GREENHOUSE GAS EMISSIONS FROM WASTEWATER TREATMENT SCHEMES - NEW ZEALAND CASE STUDY EXAMPLES

M.N. Coster, AWT New Zealand Ltd

ABSTRACT

Both public and private sector organisations are increasingly being required to report on, manage and (where possible) reduce their greenhouse gas (GHG) emissions. Key drivers in this area include central and local government level initiatives (such as the Carbon Neutral Public Service program and New Zealand's national commitment to the Kyoto Protocol).

The assessment and management of greenhouse gas emissions is of interest for wastewater treatment and conveyance facilities as these facilities can be relatively energy intensive, and can contribute to the production of greenhouse gasses such as methane, carbon dioxide and nitrous oxide.

For wastewater treatment plants GHG management typically becomes a balance between energy intensive process routes such as high rate, or forced aeration systems which use more electricity but produce a higher quality effluent and avoid methanogenic process routes and low energy process methods such as passive pond systems which use significantly less power but may produce lower quality effluent and use methanogenic process routes.

This paper discusses two recent case studies undertaken to assess GHG emissions from wastewater treatment systems within New Zealand. The first addresses a waste water treatment plant upgrading from a facultative pond system to a (more power-intensive) Sequencing Batch Reactor (SBR) activated sludge system with the key finding that (by avoiding methanogenic process routes) the more energy-intensive SBR plant may have a smaller GHG footprint than the less energy-intensive pond system.

The second discusses GHG emissions for a land disposal scheme and identifies environmental nitrogen enrichment, and on site power use as the main contributors to the system's GHG footprint. Tree planting in the site's buffer zones was also assessed in terms of its capacity to sequester carbon and thereby offset emissions.

KEYWORDS

Carbon Neutral, Greenhouse Gas, Carbon Footprint

1 INTRODUCTION

The issues around climate change, and the impact of anthropogenic greenhouse gas emissions are increasingly well understood by the scientific community, and this understanding is reflected by efforts to reduce or offset emissions by organisations in both the public and private sector.

In the private sector, companies are increasingly driven to pursue "carbon neutral" status and emissions reduction in their "triple bottom line" reporting and management. Two of the world's largest retailers (Tescoes in the United Kingdom and Wal-Mart in the USA) now require that all their suppliers undertake some form of emissions reporting and management if they are to get shelf space at these outlets (BBC, 2007).

Central government is in the process of implementing a Carbon Neutral Public Service, with six agencies (Department of Conservation, Inland Revenue, Ministry for the Environment, Ministry of Economic Development, Ministry of Health and Treasury) to be carbon neutral by 2012 (MfE 2009).

Internationally, local government is also increasingly being pressured to demonstrate a commitment to reducing carbon emissions through their activities. In Australia for example, 220 local Councils are involved in emissions abatement schemes of one form or another.

For most organisations, the first step in managing greenhouse gas emissions is to calculate the organisation or facility's "carbon footprint". A carbon footprint or "GHG emissions inventory" is an assessment of the amount of greenhouse gas that is released to the atmosphere on an annual basis as a result of activities attributable to that facility.

2 METHODOLOGY

2.1 SCOPES

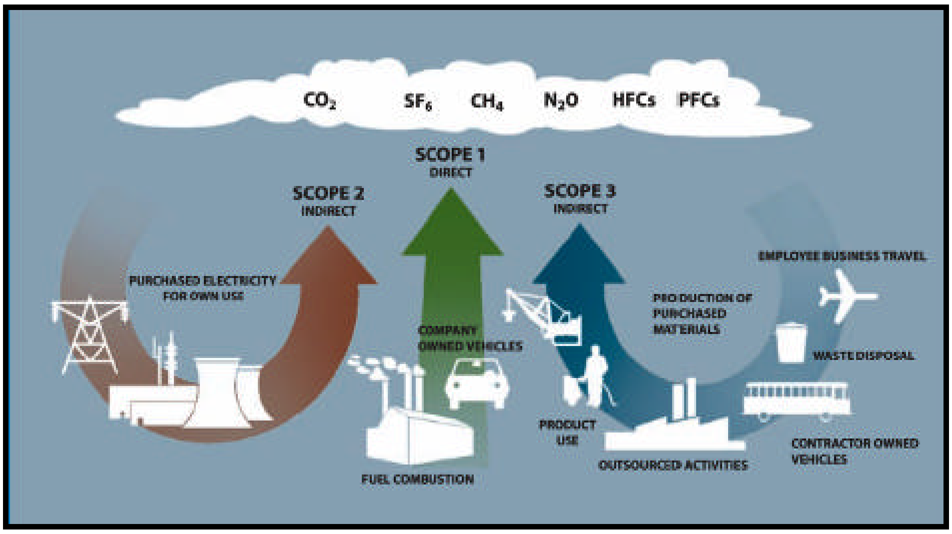
Assessments of Greenhouse Gas emissions generally divide facilities emissions into three areas or "scopes" (Word Resources Institute, 2001).

