U.S. Community Protocol
for Accounting and Reporting of Greenhouse Gas Emissions

Appendix F: Wastewater and Water Emission Activities and Sources

Version 1.1

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Developed by
ICLEI – Local Governments for Sustainability USA

For the latest version of this Protocol, and other tools and resources that can help you report on community GHG emissions, visit www.icleiusa.org.

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Introduction

Emissions Associated with Wastewater Treatment[1]

Wastewater treatment can create a unique set of process, stationary, and fugitive greenhouse gas emissions. Methane (CH_4) is produced when microorganisms degrade the soluble organic material in wastewater under anaerobic conditions. During collection and treatment, wastewater may be unintentionally or deliberately managed under anaerobic conditions, potentially releasing some uncaptured or uncombusted CH_4 into the environment.

Nitrous Oxide (N_2O) is an intermediary product of both conventional treatment and specialized biologically mediated processes to remove excess nitrogen in wastewater. A fraction of the nitrogen discharged into natural waters may undergo similar processes and also produce N_2O.

Carbon Dioxide (CO_2) emissions from wastewater treatment are distinguished as either biogenic or fossil fuel based. Biogenic CO_2 is part of the short-term carbon cycle; these emissions may be optionally reported as a line item, but they should not be added into any inventory total. Fossil fuel based CO_2 emissions may come from the use of the use of fossil-based methanol in wastewater treatment plants (WWTP). Local governments are encouraged, but not required to track and report these emissions if they occur and if the local government has significant influence over them. Methane emissions from wastewater treatment are always anthropogenic.

Table WW.1 below summarizes the sources of stationary, fugitive and process greenhouse gas emissions outlined in this chapter. Paired with each source is a methodology explained later in this chapter. For any source, these methodologies may be substituted with on-site source tests using methodologies drawn from approved regulatory methods. On-site emissions results should be more representative of the emissions than the generic emission factors in this chapter and thus are preferred.

On the community level, power consumed to operate wastewater facilities located within the community will be bundled with energy consumption from the other sectors. Any electricity, natural gas or other fossil fuel consumed to power devices at these facilities should be included in the Industrial sector.

Every community generates wastewater, but not every community harbors or manages its own treatment system(s). Because every jurisdiction will have different kinds of wastewater treatment facilities, be very cautious in comparing emissions associated with wastewater treatment between communities. Regardless of community size, demographics or economic status, wastewater generation is unavoidable and these wastes must be treated before water is

[1] Currently, the understanding of greenhouse gases from all of these sectors is emerging. More resources may be added as our understanding improves.

returned to the environment. The wastewater treatment protects watersheds and prevents the spread of waterborne diseases. The practice of wastewater treatment thus provides a non-discretionary service to society.

Communities may achieve the goal of treating wastewater through either decentralized systems with treatment occurring at many locations; a main centralized facility at the terminus of an extensive sewage collection system; or a mix of the two. Communities may also enter into partnerships with other communities to treat their collective wastewater at a shared facility.

Communities adopting a decentralized approach have numerous systems scattered over a wide geographic area, and typically these disparate systems are not owned, operated or maintained by a local governing authority. Usually property owners are responsible for maintenance; however, a local enforcement agency may be responsible for inspecting and regulating these units.

Rural communities with dispersed population centers as well as many suburbs typically adopt a decentralized approach to wastewater treatment by using either household septic systems or cluster package systems. These smaller, remote and isolated systems rarely employ the complicated processes used at centralized facilities. Treatment and ultimate discharge is often very near the origins of the wastes treated.

A centralized system treats wastewaters collected in a network of sewers that lead to a larger, dedicated facility typically many miles from the origins of those wastes. Separately, many communities are members of a joint powers agreement with other communities or "special districts" that outsource the treatment responsibilities to one (or a few) of its members.

Urban communities with more densely packed population centers are more likely to use one or more centralized facilities for wastewater treatment. Most communities in the United States are served by collection systems that convey the sewages to such centralized facilities. When in doubt, assume a centralized aerobic treatment process is being used.

Centralized facilities typically employ an aerated treatment process to destroy soluble organics in wastewater. This aerated step may be configured to simply destroy only the organics in the sewage, or more advanced treatment may be included to remove other nutrients like nitrogen. The processes employed in these facilities are identical to processes that occur in nature and are managed to accelerate these natural processes within the controlled environment of the plant. These organics are derived from plant-based carbon hence CO_2 emissions from these processes, including the CO_2 generated from the combustion of digester gas, are considered a waste-derived biogenic source of CO_2 and are considered carbon-neutral for GHG accounting purposes.

Wastewater utilities may provide opportunities to offset GHG emissions from other sources. Utilities may generate renewable power from the biogas and/or biosolids produced from wastewater treatment, reducing reliance on other nonrenewable fuel sources. Some wastewater treatment facilities may treat the water to advanced levels that may approach or even exceed drinking water standards. Such reclaimed waters can be used to displace imported water that may have a higher greenhouse gas footprint. Utilities may also have the opportunity to recover nutrients during wastewater treatment or to use biosolids as fertilizer, reducing greenhouse gas emissions from the production of synthetic fertilizers. Each wastewater utility is unique and will have its own site-specific opportunities and challenges related to offsetting GHG emissions.

Unit Operations Associated with Wastewater Treatment

Wastewater treatment may employ one or more unit operations that may result in emissions of greenhouse gases. Although the number of unit processes is far greater than those presented here, this discussion is limited to those processes relevant to the protocols that have been developed thus far. These are:

Septic Tanks: Roughly one in five households in the United States depends on an individual septic (onsite) system to treat wastewater. Septic tanks typically contain underground stagnant and unaerated tank(s) where the treatment occurs by physical settling and biological activity. These systems typically do not have other wastewater unit operations associated with them. Emissions are mainly CH_4 with very little N_2O generated.

Lagoons: Lagoons are shallow earthen basins varying in depth from 2 to 5 meters and yet may cover many acres. Some are operated with mechanical aeration while others are allowed to remain stagnant and may have periods of anaerobic activity where CH_4 may be produced. These basins use some combination of physical, chemical, and/or biological treatment processes that renders the wastewater more acceptable for discharge to the environment. They are not widely used because they tend to require large areas and supplemental treatment. These are typically centralized systems that may employ solids processing like anaerobic digestion.

Conventional Treatment: For purposes of this Protocol, conventional treatment refers to any centralized system other than a lagoon that degrades the dissolved organics in wastewater under aerobic conditions. When determining process and fugitive emissions, disparate systems such as attached growth (e.g. trickling filter) and activated sludge are treated the same. Currently, methods do not yet exist to distinguish between these (and other) broad categories of BOD removal. These complicated systems may also employ anaerobic digestion for solids processing. When in doubt, calculate the emissions using formulas that apply to conventional activated sludge without nitrification or denitrification.

