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Assessment of Potential for Energy Generation from Expanding Industrial Wastewater Treatment Facilities

Project Name:	Energy from expanding WWT facilities
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1 EXECUTIVE SUMMARY

A review of the current greenhouse gas (GHG) emissions from industrial wastewater treatment was undertaken in order to assess the potential for emissions reduction potentially achievable by processing residual waste in anaerobic digestion plants to produce energy and fertiliser.

The report evaluated three scenarios, i.e. business as usual (BAU), encouraged uptake and accelerated uptake.

The BAU scenario will see the GHG emissions increase at a rate corresponding to the industry growth. The encouraged uptake scenario, with low-cost improvements to existing treatment facilities and an increased use of biogas as a fuel substitute, will provide GHG emissions reduction in the order of 31-55 kt CO_2-e per annum or 29-41% of total projected emissions from the industrial waste treatment sector.

Accelerated growth, where gradually increasing portion of emission-intensive treatment methods are replaced with anaerobic digestion at new or existing anaerobic digesters with complete biogas utilisation, has a potential to provide additional 151 kt CO_2-e per annum of emissions reduction by 2050. This approach will make industrial wastewater treatment sector carbon negative and offset the GHG emissions of other sectors by 72 kt CO_2-e.

2 PROJECT BRIEF

The Bioenergy Association of New Zealand (BANZ) is undertaking a project funded by the Energy Efficiency and Conservation Authority (EECA), which is to assess the opportunities for processing residual waste in anaerobic digestion plants to produce energy and fertiliser in order to reduce emissions of methane to air. The aim is to refine the targets for greenhouse gas (GHG) emission reduction which BANZ has advised Government could be achieved by 2030, 2040, and 2050.

This report covers the emission reductions potentially achievable from industrial waste treatment. Greenhouse gas emission reductions from municipal and agricultural waste treatment are assessed elsewhere (Calibre, 2018).

3 METHODOLOGY

Due to the lack of available real industry data on the amount of waste currently produced, the work was based on a report prepared by Cardno (Cardno, 2015) for the Ministry for the Environment as a basis for the New Zealand's Greenhouse Gas Inventory 1990 – 2015 (MfE, 2015). The distribution of GHG emissions within the individual industries and the treatment technologies stated in the Cardno report was assessed to identify the most significant source of emissions.[1]

Three scenarios were assessed as part of the project:

Business As Usual (BAU)

General summary: No particular efforts from wastewater treatment plant (WWTP) owners are taken to maximise the gas capture and utilisation in existing plants. Landfill owners are enticed to gradually improve the average landfill gas capture efficiency. The carbon price and power price are low and therefore there is an insufficient incentive to generate and capture biogas for use as an alternative heat or electricity source.

Specific conditions:

- Industry growth corresponds to the long-term average annual production increase of 0.6%, 3.3%, 1.1% and 4.2% for meat (and poultry), dairy, pulp and paper and winemaking industry, respectively.
- No change to the current treatment approach or efficiency.

BANZ Scenario 1

General summary: The carbon price increases as well as the price for industrial heating fuel (natural gas) and trade waste disposal costs to landfill. Public pressure incentivises councils and water corporations to create a more positive environment for energy efficient treatment at source.

Landfill owners are enticed to gradually improve the average landfill gas capture efficiency. Only enthusiastic businesses start using process waste to produce energy. Most process waste still goes to disposal or other uses such as animal feed.

Power price is low, generation of electricity from biogas is economical but limited to Behind The Meter (BTM) utilisation. BTM system is a renewable energy generating facility (in this case biogas genset) that produces power intended for on-site use in a home, office building, or other commercial facility.

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[1] The industry GHG emissions in the Cardno report differ slightly (by less than <3%) from the final MfE report. Cardno data was used as a basis for this report as it provided sufficient detail for the task.

Specific conditions:

- Industry growth corresponds to the long-term average annual production increase of 0.6%, 3.3%, 1.1% and 4.2% for meat (and poultry), dairy, pulp and paper and winemaking industry, respectively.
- Existing industrial anaerobic treatment ponds are gradually retrofitted with efficient gas capture and utilisation. All of the generated and captured gas is used for industrial heat in co-located commercial and industrial businesses and local gas networks with embedded electricity generation a secondary use on larger sites with high electricity demand. This scenario does not assume export of electricity for sale.
- The following rate of change implementation was used: 59% by 2030, 69% by 2040 and 80% by 2050.