Scope 1 - Emissions refer to emissions generated on site as part of an industrial process. These might refer to the emissions generated by the direct combustion of fuel, or fugitive emissions produced from an industrial process (such as the accidental release of coolant or other gases).

Scope 2 - Emissions refer to emissions arising from the generation of the electricity used on site. Because electricity is generally generated centrally, scope 2 emissions are assessed by calculating a national average CO_2-equivalent emission factor per kilowatt generated, and then multiplying this factor by the number of kilowatt hours used by the facility.

Scope 3 - Emissions refer to emissions arising from activities outside of the direct operational control of an entity. Examples of this include emissions from outsourced activities, from contractor-owned vehicles, and from employee business travel. In many methodologies, scope 3 emissions are not calculated as part of an organisation's carbon inventory so as to avoid those emissions being "double counted" (i.e. being reported by more than one entity).

Figure 1: Definition of Scopes (WRI 2001)



2.2 GAS EMISSIONS – GLOBAL WARMING POTENTIAL

Carbon Dioxide is the most common "greenhouse gas" in the atmosphere along with steam and water vapour. Carbon Dioxide contributes to heating the earth's atmosphere by "trapping" solar energy as heat (UNFCCC p8).

Some other greenhouse gasses have a greater insulating effect, which is measured as the Carbon Dioxide Equivalent. For instance, Methane "insulates" the atmosphere 21 times as well as carbon dioxide. As such each ton of methane emitted is calculated as 21 tons CO_2 equivalent. This is also described as gasses "Global Warming Potential" or GWP (NZ MfE 2006). As such where scope 1 (direct emissions) are calculated, the resulting emissions are recorded as carbon dioxide equivalent amounts. Table 1 below shows the GWPs for the most common gasses associated with the wastewater sector.

Table 1: Global Warming Potential

Gas	GWP	Emission equivalent to
Carbon Dioxide	1	1 ton CO_2e
Methane	21	21 tons CO_2e
Nitrous Oxide	310	310 tons CO_2e
Emissions factors are based on the equivalent global warming potentials published in "Ministry For The Environment Guidance for Voluntary, Corporate Greenhouse Gas Reporting- Data and methods for the 2006 calendar year."		

3 TAUPO LAND DISPOSAL SCHEME

3.1 DESCRIPTION OF SYSTEM

Taupo District Council commissioned the View Road land disposal scheme (LDS) in 2007. The scheme is operated as a "cut and carry" system where wastewater is irrigated onto 117 Ha of paddock area. The irrigated areas are mowed and the haylage or silage is taken off site effectively removing the applied nitrogen load from the catchment.

At present aspects of the management of the cut and carry scheme (in terms of wastewater application rates, frequency of mowing and other factors) are being tested and trialled to identify ways to maximize nutrient uptake.

It should be noted that the GHG inventory below addresses emissions related to *disposal* of wastewater at the View Road site, and excludes those related to treatment (which occurs at the Taupo Wastewater Treatment Plant).

3.2 ORGANISATIONAL BOUNDARIES

In order to put any assessment of greenhouse gas emissions into context it is important to first delineate the operational boundaries of the entities and activities that are reported on. (World Resources Institute, 2002).

In this assessment, calculations of greenhouse gas emissions are limited to scopes 1 and 2 activities, that is those activities that are under the direct operational control of the View Road LDS operations staff, and which occur at the View Road site.

This includes emissions and power use related to:

Discharge of wastewater to land, and

Operation of the Operations Building.