Conventional Treatment with Nitrification or Denitrification: These are centralized aerobic systems with additional treatment to either oxidize nitrogenous wastes to oxidized forms of nitrogen or the removal of nitrogen by a subsequent anoxic step that reduces the oxidized forms to elemental nitrogen gas. This latter conversion may be assisted by the oxidation of a supplemental form of carbon like methanol that results in the release of fossil-based carbon as CO_2. These systems may employ digesters to manage the process solids. According to the United States Environmental Protection Agency (EPA) Clean Water Needs Survey, denitrification processes served only 2.4 million people in 2004, though this number is expected to increase.

Digester Gas: Organic solids from any of the above treatment processes may be further treated in enclosed, anaerobic tanks. Naturally occurring microorganisms (obligate anaerobes) degrade these organics in the absence of atmospheric oxygen to produce a gas consisting of roughly 65% CH_4 and 35% CO_2[2]. This gas can be captured and burned in devices to generate renewable, carbon-neutral energy. These tanks (digesters) are typically located at centralized facilities. Although septic tanks do not have digesters closely associated with them, settled material may periodically be siphoned out of a septic tank and hauled to a centralized facility where the solids could undergo anaerobic digestion.

Combustion Devices: These may include flares to combust excess anaerobic digester gas, boilers to generate steam to heat digesters or for facility space heating, internal combustion engines to generate either electric power or motive power to drive pumps and turbines for power and/or steam generation, or fuel cells. Although in practice the emissions from these devices will vary greatly, the accepted emission factors assume the same emissions profile regardless of the device used. Combustion devices may emit CH_4 from any uncombusted portion of the gas and N_2O from the oxidation of nitrogen introduced in the combustion air. Since the gas generation processes are enclosed and must be kept free from exposure to atmospheric oxygen, the collections efficiencies are assumed to be 100% and the emission factors are based on emissions at the stack.

Determining Contributions from Industrial Waste Discharges

Box.1 is relevant for users determining whether a discharger is industrial and, therefore, whether a community should use the $F_{ind\text{-}com}$ factor of 1.25. $F_{ind\text{-}com}$ is meant to represent the level of industrial-commercial contributors to the collection system. Users have the option of using 1.0 for $F_{ind\text{-}com}$ if there is a demonstrated lack of significant industrial-commercial contributors. Otherwise, 1.25 should be used.

[2] See: Inventory of U.S. Greenhouse Gas Emissions and Sinks, http://epa.gov/climatechange/emissions/downloads12/US-GHG-Inventory-2012-Chapter-8-Waste.pdf

Box. 1 Non-significant Categorical Industrial User (NSCIU)[3]
An industrial user subject to categorical pretreatment standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N, that is exempt from the definition of SIU on a finding that the industrial user never discharges more than 100 gpd of total categorical wastewater (excluding sanitary, noncontact cooling and boiler blowdown wastewater, unless specifically included in the pretreatment standard). The industrial user must also meet the following conditions: • The industrial user has consistently complied with all applicable categorical pretreatment standards and requirements. • The industrial user annually submits the certification statement required in 40 CFR 403.12(q) together with any additional information necessary to support the certification statement. The industrial user never discharges any untreated concentrated wastewater.
Source: *40 CFR 403.3(v)(2)*

Uncertainties

According to the latest EPA national inventory of greenhouse gas emissions considerable uncertainty exists within any of the EPA/IPCC-based methodologies. EPA states that the estimates can under predict CH_4 emissions by 37% or over-predict by 47%. The range of uncertainty is even greater for N_2O: the EPA-based methodologies could be under predicting by 76% or over predicting by 93%.[4] Emission estimates based on direct source measurements can possibly have higher accuracy and less uncertainty.

This extreme degree of uncertainty exists because these methodologies were originally developed for international countrywide inventories that were mainly population-based. By necessity, these methodologies were generalized "top-down" approaches that sought to provide emissions estimates for countries where detailed information would be impractical to obtain. Although these methodologies had the advantage of being relatively simple to calculate, the trade-off was a compromised level of accuracy. Nevertheless, the methodologies in this Appendix reflect the evolution of knowledge since the development of the LGOP.

In some cases, especially where the emissions are based on population and default inputs, communities should exercise caution in drawing conclusions or establishing policy. Moreover, communities should include a discussion of these uncertainties in their final analysis. As the methods evolve and these uncertainties are clarified ICLEI will update them.

[3] This reference is relevant for methods *WW.12.(alt)*, *WW.6.(alt)*, and *WW.8*.

[4] See: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2009, EPA, 4/12/2011, Table 8-15, p. 8-16, http://epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Chapter-8-Waste.pdf

Overall Strategy for Determining Wastewater Emissions

Please refer to Chart WW.1 to determine your initial steps in calculating your greenhouse gas emissions from wastewater treatment processes. Each decision result in that flow chart guides the user to methods needed to calculate emissions in Figures WW.2 through WW.4. In some cases, a community may employ a mix of strategies to meet their wastewater needs, so emissions may be calculated using more than one method. These results should be in proportion to the percentage of the population served by that process.

Flow charts for calculating electricity demand for water and wastewater management are found with methods WW.14 and WW.15 respectively.

CHART WW.1: Decision Tree for Reporting Emissions from Wastewater Treatment Technologies within your Community