BANZ Scenario 2

General summary: The carbon price increases considerably as well as the price for industrial heating fuel (natural gas) and trade waste costs for landfill disposal.

Public pressure drives the market to divert all organic waste from landfill and convert high-strength organic waste to renewable energy. Renewable energy is produced from residual waste unsuitable for reuse or recycling. All industries are encouraged and respond to using waste productively. The percentage of the NZ population serviced with WWTP with anaerobic digestion increases from 53% (today) to 68% (2050).

Power price is low, generation of electricity from biogas is economical, primarily as Behind The Meter (BTM) system. Export of electricity is occurring more often as an outlet for the waste processing facilities with insufficient energy demand.

Specific conditions:

- Industry growth corresponds to the long-term average annual production increase of 0.6%, 3.3%, 1.1% and 4.2% for meat (and poultry), dairy, pulp and paper and winemaking industry, respectively.
- An increasing portion of the industrial waste (dairy, meat processing) can be converted to biogas either at significantly upgraded existing municipal digesters, or new regional anaerobic treatment facilities constructed at large industrial sites with 70:30 (municipal:industrial) ratio for dairy and meat and 20:80 ratio for poultry, pulp & paper and wine industry. For details refer to the accompanying report (Calibre, 2018).
- Existing anaerobic treatment ponds are gradually retrofitted with efficient biogas capture and utilisation.
- All of the biogas produced is used for industrial heat in co-located commercial and industrial businesses and local gas networks with embedded electricity generation a secondary use on larger sites with high electricity demand. Export of electricity for

sale from the site is only done when waste utilisation is the primary driver and there is a need for an outlet for the excess energy produced.

- The following rate of change implementation was used: 59% by 2030, 69% by 2040 and 80% by 2050.

Photo 1: Upgraded anaerobic digester at Palmerston North Wastewater Treatment Plant. A cost-effective upgrade works increased the digester treatment capacity and enabled co-digestion of locally produced industrial waste with municipal biosolids (BANZ, Occasional Paper 11: Potential energy production from waste water treatment in NZ, 2013).

4 BACKGROUND INFORMATION

In 2015, emissions from the waste sector contributed 4,000.7 kilotonnes carbon dioxide equivalent (kt CO_2-e) or 5.0 per cent of New Zealand's gross greenhouse gas emissions. The largest source category is the solid waste disposal category. Wastewater treatment and disposal contributed 372.4 kt CO_2-e, with a reported increase of 11.2% since 2009 due to increases in emissions from the volume of industrial and domestic wastewater handled over this period.

GHG Emissions by Industries

The industrial wastewater treatment accounted for 94.22 kt CO_2-e of which 86.40 kt CO_2-e was attributed to methane emissions and 7.82 kt CO_2-e was attributed to nitrous oxide emissions[2]. The major sources of industrial wastewater emissions in New Zealand are the meat and the pulp and paper industries (see Table 1).

Table 1: A summary of industrial wastewater treatment GHG emissions as reported in 2015.

	CH_4 Emissions kt CO_2 p.a	N_2O Emissions kt CO_2 p.a	Total Emissions kt CO_2 p.a	Total Emissions %
Meat Processing	51.82	3.29	55.11	58%
Pulp and Paper Processing	25.42	0.00	25.42	27%
Poultry Processing	7.44	0.70	8.15	9%
Dairy Processing	0.00	3.82	3.82	4.1%
Winemaking	1.71	0.00	1.71	1.8%
Total	86.40	7.82	94.22	100%

Methane emissions arising from the meat industry wastewater treatment are predominantly (64%) associated with sites employing only primary treatment. In most cases the pre-treated wastewater is discharged to sewer and further emissions are accounted for in the municipal wastewater treatment inventory. The primary treatment solid residue is usually disposed at landfills or at composting plants (emissions accounted for in solid waste inventory) or processed at rendering plants.

[2] In line with the Cardno report, the fellmongers and tanneries were excluded from the assessment. The emission factor for this industry is assumed to be zero for both fellmongers and tanneries. Fellmongery wastewater is unsuitable for anaerobic treatment due to high concentrations of sulphur and other inhibiting components in the wastewater. Therefore, aerobic treatment is provided for those sites that do not discharge to sewers. Tanneries in New Zealand are all located in towns and discharge to sewer (Cardno, 2015).