Emissions related to harvesting of hay from the site are excluded from this assessment as they are to be carried out by a contractor and are therefore outside of the operational control of the View Road LDS. Similarly this assessment excludes emissions and power use relating to the treatment and conveyance of wastewater before it reaches the View Road site.

3.3 SCOPE 1 EMISSIONS

The most common GHG's emitted from wastewater treatment schemes are Carbon Dioxide, Methane and Nitrous Oxide.

The IPCC (2006) methodologies method recommends assessment of methane and nitrous oxide production from wastewater treatment plants as representative of their scope 1 ‘fugitive’ emissions. Carbon dioxide is specifically excluded from that assessment as discussed below.

3.3.1 CARBON DIOXIDE

It is likely that the View Road LDS has a non-zero CO_2 emission from CO_2 released when carbonaceous material (measured as COD) in the wastewater is broken down under aerobic conditions in the soil.

However, under the IPCC methodologies for assessment of fugitive greenhouse gas emissions, this carbon is not counted as an emission from the site. The reason for this is that any carbon that is present in wastewater is biogenic (that is to say it was initially drawn down from the atmosphere in the production of food crops). As such, returning the carbon in this material to the atmosphere as CO_2 represents no net flux to the system (IPCC 2006).

3.3.2 METHANE

Methane is produced by breakdown of carbon under anaerobic conditions (IPCC 2006). In this case the transformations occurring in the soil will be under aerobic, rather than anaerobic conditions. As such, methane production from discharge of wastewater to land on the site is assessed as nil.

3.3.3 NITROUS OXIDE

Nitrous oxide is produced as a by product of nitrification – denitrification by bacteria in the soil. Where there is additional bioavailable nitrogen in the soil this may increase the amount of nitrous oxide produced. This increase in nitrous oxide production is assessed against as an emission from whichever activity causes the additional nitrogen to be present in the soil (IPCC 2006).

Common examples of this include:

Additional of fertiliser to soil for agricultural purposes;

Application of wastewater biosolids to soil; and

Inputs of animal excreta on grazed areas.

The nitrous oxide production is therefore calculated based on the total nitrogen load applied to the land area, multiplied by an emission factor which represents the amount of N_2O released for every Kg of nitrogen applied.

The calculation for this may be represented as:

$$\text{Nitrous Oxide Production (Kg/year)} = \text{Total Nitrogen Applied (Kg/yr)} \times \text{Emission factor} \qquad (1)$$

New Zealand is one of the few Kyoto signatory countries in the world where wastewater is discharged to land. At present as there is not yet any well - established emission factor for the conversion of nitrogen from wastewater to nitrous oxide.

There are, however well - established methodologies (with emissions factors) for broadly analogous activities, such as:

Application of nitrogen in biosolids to land, and

Application of nitrogen in fertilisers to land.

Calculating the emissions based on the rate for biosolids application to land (Ef- 0.008) may under-estimate the rate of nitrous oxide production. This is because as the nitrogen in biosolids may be in a less bioavailable form than the nitrogen in wastewater.

Calculating the nitrous oxide production based on the emissions factors for application of fertiliser to land (Ef-0.01) may over estimate the production of N_2O, as the nitrogen in fertilisers is likely to be in a much more bioavailable form than that in wastewater-derived sources such as biosolids (Spicer 2002). However, for conservatism this higher rate (IPCC 2006) was used in this calculation.

The assessed nitrous oxide production due to this environmental enrichment is provided below:

Table 2: View Road Annual Nitrous Oxide Production

Period	Tons TN	Emissions Factor	Tons N_20	Equivalent CO_2 Tonnage
Annual	40.2	0.01	0.402	124.6

3.4 SCOPE 2 EMISSIONS

The expected power use on site was calculated based on AWT's design engineering data on the electricity demand from the following components:

Irrigation pumps

Booster pumps

Filters, and

Sump pump

Combined, these estimates assessed annual power use by the discharge infrastructure on site as being in the order of 702,727 kilowatt hours per year.

The Operations Buildings are a stand-alone building on site. In the absence of specific design data the power use in the Operations Building has been calculated as being equivalent to that of a standard New Zealand house.