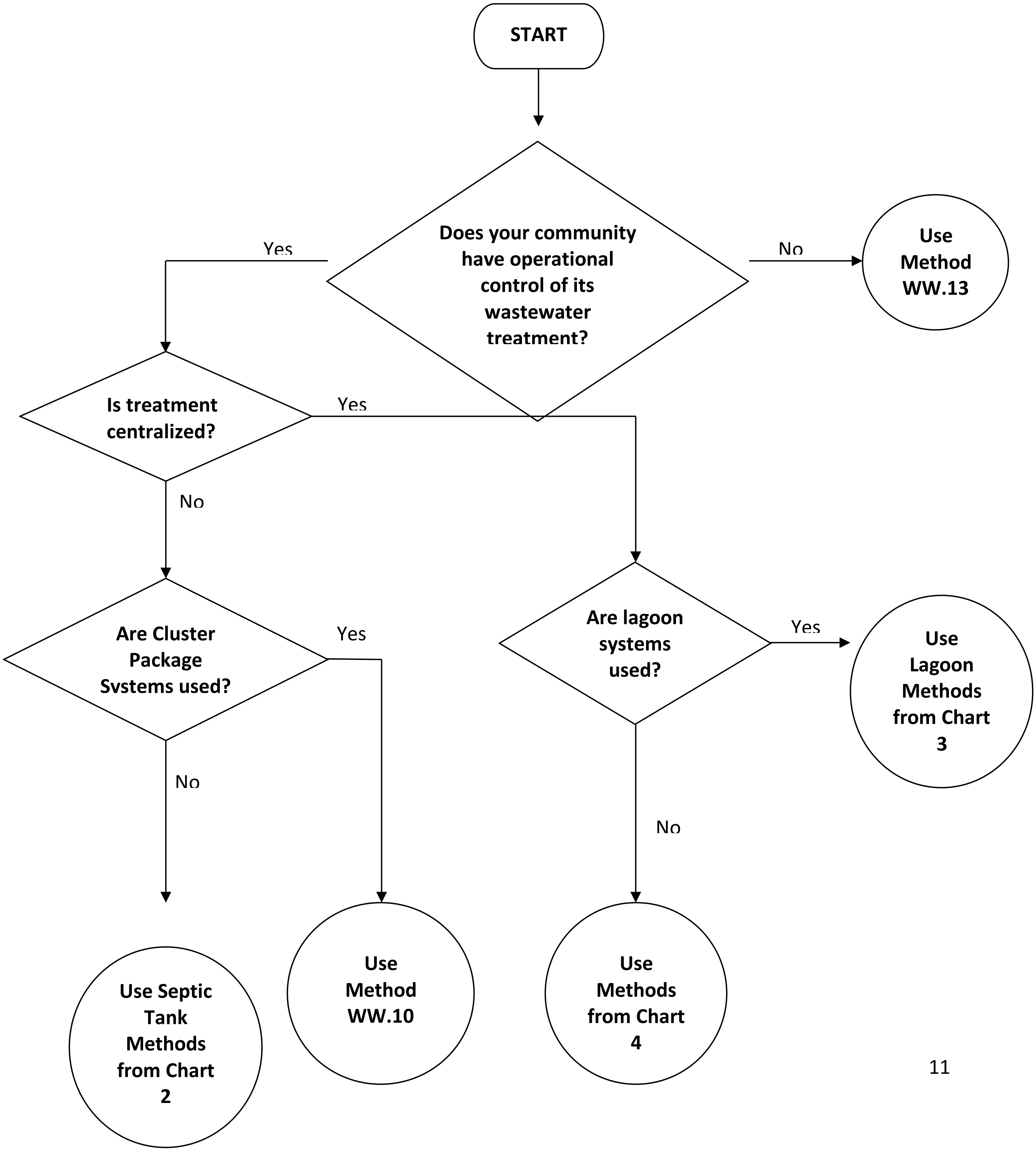

CHART WW.2: Decision Tree for Reporting Emissions from Community Septic Tanks

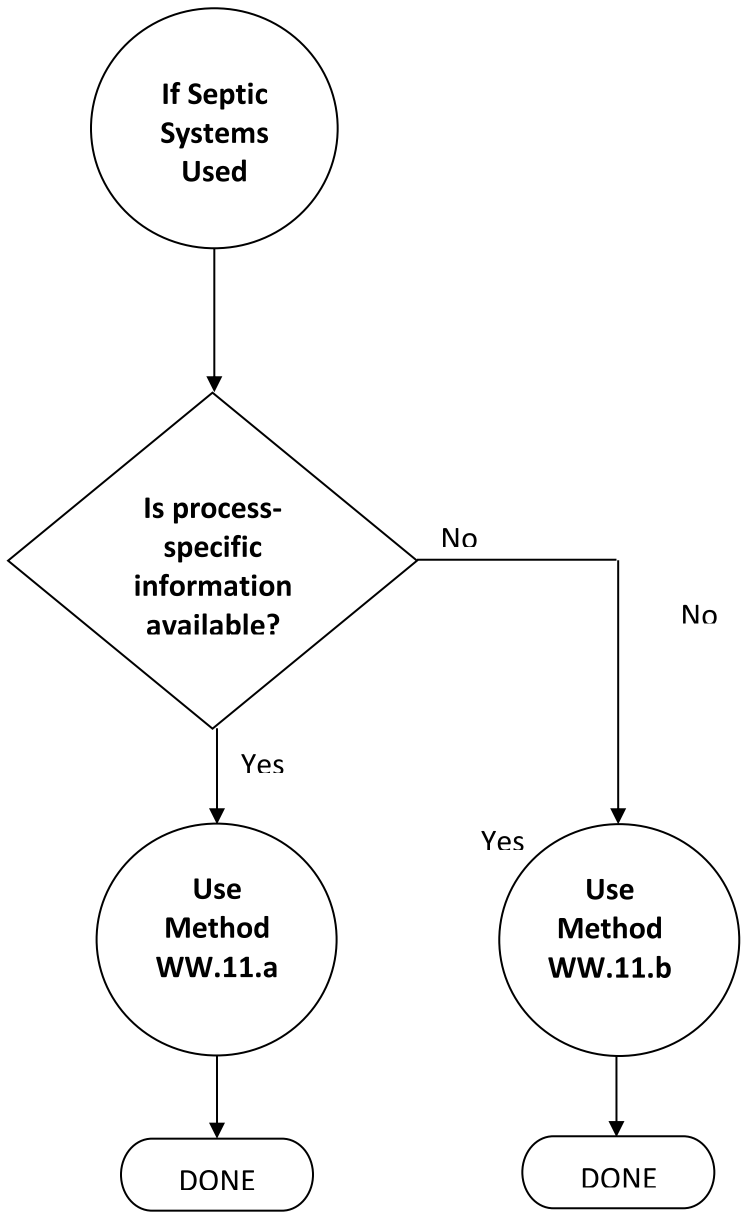

CHART WW.3: Decision Tree for Reporting Emissions from Wastewater Treatment Lagoons within your Community