The second largest source of methane emissions in the meat industry wastewater is treatment in anaerobic treatment ponds followed by aerobic treatment ponds.

The poultry industry, although being meat industry, is treated separately in the NZ GHG emissions inventory and contributes a substantial 8.15 kt CO_2-e of emissions to the total national emissions count. Again, the largest portion of methane emissions (40%) comes from sites with primary treatment only. Due to the inherent bias (see note in Section 6 below, 2nd point) in the way the emissions are calculated, the second largest contributors are paradoxically aerobic treatment processes at 35%.

Pulp and paper wastewater is treated largely in aerobic treatment ponds and aerobic processes. Partially mixed aerobic ponds are the largest source of methane emissions in this industry.

Dairy processing industry predominantly uses aerobic treatment. There is only one factory that uses anaerobic treatment. The emissions from this wastewater treatment process are recovered and most of the captured biogas (consisting of 55% CH_4) is used in boilers. The remainder is flared. Consequently, no CH_4 emissions are reported from the dairy industry. Nitrous oxide emissions arising from aerobic treatment of dairy industry wastewater are included in the inventory, contributing 4.1% of the industrial wastewater total emissions count.

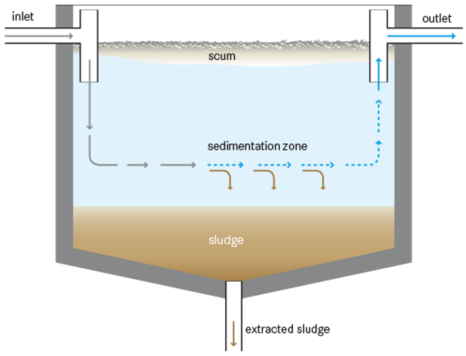
Winemaking industry contributes 1.8% of the total emissions. With an average annual production increase of 4%, this is the fastest growing food processing industry in the inventory. The main source of emissions here are anaerobic storage pond (65%) followed by primary treatment (33%).

GHG Emissions by Treatment Methods

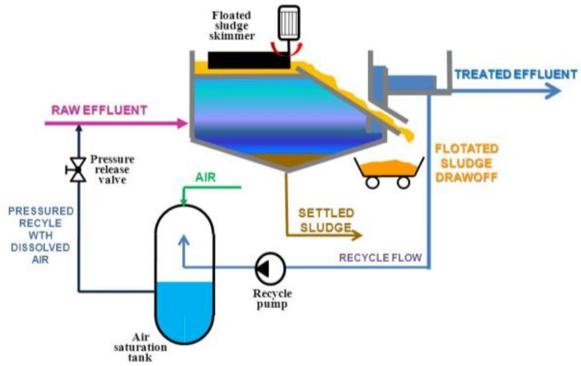
The distribution of GHG emissions among different treatment methods is summarised in Table 2 below.

Table 2: Proportion of different types of wastewater treatment in the total GHG emissions inventory.

Treatment method	CH_4 Emissions kt CO_2 p.a	N_2O Emissions kt CO_2 p.a	Total Emissions kt CO_2 p.a	Total Emissions %
Primary treatment	39.00	0.94	39.9	39%
Anaerobic treatment ponds	29.44	0.65	30.1	29%
Aerated Processes	17.96	6.23	24.2	24%



A)



B)

Primary treatment *separates readily-removable suspended solids and wastewater constituents that exist as floating and settleable solids or are sorbed to these solids. This is usually done by screening, gravity settling (image A) and/or by chemically-assisted mechanical separation (image B, Dissolved Air Floatation device).*

As shown in Table 2, 39% of the total GHG emissions from industrial wastewater treatment is generated at sites with only primary treatment of wastewater, equivalent to 39.9 kt CO_2-e. Primary treatment typically aims to separate organic solids from the liquid effluent prior to discharge to sewer, land or surface water.