As discussed in section 3.2, in order to calculate Greenhouse Gas Emissions from electricity use, the sites power consumption is multiplied by an emission factor for each kilowatt hour. The calculation for this may be represented as:

Carbon Dioxide Emissions (T/year)

= Total Power Use (KwH/yr) x Emission factor (kg/kwh) (2)

The emissions factor used to calculate the equivalent CO_2 emission is based on the Ministry for the Environment assessment of greenhouse gas emissions data for 2006, the most recent full year information available at the time of writing. This set an emission factor of 0.209 kg CO2e per kilowatt hour of electricity used.

As such, the estimated scope 2 emissions are shown in Table X below:

Table 3: View Road Scope 2 Emissions

Area	KWH Used	Emissions Factor	Total Scope 2 Emissions CO2e
Discharge Infrastructure	702,727 KwH /yr	0.209 kg CO2e/ kwH	146 T/yr
Operations Buildings	9,000 KwH /yr	0.209 kg CO2e/ kwH	1.81 T/yr

Total	710,727 KwH /yr		147.8 T/yr

3.5 SCOPE 3 EMISSIONS

Indirect emissions refer to emissions that are outside the operational control of an entity.

For example these might include:

Fuel used by mowing contractors.

Carbon emission related to waste disposal from the administration block.

Staff coming to work at the site in their personal vehicles.

In this calculation, scope 3 emissions were not included in the View Road LDS carbon inventory.

3.6 SUMMARY / DISCUSSION

As shown in Table 1 below nitrous oxide production and power use represent the two major components of the plant's "carbon footprint". This footprint may be reduced by installing more energy efficient pumping infrastructure as improved technology becomes available in the future.

Table 3: View Road - Total Emissions

Scope	Emissions Source	Total Co2 equivalent
Scope 1	Nitrous Oxide Production	124.6 T Co2 e
Scope 2	Power Use	147.8 T Co2 e
Scope 3	Fuel use by contractors Waste disposal Staff Transport	Not Assessed
Total		272.4 T CO2 e

It should be noted that the assessment of environmental nitrogen enrichment (in section 3.3.3) is based on the "gross" amount of nitrogen applied at the site. As discussed in section 3.1 the LDS is currently being managed in order to find ways to maximize nutrient uptake by forage crops. This has two implications from a greenhouse gas standpoint.

- Firstly once more data is available on the uptake rate by the forage crops, it is likely that the net nitrogen enrichment in the environment will be able to be calculated, and this is likely to be lower than is reported here (as a proportion of the nitrogen will be removed as plant biomass).

- Secondly this means that the ongoing optimization work will have effects both in terms of reducing nitrogen load to the groundwater on site, but will also reduce the plant's carbon footprint through reduced attributable nitrous oxide production.

4 PUKEKOHE WWTP

This section compares the greenhouse gas (GHG) emissions from the existing Pukekohe wastewater treatment plant (based on a pond and wetland system) with an assessment of proposed upgrades to that system (installation of a Sequencing Batch Reactor with UV disinfection).

As this assessment was prepared with a focus on comparing emissions from the two systems, in some cases activities which were common to both designs were excluded from this assessment.

These included:

- Wastewater pumping and reticulation
- Administration buildings
- Management of sludge and biosolids, and
- General site maintenance (mowing, etc)

As such this assessment represents a comparison of emissions directly attributable to the two **treatment** processes, rather than the site as a whole.

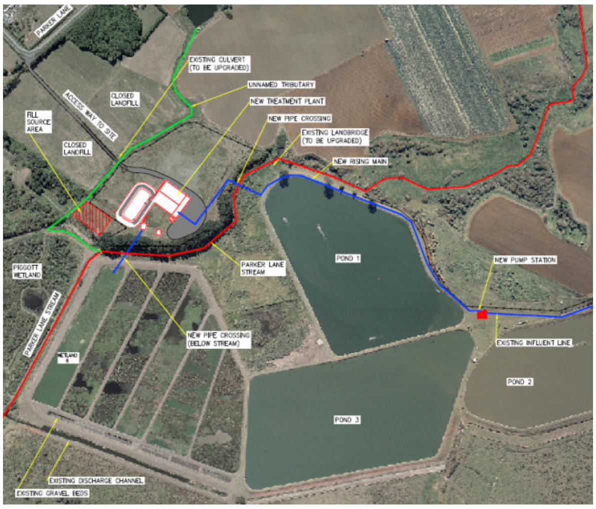
4.1 CURRENT INFRASTRUCTURE

The existing system comprises of 3 large facultative treatment ponds, a number of wetland cells and a seepage bed. Untreated effluent is screened prior to entry into Pond 1 and 2 where solids are settled prior to discharging into Pond 3. Aeration occurs within Pond 1 and 2 and the partially treated effluent then flows into Pond 3 where further settlement occurs. The effluent then discharges to the wetland where it moves through a series of cells prior to discharging to the discharge channel via a seepage bed (rock filter).