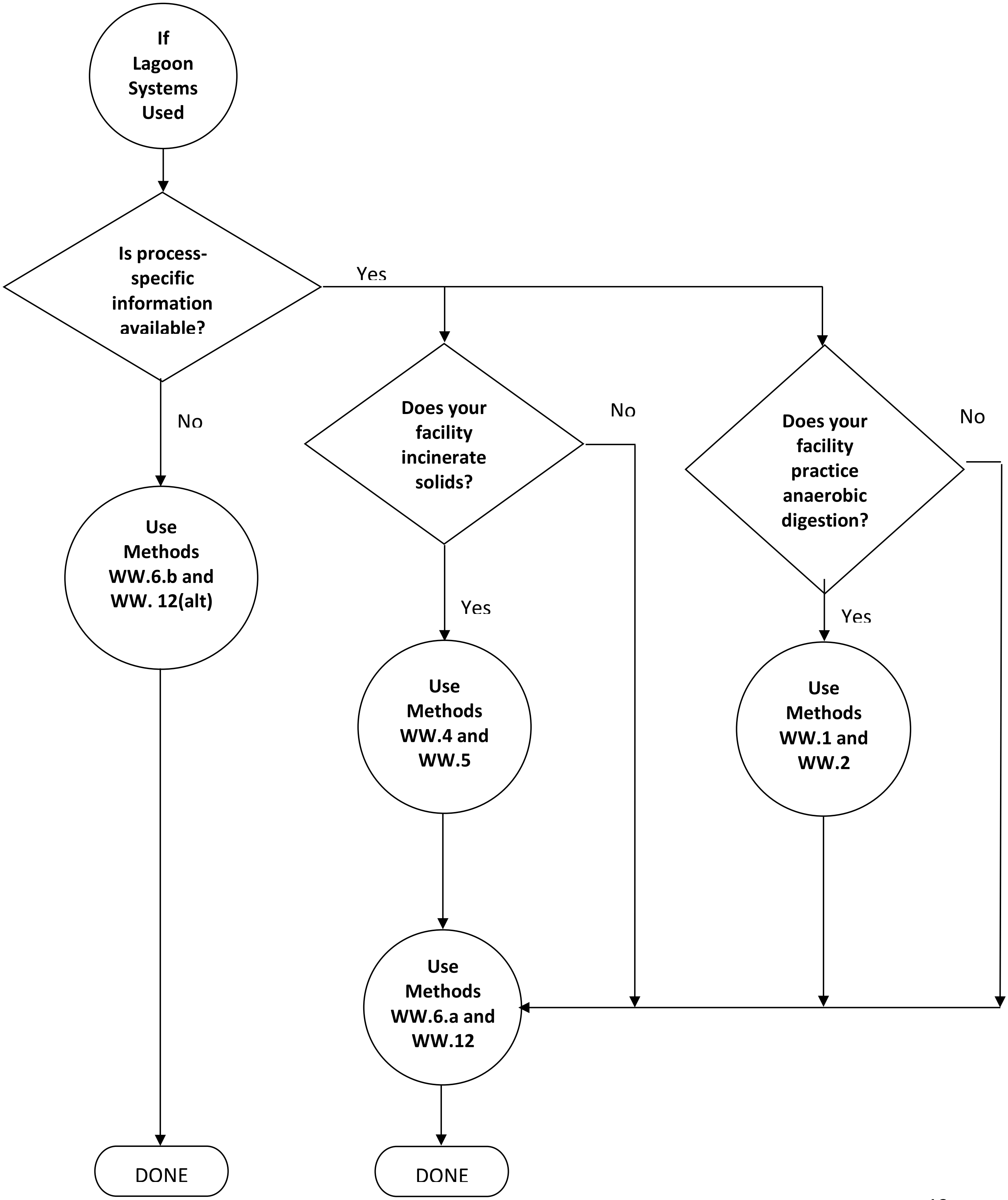

CHART WW.4: Decision Tree for Reporting Emissions from Conventional Aerobic Wastewater Treatment Systems

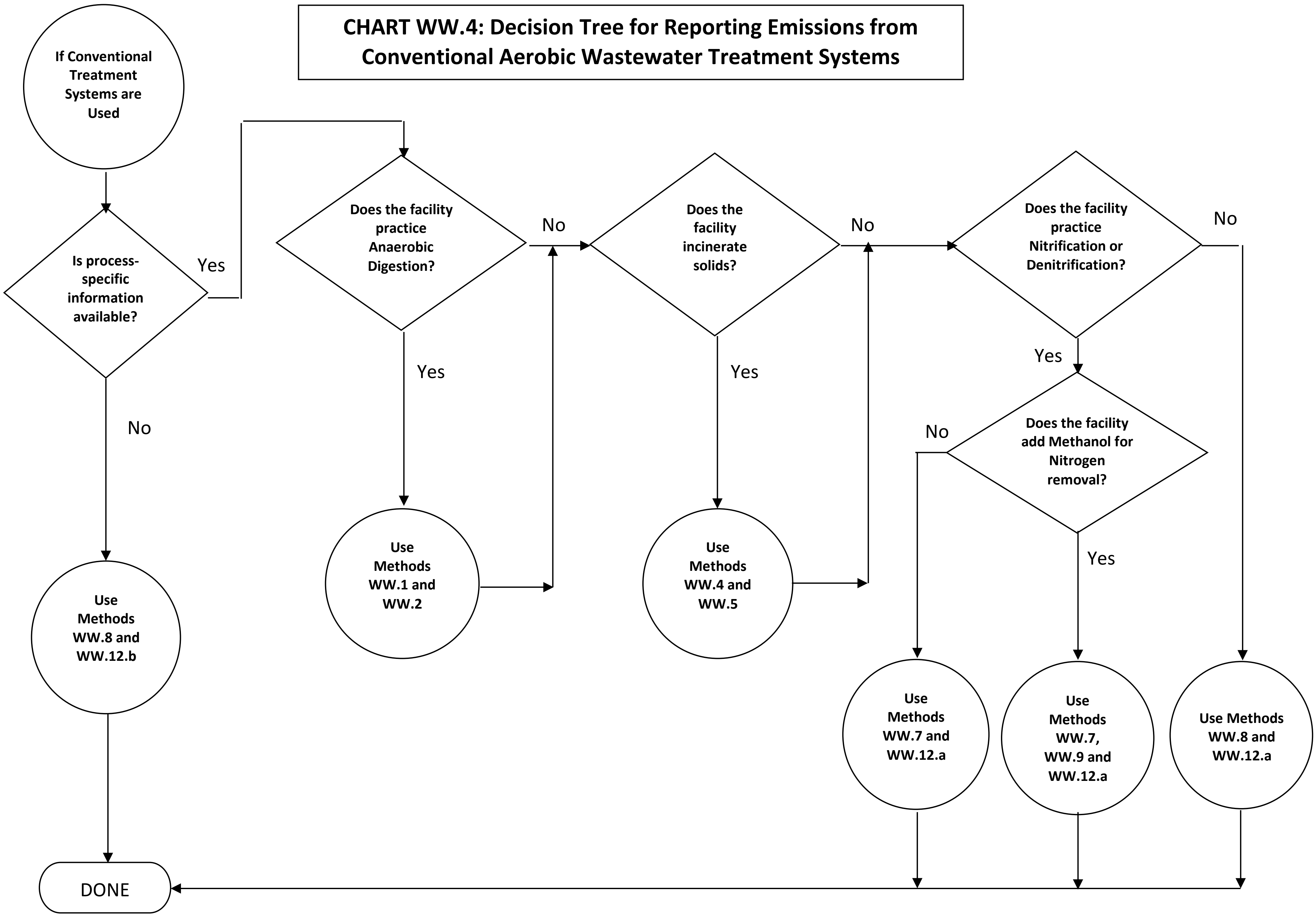

Table WW.1 Summary of Wastewater Treatment Process, Fugitive and Stationary Greenhouse Gas Emission Sources