The solids removed by primary treatment can be disposed on landfill, composted, processed in rendering plants or used, in some instances, as animal feed. The emissions originating from decomposition of organic industrial waste on landfills is accounted for in the solid waste portion of the inventory. The majority of the 24 currently operational large municipal landfills have implemented gas recovery and further improvements are being realised to reduce emissions through increased capture and utilisation efficiency. In the 2015 GHG emissions inventory, emissions arising from composting are being considered immaterial. Emissions from rendering plants are accounted for in the industrial wastewater treatment emissions inventory and the use of organic solids as animal feed is not considered to lead to GHG emissions.

The second largest contributing technology from the industrial wastewater treatment, with 29% of all GHG emissions (30.1 kt CO_2-e), are anaerobic (open) treatment ponds (standalone or coupled with aerobic treatment).

Anaerobic (open) treatment ponds *are designed and built to reduce organic content from wastewater. Anaerobic ponds are not aerated, heated, or mixed and contain anaerobic organisms which are able to break down complex organic waste into basic compounds in the absence of oxygen. Methane, a major greenhouse gas, is emitted into the atmosphere as a result of the treatment unless a gas-tight cover is installed to capture the generated gas. Anaerobic ponds can be coupled with aerobic treatment for further polishing prior to discharge. Installation of gas-tight cover for gas capture and treatment efficiency improvement of the existing anaerobic ponds are the main considerations in Scenario 1.*

Aerated Processes *use naturally occurring aerobic microorganisms in the presence of oxygen to convert organic matter in the wastewater into carbon dioxide and new biomass. Aerated processes can also be designed to facilitate nutrient (nitrogen, phosphorus) removal. Nitrous oxide, a greenhouse gas, can be emitted into the atmosphere as a result of the aerobic treatment. Air is supplied by means of mechanical aeration system.*

5 POTENTIAL FOR GHG REDUCTION

Emissions Reduction

Section 3 identified the primary treatment to be the highest source of GHG emissions within the industrial waste treatment sector. Substitution of primary treatment technologies with more efficient energy recovery anaerobic treatment would substantially reduce the emissions in the industrial wastewater treatment sector.

In addition to that, implementation of methane capture and utilisation and improvement of the treatment efficiency of existing anaerobic treatment facilities offer additional potential for GHG emissions reduction.

Photo 2: Fonterra's Tirau site is the only industrial operation in New Zealand employing anaerobic digestion with biogas capture and utilisation for treatment of high-strength organic waste from Tirau and other Fonterra sites. The digester has been in operation since 1983.

Energy Recovery as Means of Offsetting GHG Emissions

Table 3 shows the total biodegradable organic load (Chemical Oxygen Demand or COD load) from all considered industries as reported in 2015.

> *Chemical Oxygen Demand (COD) is a measure of organic pollution in wastewater. Biodegradable COD is the portion of all organics in the wastewater that can be degraded by biological aerobic or anaerobic treatment systems.*

Table 3: Total biodegradable COD load contribution by industries as reported in 2015.

	Biodegradable COD Load kt p.a.	COD Load %
Meat Processing	58.0	26%
Poultry Processing	8.7	4%
Dairy Processing	66.4*	30%
Pulp and Paper Processing	86.9	39%
Winemaking	4.1	2%
Total	224.1	100%

*Note: Fonterra Tirau currently processes 7.63 kt COD per annum to biogas which is utilised in boilers.

The largest contributor is pulp and paper industry followed by dairy and meat processing industry. When treated in well-designed anaerobic digesters (see Photos 1 and 2) , the organic matter can be more or less quantitatively converted to biogas and utilised as renewable source of energy. This can be done by improving treatment and gas capture efficiency of existing anaerobic treatment ponds at processor's sites, capture of primary sludge and transfer to municipal co-digestion plants or by implementation of new industrial wastewater digestion facilities.

Anaerobic digestion preserves the nutrients contained in the raw wastewater in form of liquid effluent, so called digestate. Digestate can be used as an environmentally sound alternative to mineral fertilisers and provides means of returning the nutrients back to the land (BANZ, Technical Guide 08: The production and use of digestate as fertiliser, 2014).

While there are no methane emissions reported for dairy industry, there is a very high potential to use this waste to offset the GHG emissions of dairy and other industries by treating the dairy waste anaerobically and using the biogas to replace fossil fuel consumption for industrial/commercial heat production. Similarly, the industrial waste in non-dairy industries currently treated only by primary treatment can be used as a feedstock for biogas production.

