purchased power there are no carbon units to be purchased as these are included in the cost of the power generator emissions. Self generation will not incur carbon units, but fugitive emissions from leakage or poor combustion will incur additional carbon units. This demonstrates how simple calculations can be used in the selection of options and consider the carbon footprint. In this example, but GHG reduction is improved and annual costs are lowered by selecting an alternative solution.

Conclusion

Fugitive emissions from wastewater treatment assets contribute 33% of all carbon emissions associated with water and wastewater assets. These fugitive gases are almost completely associated with wastewater assets in the form of methane and nitrous oxide. This means to be a net zero carbon economy it is imperative that we understand our carbon sources and ensure the choices we make minimise the production of these substances

To make improvement we need to understand our current carbon footprint, so it is recommended that a national study be undertaken to provide typical emissions that reflect NZ practices and demographics across the range of processes used.

Carbon footprint needs to become a key consideration in decision making, and a discussion point on all our NZ infrastructure considerations if we are to meet the net zero target.

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