The discharge channel ultimately discharges via Parker Lane Stream to the Waikato River.

A drawing showing the current pond system (and the proposed upgrades) is attached as appendix one and (in part) below as photograph 1.

Photograph 1: Aerial Photograph of Current Pukekohe WWTP



4.2 GENERAL APPROACH AND ASSUMPTIONS

The treatment ponds at Pukekohe were treated as "facultative" rather than "anaerobic" ponds. The conservative assumption would to treat the ponds as "anaerobic lagoons" or "shallow anaerobic lagoons" (as per the IPCC 2006 guidelines) which would therefore require that a higher methane emission factor be used.

The ponds were treated as facultative ponds as:

- The ponds are relatively shallow in places (2m or less), and
- Portions of the ponds are aerated by mechanical brush aerators.

As will be discussed below, the current data on methane emissions from facultative ponds systems is somewhat limited, and IPCC and WSAA emission factors are based on "expert opinion" rather than measured or modeled off-gas data. Further research in this area is currently under way and is expected to produce further insight into the production of methane by these systems (WSAA 2007).

Activity data for the existing ponds system was gathered from design data prepared by AWT in providing design advice to Franklin District Council. This involved a range of information sources including some operational and process monitoring, along with the use of standard design estimates.

4.3 PONDS SYSTEM - SCOPE 1

There are four direct emissions sources from the existing pond system, these are

- Carbon dioxide produced through breakdown of organic matter by aerobic processes in the ponds;
- Methane produced in the ponds through the reduction of organic matter and subsequent anaerobic digestion;
- Nitrous oxide produced in the ponds through nitrification-denitrification, and
- Nitrous oxide produced through nitrification-denitrification in the receiving environment.

4.3.1 CARBON DIOXIDE

It is likely that the Pukekohe WWTP will have a non-zero carbon dioxide emission from the treatment of wastewater on site, however similar to the case of the View Road land Disposal Scheme this CO_2 production is not attributed as part of the reportable carbon footprint for the Pukekohe WWTP (IPCC 2006).

4.3.2 METHANE PRODUCED IN THE PONDS

Methane is produced by digestion of carbon compounds under anaerobic conditions.

In a facultative pond system a proportion of the influent carbon (measured as Chemical Oxygen Demand) will be removed through aerobic respiration and released as carbon dioxide (as discussed above). A further proportion will be removed through settling of particulates, and some will be removed as biosolids. The proportion of this carbon released as methane is described using an (experimentally derived) emission factor of approximately 5% (WSAA 2007).

As such the equation for methane production is as follows:

$$\textbf{Methane Production} = (\mathrm{COD_{in}} - \mathrm{COD_{out}}) \times 0.05^{1} \textbf{ kg methane / Kg COD removed} \quad (3)$$

1 – This is based on the equation for facultative lagoons, provided in WSAA 2007, Table ES3. This emission factor reflects the WSAA recommendation based on the current best scientific understanding, however it is noted that there are considerable uncertainties around this process, and further research is needed.

In this case the terms of this calculation are as follows:

COD in influent wastewater = 971 mg/l[1] (4)

COD in effluent wastewater = 62 mg/l

:. COD removal = 909 mg/l

Flow volume = 2.3×10^9 l/yr

:. **COD removal =2,143 T/yr**

Methane production = 2,143 x 0.05 T/yr = 107 T/yr CH_4

Using a GWP for methane of 21, this is equivalent to **2,250 T** CO_2E per year.

1- This COD assessment is based on monitoring data gathered between June 2006 and September 2007.The are several trade waste inputs to the Pukekohe WWTP which contribute to a high COD load in the influent wastewater.

4.3.3 NITROUS OXIDE PRODUCTION IN THE PONDS

Nitrous oxide is produced as a by product of nitrification – denitrification by bacteria within the treatment system. The IPCC guidelines are currently based on limited data for off-gas of nitrous oxide and are treated as a "low reliability "guideline" (WSAA 2007).