Scenarios Assessment

Table 4 and Figure 1 summarise the GHG emissions projected for the three considered scenarios. The total GHG emissions (EM_{total}) for each scenario are calculated as follows:

$$EM_{total} = EM_{baseline} - EM_{reduced} - EM_{avoided}$$

Where:

$EM_{baseline}$ are emissions that would be generated if no improvements, specific to the given scenario, are executed.

$EM_{reduced}$ are emissions eliminated by implementing the proposed scenario-specific improvements. These are an improved capture of GHG emissions from existing anaerobic lagoons for Scenario 1 and a further uptake of anaerobic digestion as a replacement for existing treatment technologies for Scenario 2.

$EM_{avioded}$ are emissions that can be avoided if biogas generated from industrial waste is used as a fossil fuel substitute for energy (heat, electricity, transport fuel) generation[3].

Table 4: Total GHG emissions from industrial wastewater treatment for the three considered scenarios. "Scenario 2" accounts for all emissions reduced by uptake of anaerobic digestion as primary treatment for industrial waste and avoided by using all biogas generated to replace fossil fuels for electricity or heat generation. "Scenario 2 w/o treatment at municipal plants" shows the total emissions if upgraded municipal treatment plants are not available for treatment of industrial waste and only limited portion of industrial waste is treated in dedicated industrial or regional waste treatment facilities.

	BAU (kt CO_2-e)	Scenario 1 (kt CO_2-e)	Scenario 2 (kt CO_2-e)	Scenario 2 without treatment at municipal plants (kt CO_2-e)
2015	94.2	94.2	94.2	94.2
2017	95.9	95.9	95.9	95.9
2030	108.5	77.4	2.4	51.1
2040	120.1	78.9	-27.6	45.7
2050	134.2	79.8	-71.8	38.3

As can be seen, a modest approach as in Scenario 1 based on simple, mostly low-cost, improvements of existing anaerobic treatment systems offer emissions reductions provided all of the generated gas is utilised for heat production. The emissions reduction obtained are

[3] An average emission factor of 0.2 kg CO_2-e/kWh was used for calculation of avoided emissions from the use of biogas as energy source. This is an average of emission factors for replacement of natural gas for heat production, electricity and diesel for transport fuels (MfE, Summary of Emissions Factors for the Guidance for Voluntary Corporate Greenhouse Gas Reporting - 2015, 2018).

in the order of 31-55 kt CO_2-e per annum corresponding to 29-41% of total projected emissions from the industrial waste treatment sector.

A more aggressive approach considered in the Scenario 2, where an increasing portion of waste currently treated by primary treatment is processed in existing (upgraded) municipal anaerobic digesters or in new industrial anaerobic treatment systems, leads to substantial higher emissions reduction. In addition to the GHG emissions reduction achieved in Scenario 1, a total reduction of 151 kt CO_2-e can be achieved by the industry sector by 2050 when using the organic waste as a resource, replacing fossil fuel with biogas for heat and electricity production. This approach will make industrial wastewater treatment sector carbon negative and offset the GHG emissions of other sectors by 72 kt CO_2-e.

Carbon Negative *- any activity that removes more GHG emissions from the atmosphere than it is responsible for generating because of carbon offsetting.*
Carbon Offsetting *- the process of reducing GHG emissions in one place to offset the GHG emissions created somewhere else.*

As per the Scenario 2 specific conditions in Section 2 of this document, some of the industrial waste will be treated in upgraded municipal treatment plants rather than dedicated industrial waste treatment facilities. These municipal or regional treatment facilities play an essential role in achieving the carbon negative balance as they will process up to 70% of the industrial waste. Upgrading existing municipal wastewater treatment facilities provides a cost-effective means of treating surplus organic waste at a small portion of the price of new treatment facilities.