GHG Type	GHG Source	Data Required	Available Methodologies
Stationary CH_4 emissions	Combustion of digester gas at a centralized WWTP with anaerobic digestion of biosolids – process data known	- Digester gas (ft^3/day) - Fraction of CH_4 in biogas	WW.1.a
		OR	
		- Digester gas (ft^3/day) - BTU content of biogas	WW.1.b
Stationary CH_4 emissions	Combustion of digester gas at a centralized WWTP with anaerobic digestion of biosolids – population served basis	- Population served	WW.1.(alt)
Stationary N_2O emissions	Combustion of digester gas at a centralized WWTP with anaerobic digestion of biosolids – process data known	- Digester gas (ft^3/day) - Fraction of CH_4 in biogas	WW.2.a
		OR	
		- Digester gas (ft^3/day) - BTU content of biogas	WW.2.b
Stationary N_2O emissions	Combustion of digester gas at a centralized WWTP with anaerobic digestion of biosolids – population served basis	- Population served	WW.2.(alt)
Stationary CO_2 Emissions (optional)	Combustion of digester gas at a centralized WWTP with anaerobic digestion of biosolids – process data known	- Digester gas (ft3/day) - BTU content of biogas	WW.3
Stationary CH_4 emissions	Emissions from residuals combustion	- Mass of material sent to combustion device	WW.4
Stationary N_2O emissions	Emissions from residuals combustion	- Mass of material sent to combustion device	WW.5
Process CH_4 emissions	Anaerobic or Facultative Lagoons	- Biochemical Oxygen Demand (BOD_5) load (kilograms (kg) BOD_5/day) - Fraction of overall BOD_5 removal performance	WW.6
		OR	
		- Population served	WW.6 (alt)

GHG Type	GHG Source	Data Required	Available Methodologies
Process N_2O emissions	Centralized WWTP with nitrification/denitrification or aeration basin	- Population served	WW.7
Process N_2O emissions	Centralized WWTP without nitrification/denitrification or aeration basin	- Population served	WW.8
Process CO_2 emissions	CO_2 emissions from the use of fossil-fuel-derived methanol for biological nitrogen removal in a WWTP	- Methanol load (metric tons (mt) CH_3OH/day) - Treatment type (Raw solids, anaerobic digestion, or solid combustion)	WW.9
Process N_2O emissions	Cluster Package System	- Population served	WW.10
Fugitive CH_4 emissions	Septic Systems	- BOD_5 load (kg BOD_5/day)	WW.11
		OR	
		- Population Served	WW.11(alt)
Fugitive N_2O emissions	Effluent discharge to receiving aquatic environments	- N Load (kg N/day)	WW.12
		OR	
		- Population Served	WW.12(alt)
Attributed CH_4 Emissions	Process emissions from cluster package systems	- Population of community served by given facility - Total population the facility serves - Total CH4 emissions from facility ($mtCO_2e$)	$WW.13_{CH4}$
Attributed N_2O Emissions	Attributed emissions	- Population of community served by given facility - Total population the facility serves - Total N2O emissions from facility ($mtCO_2e$)	$WW.13_{N2O}$

GHG Type	GHG Source	Data Required	Available Methodologies
CO_2, CH_4, and N_2O from use of electricity or fuels	Lifecycle Emissions Associated with Water Acquisition, Distribution and Treatment	- Energy consumption in each process in the water supply and wastewater treatment system, applicable to the community (locally derived value for energy consumer/unit water consumed) OR - National average energy consumption/unit of water - Annual volume of water passing through each process in the water supply and wastewater treatment system	WW.14
CO_2, CH_4, and N_2O from use of electricity or fuels	Lifecycle Emissions Associated with Wastewater Acquisition, Distribution and Treatment	- Energy consumption in each process in the water supply and wastewater treatment system, applicable to the community (locally derived value for energy consumer/unit water consumed) OR - National average energy consumption/unit of water - Population - Per Capita wastewater generation - Percentage of population serviced by centralized wastewater treatment systems - Percentage of population serviced by each treatment modality	WW.15

Stationary Emissions

WW.1 Stationary Methane Emissions from Combustion of Digester Gas

Introduction

This section provides equations for calculating the stationary CH_4 emissions from devices designed to combust gas produced by anaerobic digesters based on site-specific data or the population served by a centralized WWTP that uses anaerobic digesters. Each method provides a description and appropriate default values (where applicable) for each term in the following equations. As mentioned in the Introduction to this chapter, the biogenic CO_2 emissions from the combustion of digester gas are part of the short-term carbon cycle and thus are considered Scope 3 emissions, and are optional to report.

Anaerobic digesters are often operated to treat the excess sludges produced by the wastewater treatment process, producing a final product called biosolids. The anaerobic digestion of sludges and other organic wastes also produces CH_4. This CH_4 is often re-used as a carbon-neutral fuel to produce electricity or heat. Due to small inefficiencies in any combustion process, incomplete combustion of digester gas is a source of stationary CH_4 emissions. Additionally, the combustion of this fuel in air will result in the formation of not only the criteria pollutant oxides of nitrogen (NOx), but also the greenhouse gas, N_2O. Many very small plants in the US use aerobic digestion and hence there is no digester gas produced. Also, many medium to large publicly owned treatment works on the east coast use lime stabilization and don't digest at all.

Because combustion devices are sized to match the gas production potential of the digesters, these devices are typically not found in smaller centralized WWTPs, nor in septic systems or package treatment plants. For these smaller systems, solids (septic tank residuals, primary settling sludges and secondary treatment waste activated sludges) may be removed and transported to a centralized facility where they are combined with the other organics, and ultimately digested at larger facilities. Currently a standardized methodology does not exist to estimate the sludge volumes removed from small systems and treated at a remote facility. Therefore, the equations in this section should only be applied to centralized treatment facilities that support anaerobic digestion.

Some centralized facilities may use aerobic digestion instead, or may simply dewater their sludges for alternative treatment (e.g., lime stabilization, composting, incineration), bypassing anaerobic digestion altogether. These facilities would also not use these formulas because these alternatives would not produce digester gas. Although these practices generate GHG emissions, current standardized methodologies to calculate these emissions do not exist.

To calculate the stationary CH_4 emissions from devices designed to combust digester gas, please follow *Method WW.1.a* or *Method WW.1.b* if process flow information is available.

Otherwise, follow *Method WW.1.(alt)* to estimate the emissions based on population served by the centralized facility that uses anaerobic digestion.

Please note that if you are generating power or heat at your wastewater treatment facility and the electricity and/or heat are consumed entirely within the facility, you should report the combustion emissions from generating that power in Appendix F: Wastewater Emission Activities and Sources, not in Appendix C: the Built Environment Emissions Activities and Sources. If you generate power that is distributed outside your facility, report those emissions in Appendix C: the Built Environment Emissions Activities and Sources.