In the interest of completeness IPCC have provided a methodology for assessing Nitrous Oxide emissions from WWTPs based on the population served by the plant.

It should be noted that this assessment does not differentiate between treatment methodologies, and as such the N_2O emissions are indicative only.

The calculation for the N_2O emission is provided below:

Nitrous oxide production in WWTPs = 3.6 g / PE (5)

Accounting for trade waste TN inputs AWT have assessed the PE connections to the Pukekohe WWTP in 2009 as follows:

Nitrous Oxide Production (Treatment)

3.6 g/PE (kg methane/kg COD**)**

x 32,283 (PE TN inputs)

= **0.12 T Nitrous Oxide /yr** (6)

Using a GWP for nitrous oxide of 310, this is equivalent to **36 T** CO_2e per year.

4.3.4 NITROUS OXIDE PRODUCTION IN THE RECEIVING ENVIRONMENT

As discussed above the calculation for Nitrous Oxide production due to environmental enrichment may be represented as:

Nitrous Oxide Production (Kg/year)

$$\textbf{= Total Nitrogen Discharged (Kg/yr) x Emission factor x (44/28)*} \quad (7)$$

*44/28 corrects for the molecular weight of N_2O / the molecular weight of N.

In this instance, design data used by AWT estimated the annual total nitrogen discharge as being 29.3 tons. The treated effluent is discharged into the Parker Lane Stream, and the Waikato River, as such the default emission factor **(Ef- 0.005)** for discharge into rivers and estuaries was used (IPCC 2006).

Nitrous Oxide Production (Receiving Environment)

29.3 (T TN)

x 0.005 (emission factor)

x 44/28 (correction for molecular weight of N_20)

= **0.23 T** Nitrous Oxide / yr (8)

Using a GWP for nitrous oxide of 310, this is equivalent to **71 T** CO_2E per year.

4.4 SCOPE 2 PURCHASED ELECTRICITY

The Pukekohe WWTP uses electricity in several areas, these include:

- Operation of an inlet screen to the ponds, and
- Operation of 7 mechanical aerators.

The calculation for CO_2 emissions related to electricity use may be represented as (NZ MfE 2006):

Carbon Dioxide Emissions (T/year) = Total Power Use (KwH/yr) x Emission factor (kg/kwh) (9)

The emissions factor used to calculate the equivalent CO_2 emission is based on the Ministry for the Environment assessment of greenhouse gas emissions data for 2006, the most recent full year information available. This set an emission factor of 0.209 kg CO2e per kilowatt hour of electricity used.

As such, CO2 emissions were calculated as:

Table 4: Ponds System Power Use

Area	KWH Used	Emissions Factor	Total Scope 2 emissions CO2e
Mechanical Aerators	306,600 kwH /yr	0.209 kg/kwh	64 T/yr
Screen[2]	17,520 kwH /yr	0.209 kg/kwh	3.6 T/yr
Total		0.209 kg/kwh	67.6 TCO_2e

[1] 7x 5 Kw aerators assumed to be running 24 hours / day 365 days / yr.

[2] 2 Kw screen assumed to be running 24 hours / day 365 days / yr.

4.5 TOTAL SOURCES

Table 5 below shows the sources of GHG emissions for the facultative ponds system.

Table 5: Ponds System Total Emissions

Area	Source	CO2e Emissions
Scope 1	Methane	2,250 T CO2e
	Nitrous Oxide (Treatment).	71 T CO2e
	Nitrous Oxide (Receiving environment).	36 T CO2e
Scope 2	Electricity Use	67.6 T CO2e
Scope 3	Not Assessed	
Total		2,424.6 T CO2e

4.6 PROPOSED UPGRADE

The upgraded Pukekohe WWTP is still under construction, however greenhouse gas emissions were estimated based on the design specifications for the upgraded plant, which detailed the proposed process routes and anticipated energy use.

The main greenhouse gas emission from the proposed SBR plant will be CO_2 emitted from the generation of power used on site. The power use on site is based on the major power using the most current design data available as at August 2008. As such it is possible that the plant's actual emissions will differ from those discussed below depending on the final installation and operation of the plant.