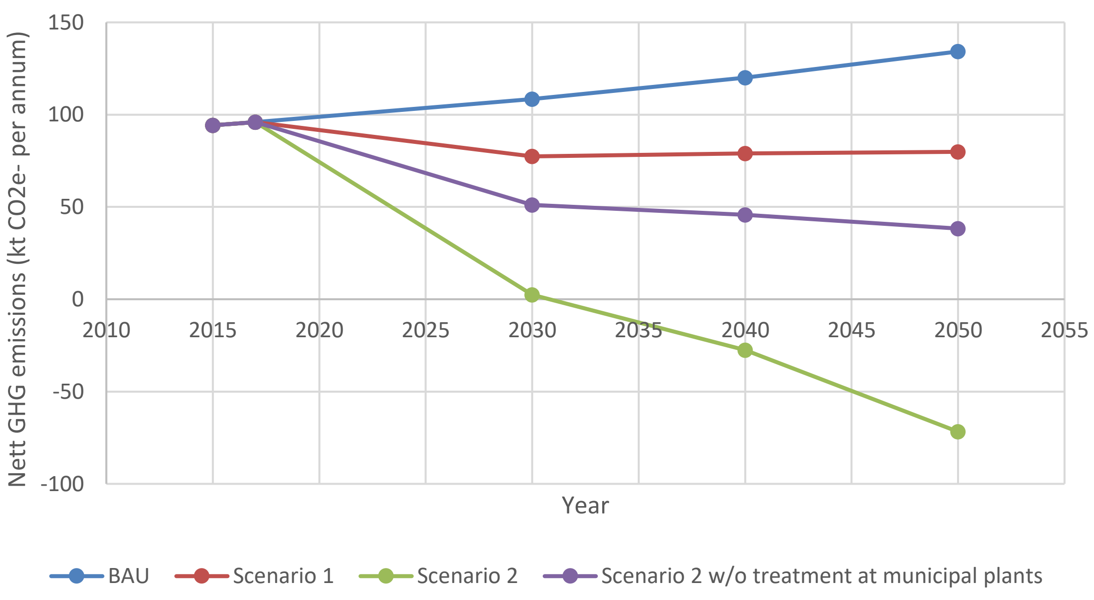


Figure 1: GHG emissions predictions for the three considered scenarios.

6 CONCLUSION

Overall, there is a potential for reduction of emissions from industrial wastewater treatment by improving the efficiency of the existing anaerobic treatment plants (mostly ponds) and using the generated gas as fossil fuels substitute. In addition to that, replacing of primary treatment technologies with anaerobic treatment coupled with efficient gas capture and utilisation has a potential to generate additional GHG emissions reduction (i.e. carbon charge reduction for industrial emissions) and provide renewable energy source for industrial heating. Further improvement can be achieved by maximising the use of the organic waste as energy source for production of renewable heating fuel in existing municipal or new regional organic waste processing centres. If executed to its predicted extent, the industrial waste sector has a potential to offset up to 150 percent of its projected GHG emissions by 2050 and become carbon negative.

7 COMMENTS ON THE GHG EMISSIONS INVENTORY CALCULATION

Several observations were made regarding the GHG emissions inventory calculation principle, which are summarized below.

1. Country specific Methane Correction Factors (MCF) were used in the calculations, some of which were developed in 2005 and have not been revised since. More up to date data was used for winemaking, and pulp and paper industries. The likelihood is that process efficiencies have been improved since 2002 which should lead to a reduction of the MCF and consequently of the GHG emissions total.

2. The industry emission factor is calculated as a weighted average emission factor according to the following equation:

$$IEF = \Sigma\, p_n\, EF_n\, (1 - s_n)$$

   Where:

   IEF = Emission Factor (kg CH_4/kg COD)

   pn = Fraction of total industry waste treated using process n

   EFn = Emission Factor for process n (kg CH_4/kg COD)

   sn = Fraction of influent biodegradable COD removed from site as biodegradable sludge

   The total emissions for each industry are then calculated as a sum COD mass treated by each given technology multiplied by the IEF less amount of methane flared or utilised. Based on this principle, aerobic treatment technologies, which are normally assumed free of methane emissions, end up carrying a portion of the industry's methane emissions, if both anaerobic and aerobic treatment technologies are used. On the other hand, in industries strictly using aerobic technologies, i.e. New Zealand dairy industry, no emissions are assigned to the treatment since EF equals to zero.

3. The GHG emissions from winemaking solid organic residue are not included in the inventory. The current methodology does not include the storage and disposal of grape marc, i.e. the solid residue from grape processing. This waste is usually stockpiled and spread on land as a fertiliser substitute. The lack of industry standard (and its enforcement) for disposal of grape marc often leads to uncontrolled storage with a high potential for methane or nitrous oxide emissions. Due to the exponential growth of the winemaking industry, it would be prudent to include the emissions associated with grape marc disposal into the national survey.

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