Although this Protocol <u>cannot</u> be used to generate reports required under the EPA or the California Air Resources Board mandatory reporting rules, facilities that are subject to those requirements can use *Method WW.1.a* OR *WW.1.b* to avoid having to prepare multiple reports with differing requirements. Facilities not subject to mandatory reporting rules that have site-specific digester gas heat or CH_4 content information are also welcome to use these methods.

Finally, site-specific source test information using methods developed or approved by regulatory agencies is often better than any of these methods.

WW.1 Data Needs

Below are the data inputs a user will need to collect in order to estimate the stationary CH_4 emitted by a digester gas combustion device:

If Process Information is Available:	Measured standard cubic feet of digester gas produced per day (std ft^3/day) (*Methods WW.1 a* &*b*)
	Fraction of CH_4 in biogas (*Method WW.1.a*) OR BTU content (*Method WW.1.b*)
If Only Population Served is Available:	Population (*Method WW.1.(alt)*)

WW.1.a Method for CH_4 Emissions from the Combustion of Anaerobic Digester Gas when fraction of CH_4 is known

WW.1.a Data Needs

- Measured standard cubic feet of digester gas produced per day (std ft^3/day)
- Fraction of CH_4 in biogas

WW.1.a Calculation Method

The method presented consists of the following three steps:

Step 1: Determine the amount of volume of digester gas produced per day. This is the total volume of digester gas produced per day by the digesters at the facility.

Step 2: Determine the fraction of CH_4 in that gas. Since not all the gas produced by the digester is CH_4, focus only on the CH_4.

Step 3: Enter above variables into *Equation WW.1.a.* Use the default values provided in the equation for kg CH_4 per million BTU combusted, GWP, and unit conversions. Enter these values along with the obtained values for volume of digester gas and fCH_4 into *Equation WW.1.a* to calculate stationary CH_4 emissions from the incomplete combustion of digester gas in $mtCO_2e$. Note: that although some facilities do not burn all the gas in a boiler, but flare some portion of it, there is currently no approved methods that distinguish between fuel burning devices. Moreover, the overall combustion inefficiency of different devices (boilers, engines, combustion turbines, conventional flares, and low-emissions/low-NOx flares) can vary widely.

Equation WW.1.a **Emissions from Devices Designed to Combust Digester Gas, with CH_4 Content Known**		
Annual CH_4 emissions = *$(\text{Digester Gas} \times fCH_4 \times BTU_{CH4} \times 10^{-6} \times EF_{CH4} \times 365.25 \times 10^{-3}) \times GWP$* Where:		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by incomplete combustion ($mtCO_2e$)	Result
Digester gas	= Standard cubic feet of digester gas produced per day (std ft^3/day)	User Input
fCH_4	= Fraction of CH_4 in gas	User Input
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028 (nation-wide average)
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{CH4}	= CH_4 emission factor (kg CH_4/MMBTU)	3.2×10^{-3} kg CH_4 per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[5]
Equation WW.1.a **Emissions from Devices Designed to Combust Digester Gas, with CH_4 Content Known**		
Source: In 40 CFR Part 98, Mandatory Reporting of Greenhouse Gases; Final Rule, Table C-2, page 79154 of the Federal Register / Vol. 75, No. 242 / Friday, December 17, 2010 / Rules and Regulations, is referenced an emission factor for digester gas combustion: 3.2×10^{-3} kg CH_4 per million BTU. See: http://edocket.access.gpo.gov/2010/pdf/2010-30286.pdf		

WW.1.b Method for CH_4 Emissions from the Combustion of Anaerobic Digester Gas when BTU content is known

WW.1.b Data Needs

- Measured standard cubic feet of digester gas produced per day (std ft^3/day)
- BTU content

WW.1.b Calculation Method

The method presented consists of the following three steps:

Step 1: Determine the volume of digester gas produced per day.

[5] See Appendix GWP for value.

Step 2: Determine the BTU content of that gas. The BTU content is de-rated from natural gas because not all the gas is CH_4 and is obtained from either on-line analyzers or routine laboratory analysis.

Step 3: Enter above variables into *Equation WW.1.b*. Use the default values for kg CH_4 per million BTU combusted, GWP, and unit conversions. Enter these values along with the obtained values for volume of digester gas and BTU into *Equation WW.1.b* to calculate stationary CH_4 emissions from devices designed to combust digester gas in $mtCO_2e$

Although CH_4 constitutes the vast majority of combustible materials in digester gas, there are many other trace hydrocarbons, which may affect the BTU content of that fuel. Therefore, if the BTU content is known, more accurate results will be obtained even if the percent CH_4 is known as well. In that case, use *Equation WW.1.b* below:

***Equation WW.1.b* Emissions from the Incomplete Combustion of Anaerobic Digester Gas with BTU Content Known**		
Annual CH_4 emissions = (Digester Gas $\times BTU_{digester\ gas} \times 10^{-6} \times EF_{CH4} \times 365.25 \times 10^{-3}) \times GWP$		
Where: Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by incomplete combustion ($mtCO_2e$)	Result
Digester gas	= Standard cubic feet of digester gas produced per day (std ft^3/day)	User Input
$BTU_{digester\ gas}$	= BTU content of digester gas, higher heating value (BTU/ft^3)	User Input
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{CH4}	= CH_4 emission factor (kg CH_4/MMBTU)	3.2×10^{-3} kg CH_4 per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[6]
Source: In 40 CFR Part 98, Mandatory Reporting of Greenhouse Gases; Final Rule, Table C-2, page 79154 of the Federal Register / Vol. 75, No. 242 / Friday, December 17, 2010 / Rules and Regulations, is referenced an emission factor for digester gas combustion: 3.2×10^{-3} kg CH_4 per million BTU. See: http://edocket.access.gpo.gov/2010/pdf/2010-30286.pdf		

[6] See Appendix GWP for value.

WW.1.(alt) Alternative Method for Methane Emissions from Devices Designed to Combust Anaerobic Digester Gas if Only the Population is Known

If site-specific data on volume of digester biogas produced and the fraction of CH_4 in the biogas or the BTU content are not available, the alternative methodology should be employed. The only data collection required by this methodology is the population served by the WWTP with anaerobic digesters.

WW.1.(alt) Data Needs

- Population served by the facility (P)

WW.1.(alt) Calculation Method

The method presented consists of the following two steps:

Step 1: Determine the population served by the facility with digesters.

Step 2: Enter above variables into *Equation WW.1.(alt).* Use the provided default values for digester gas, fCH_4 BTU_{CH4}, EF_{CH4}, GWP, and unit conversions. Enter these values into *Equation WW.1(alt)* to calculate CH_4 emissions from devices designed to combust digester gas in $mtCO_2e$.