4.7 SCOPE 1 DIRECT EMISSIONS

There are two direct emissions sources from the proposed SBR system, these are:

- Carbon dioxide produced through breakdown of organic matter during the aerobic phases of the SBR process, and

- Nitrous Oxide produced through nitrification denitrification in the receiving environment.

4.7.1 CARBON DIOXIDE

As for the ponds system, carbon dioxide emissions from aerobic breakdown of organic matter are not counted towards the plant's emissions profile, as they are biogenic in origin (IPCC 2006).

4.7.2 NITROUS OXIDE PRODUCTION IN THE TREATMENT SYSTEM

As the PE flows are the same as for the previous example, the same CO_2e emissions are used as for section 4.3.3, ie 36 T CO_2e.

4.7.3 NITROUS OXIDE PRODUCTION IN THE RECEIVING ENVIRONMENT

As discussed above, attributable nitrous oxide emissions due to the enrichment of nitrogen in the receiving environment are calculated by the formula below (WSAA 2007):

Nitrous Oxide Production (Kg/year)

$$\text{Nitrous Oxide Production (Kg/year)} = \text{Total Nitrogen Discharged (Kg/yr)} \times \text{Emission factor} \times (44/28) \qquad (10)$$

Based on projected design data the total TN discharged by the system will be as approximately 17.6 tons, reflective of the higher effluent quality that is anticipated achieved using the SBR process.

Using the calculation from section 4.3.4 , the nitrous oxide emission is therefore:

Nitrous Oxide Production (Receiving Environment)

17.6 (T TN)

x 0.005 (emission factor)

x 44/28 (correction for molecular weight of N in N2O)

= **0.14 T** Nitrous oxide / yr (11)

Using a GWP for nitrous oxide of 310, this is equivalent to **43 T** CO_2E per year.

4.8 SCOPE 2 PURCHASED ELECTRICITY

The proposed SBR plant will use the majority of its electricity in the following areas:

- Inlet pumps
- Fine air aeration
- Mechanical mixing, and
- Influent Screens
- Effluent Discharge pumps

As above the calculation for CO_2 emissions related to electricity use may be represented as:

$$\textbf{Carbon Dioxide Emissions (T/year)} = \textbf{Total Power Use (KwH/yr)} \times \textbf{Emission factor (kg/kwh)} \quad (12)$$

As such, CO_2 emissions may be calculated as follows:

Table 6: SBR System Power Use

Area	**KWH Used**	**Emissions Factor**	**Total Scope 2 CO2e**
Inlet Pumps	319,000	0.209 kg/kwh	67 TCO2e
Fine Air	3,260,000	0.209 kg/kwh	681 TCO2e
Mixing	127,000	0.209 kg/kwh	27 TCO2e
Screens	57,000	0.209 kg/kwh	12 TCO2e
Effluent Discharge pumps	163,000	0.209 kg/kwh	34 TCO2e
UV Disinfection	204,000	0.209 kg/kwh	43 TTO2e
Allowance for small users [1]	100,000	0.209 kg/kwh	21 T CO2e
Mechanical Aerators	306,600	0.209 kg/kwh	64 T CO2e
Total	4,536,600	0.209 kg/kwh	949 TCO2e

1- An Allowance for small users was made in the early design phases of the plant to account for control infrastructure, PLC and other equipment.

4.9 TOTAL SOURCES

Under the proposed configuration, the plant's greenhouse gas footprint is comprised mainly of scope 2 emissions related to the operation of the SBR process and associated equipment. Methane production is assessed as nil, which significantly reduces the plant's overall GHG production.