Equation WW.1. (alt) **Emissions from Devices Designed to Combust Anaerobic Digester Gas**		
Annual CH_4 emissions = (P x Digester Gas $\times fCH_4 \times BTU_{CH4} \times 10^{-6} \times EF_{CH4} \times 365.25 \times 10^{-3}) \times GWP$		
Where:		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by devices designed to combust digester gas ($mtCO_2e$)	Result
P	= Population served by the WWTP with anaerobic digesters	User input
Digester gas	= Standard cubic feet of digester gas produced per person per day (std ft^3/person/day)	1.0
fCH_4	= Fraction of CH_4 in gas	0.65
BTU_{CH4}	= Default BTU content of CH4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{CH4}	= CH_4 emission factor (kg CH_4/MMBTU)	3.2×10^{-3} kg CH_4 per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[7]
Source: As listed in LGO Equation 10.2 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-7 (2009) and 40 CFR Part 98, Mandatory Reporting of Greenhouse Gases; Final Rule, Table C-2, page 79154 of the Federal Register / Vol. 75, No. 242 / Friday, December 17, 2010 / Rules and Regulations, is referenced an emission factor for digester gas combustion: 3.2×10^{-3} kg CH_4 per million BTU. See: http://edocket.access.gpo.gov/2010/pdf/2010-30286.pdf		

[7] See Appendix GWP for value.

WW.2 Stationary Nitrous Oxide Emissions from Combustion of Digester Gas

Introduction

N_2O is not generated in significant amounts in anaerobic digesters. However, other nitrogen containing compounds in the gas or nitrogen in the combustion air may be converted in small amounts to N_2O during combustion. Please note that N_2O is NOT considered the same as NOx, which is a criteria pollutant[8], so a facility should not use NOx information to estimate their N_2O emissions.

For N_2O emissions from the combustion of digester gas, use **the same formulas** as for CH_4 (either *WW.1.a*, *WW.1.b*, or *WW.1.(alt)*)**except**:

- Replace the CH_4 emission factor**,** EF_{CH4} (3.2 X 10^{-3} kg CH_4 per MMBTU) with the N_2O emission factor, EF_{N2O} (6.3 X 10^{-4} kg N_2O per MMBTU)
  AND
- Replace the CH_4 GWP (21) with the N_2O GWP (310).

Examples are provided below.

Please note that if you are generating power or heat at your wastewater treatment facility and the electricity and/or heat are consumed entirely within the facility, you should report the combustion emissions from generating that power in Appendix F: Wastewater and Water Emission Activities and Sources, not in Appendix C: the Built Environment Emissions Activities and Sources. If you generate power that is distributed outside your facility, report those emissions in Appendix C: the Built Environment Emissions Activities and Sources.

Although this Protocol cannot be used to generate reports required under the EPA or the California Air Resources Board mandatory reporting rules, facilities that are subject to those requirements can use *Method WW.2.a* OR *WW.2.b* for consistency's sake. Facilities not subject to mandatory reporting rules that have site-specific gas heat or CH_4 content information are also welcome to use these methods.

Finally, site-specific source test information using methods developed or approved by regulatory agencies is often better than any of these methods.

WW.2.a Method for N_2O Emissions from the Combustion of Anaerobic Digester Gas when fraction of CH_4 is known

Box WW.2.a below gives an example of how to calculate the N_2O emissions from the combustion of digester gas using the methodology consistent with the EPA and California Air

[8] The South Coast Air Quality Management District in their Rule 1110.2 defines NOx as "*OXIDES OF NITROGEN (NOx) means nitric oxide and nitrogen dioxide.*" See: http://www.aqmd.gov/rules/reg/reg11/r1110-2.pdf, §(c)(13).

Resources Board mandatory reporting rules if the fraction of CH_4 in the digester gas is known, using *Method WW1.a*.

Box WW.2.a	**Example Calculation of N_2O Emissions from the Combustion of Anaerobic Digester Gas when fraction of CH_4 is known**	
A wastewater facility generates 1,000,000 ft^3 per day of digester gas containing 65% CH_4. The BTU content of the digester gas is not available. Based on this scenario the N_2O emissions from the combustion of digester biogas can be calculated as follows		
Description		Value
N_2O emissions	= Total N_2O emitted by combustion ($mtCO_2e$)	Result
Digester gas	= Measured standard cubic feet of digester gas produced per day (std ft^3/ day)	1,000,000
fCH_4	= Fraction of CH_4 in biogas	0.65
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{N2O}	= N_2O emission factor (kg N_2O/MMBTU)	6.3 X 10^{-4} kg N_2O per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[9]
Sample Calculation:		
Annual N_2O *emissions* = $(1{,}000{,}000 \times 0.65 \times 1028 \times 10^{-6} \times (6.3 \times 10^{-4}) \times 365.25 \times 10^{-3}) \times 310$ = 47.7 $mtCO_2e$		

[9] See Appendix GWP for value.

WW.2.b Method for N_2O Emissions from the Combustion of Anaerobic Digester Gas when BTU content is known

Box WW.2.b below gives an example of how to calculate the N_2O emissions from the combustion of digester gas using the methodology consistent with the EPA and California Air Resources Board mandatory reporting rules if the BTU content is known, using *Method WW.1.b*.

Box WW.2.b	**Example Calculation of** N_2O **Emissions from the Combustion of Anaerobic Digester Gas when BTU content is known**	
A wastewater facility generates 1,000,000 ft^3 per day of digester gas containing 60% CH_4 and has a BTU content of 622 BTU/ft^3. Based on this scenario the N_2O emissions from the combustion of digester biogas can be calculated as follows using *Equation WW.2.b*		
Description		Value
N_2O emissions	= Total N_2O emitted by combustion ($mtCO_2e$)	Result
Digester gas	= Measured standard cubic feet of digester gas produced per day (std ft^3/ day)	1,000,000
$BTU_{digester\ gas}$	= BTU content of digester gas, higher heating value (BTU/ft^3)	622
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{N2O}	= N_2O emission factor (kg N_2O/MMBTU)	6.3×10^{-4} kg N_2O per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
Description		Value
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[10]

Sample Calculation:

Annual N_2O *emissions* $= (1{,}000{,}000 \times 622 \times 10^{-6} \times (6.3 \times 10^{-4}) \times 365.25 \times 10^{-3}) \times 310$

$= 44.4\ mtCO_2e$

[10] See Appendix GWP for value.

WW.2.(alt) Method for N_2O Emissions from Combustion when only Population Served by System is Known

Box WW.2.(alt) below gives an example of how to calculate the N_2O emission from the incomplete combustion of digester gas when the only data obtainable is population served by the facility supporting digestion, using *Method WW.1.(alt)*.