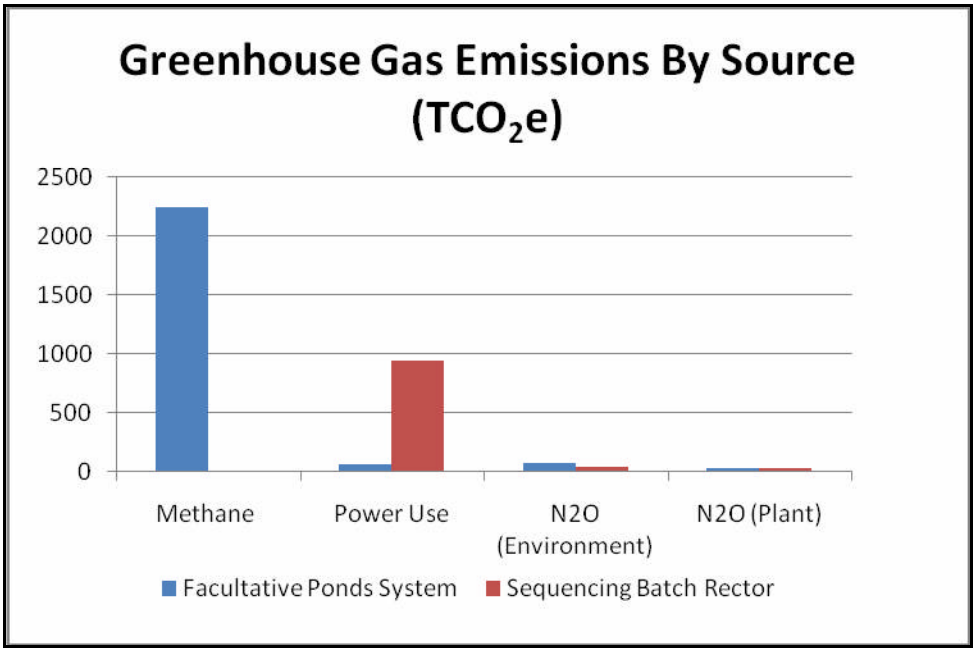
In addition the reduced TN loads to the receiving environment (and resulting attributable Nitrous oxide emissions) are also reduced.

Table 7: SBR System Total Emissions

Area	**Source**	**CO2e Emissions**
Scope 1	Methane	Nil
	Nitrous Oxide (Treatment).	43 T CO2e
	Nitrous Oxide (Receiving environment).	36 T CO2e
Scope 2	Electricity Use	949 T CO2e
Scope 3	Not Assessed	
Total		1,028 T CO2e

4.10 DISCUSSION

Figure 2: Greenhouse Gas Emissions By Source



The SBR plant produces a total of 1,208 T CO_2e, whereas the facultative pond system produces 2,424 T CO_2e per year. The emissions reduction saving would be valued at approximately $18,000 per year (assuming the offsets could be verified under an appropriate certification scheme).

The primary source of emissions for the pond system is from the emission of methane in the anaerobic layers of the facultative ponds (and possibly further methane emission in the wetland system). However, it should be noted that the operation of mechanical aerators are also a significant power user.

The SBR system uses significantly more electricity than the facultative ponds, but has an overall lower greenhouse gas footprint due to the absence of methane emissions.

One significant finding is that the methane produced in the facultative ponds accounts for the vast majority of its emissions, which is broadly in line with current academic literature in the area (Shilton et al 2008).

Whilst there is considerable uncertainty around characterizing the emissions factors for facultative ponds, even using less conservative emissions factors the general trend (of methane emissions representing a significant GHG emission) would still apply.

However it should be noted that there remains considerable uncertainty around the rate of production of methane in facultative ponds. Changes to the emissions factors used in this calculation (such as may be warranted if facultative ponds are found to have lower emissions rates than are detailed in the current IPCC and WSAA literature) may significantly alter the balance between power use, methanogenesis, and nitrogen enrichment, as it pertains to optimizing wastewater treatment plants for their GHG emissions. We suggest that further work be carried out in this area.

5 CONCLUSIONS

The analyses above illustrate three key aspects of carbon foot printing for the wastewater sector.

Firstly for the View Rd LDS the effect of environmental nitrogen enrichment represents a significant contributor to the site's overall carbon footprint. As such, this factor should not be neglected in making carbon emissions management decisions. Improved effluent quality (in terms of reduced TN load) may have benefits for facilities in terms of carbon footprint, beyond their "direct" environmental effects.

Secondly the comparison between the current and proposed configurations of the Pukekohe WWTP illustrates the balance between power use, effluent quality and methanogenic process routes. In this case reducing methane production (despite requiring further energy inputs in terms of electricity) through aerobic process routes significantly reduces the plant's overall carbon footprint.

Finally it should be noted that there remain considerable uncertainties around the emission factors used. In the case of the facultative ponds system, more accurate emissions factors may have significant implications in terms of the balance between power use, methane emissions and effluent quality.

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