Box WW.2.(alt)	**Example Calculation of N_2OEmissions from Combustion when only Population Served by System is Known**	
A centralized wastewater facility serves a city with a population of 100,000 people. No other data is available. Based on this scenario the N_2O emissions from the combustion of digester biogas can be calculated as follows		
Description		Value
N_2O emissions	= Total N_2O emitted by combustion ($mtCO_2e$)	Result
P	= Population served by anaerobic digester	100,000
Digester gas	= Measured standard cubic feet of digester gas produced per person per day (std ft^3/person/day)	1.0
fCH_4	= Fraction of CH_4 in biogas	0.65
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{N2O}	= N_2O emission factor (kg N_2O/MMBTU)	6.3 X 10^{-4} kg N_2O per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[11]
Sample Calculation: *Annual* N_2O *emissions* = $(100,000 \times 1 \times 0.65 \times 1028 \times 10^{-6} \times (6.3 \times 10^{-4}) \times 365.25 \times 10^{-3}) \times 310$ = $4.8\ mtCO_2e$		

[11] See Appendix GWP for value.

WW.3 Stationary CO_2 Emissions from Digester Gas Combustion

Introduction

This section provides equations for calculating biogenic CO_2 emissions from the combustion of carbon-neutral gas produced by anaerobic digesters. The method provides a description and appropriate default values (where applicable) for each term in the following equation. As explained in the Introduction to this chapter, CO_2 emissions from this source are part of the short-term carbon cycle and thus are considered Scope 3 emissions from renewable fuels meant to displace fossil-fuel use. The methodology presented below is an optional method to track biogenic CO_2.

> Please note that if you are generating power or heat at your wastewater treatment facility and the electricity and/or heat are consumed entirely within the facility, you should report the combustion emissions from generating that power in Appendix F: Wastewater and Water Emission Activities and Sources, not in Appendix C: the Built Environment Emissions Activities and Sources. If you generate power that is distributed outside your facility, report those emissions in Appendix C: the Built Environment Emissions Activities and Sources.

WW.3 Data Needs

- Cubic feet of digester gas produced per day (digester gas), standard cubic feet/day
- BTU content of digester (BTU_{CO2}), MMBtu/scf (default available if there is no site-specific data)

WW.3 Method Calculation

The method presented consists of the following three steps:

Step 1: Determine the amount of volume of digester gas produced per day.

Step 2: Determine the BTU content of the digester gas in MMBTU/scf. If no data is available on the BTU content of the gas then the default value of 0.00084 MMBTU/scf can be used. Please note this value is MUCH higher than the typical BTU content of digester gas. Using this default value will significantly elevate the emissions estimate.

Step 3: Enter above variables into *Equation WW.3* below. Use the default values for the emissions factor and the conversion factors provided to determine the annual CO_2 emissions from digester gas combustion.

Equation WW.3 **CO_2 Emissions from Digester gas Combustion**		
*Annual CO_2 emissions = Digester gas * BTU_{CO2} *EF_{CO2} * 365.25 *10^{-3}*		
Where:		
Description		Value
CO_2 emissions	= Total annual biogenic CO_2 emitted by combustion of biogas ($mtCO_2e$)	Result
Digester gas	= Standard cubic feet of digester gas produced per day (std ft^3/day)	User input
BTU_{CO2}	= BTU content of biogas (MMBTU/scf)	User input or 0.000841
EF_{CO2}	= Emission factor for CO_2 (kg CO_2/ MMBTU)	52.07
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion factor kg to mt	10^{-3}
Source: Table G.2 of the Local Government Operations Protocol version 1.1 May, 2010		

WW.4 Stationary Methane Emissions from Combustion of Biosolids and Sludges

Introduction

This section provides equations for calculating the stationary CH_4 emissions from the combustion of biosolids and sludges produced by treatment plant processes based on site-specific data. There is no alternative method based solely on population. The method provides a description and appropriate default values (where applicable) for each term in the following equation.

The CO_2 emissions from this combustion of biosolids and sludges are part of the short-term carbon cycle. The methodologies for the CO_2 emissions from combustion of biosolids and sludges are contained in the Power Generation chapter of this Protocol, and should be used when these fuels are used to generate power for export. When these fuels are burned to meet internal facility power needs or for purposes other than exporting power, the methods in this section should be used.

Sludges generated by processes within the treatment plant are concentrated and collected in settling basins. Solids from primary sedimentation tanks derive from the settled organic material collected by those tanks. Similarly, secondary treatment sludges derive from the settled biomass generated in the biological treatment step and settled out in the secondary clarifiers. Advanced wastewater treatment methods may generate organic sludges as well.

Anaerobic digesters are often operated to stabilize the sludges produced by the wastewater treatment process, producing a final product called biosolids. The anaerobic digestion of sludges and other organic wastes produces biogas-containing CH_4. Although significant amounts of CH_4 are produced, the biosolids leaving the digester will contain organics that may be combusted. The organics in raw (un-digested) sludges may also be combusted. Dewatering of these residuals is required before any combustion can occur.

Because combustion devices are sized to match the solids production potential of the treatment plant, these devices are typically not found in smaller centralized WWTPs, or in septic systems or package treatment plants. For these smaller systems, solids (primary settling sludges and secondary treatment waste activated sludges) are occasionally removed and transported to a centralized facility. Combined with the other organics, the sludges are ultimately digested at those larger facilities. Currently a standardized methodology to estimate the sludge volumes removed from small systems and treated at a remote facility does not exist. Therefore, the equations in this section should only be applied to centralized treatment facilities that support solids treatment.

To calculate the stationary CH_4 emissions from the combustion of treatment plant residuals please follow *Method WW.4 Stationary Methane Emissions from Combustion of Sludges and Biosolids* if process information is available. If no process information is available, it is not possible to calculate emissions from this source. Also, this factor is based on a wet weight basis.

If the dry weight is reported and the percent by weight of water is known after the dewatering step, the user should back-calculate the wet weight and then perform the calculations.

Larger municipalities often employ a portfolio of methods to affect final disposal of their WWTP residuals. Incineration may be one of several options used by a municipality to diversify their options. Therefore, it is not always the case that 100% of the residuals will be incinerated. The user of this protocol should verify that the mass of material entered into the equation accurately reflects the mass incinerated and not blindly assume all the facility's residuals are processed that way.

Please note that if you are generating power or heat at your wastewater treatment facility and the electricity and/or heat are consumed entirely within the facility, you should report the combustion emissions from generating that power in Appendix F: Wastewater Emission Activities and Sources, not in Appendix C: the Built Environment Emissions Activities and Sources. If you generate power that is distributed outside your facility, report those emissions in Appendix C: the Built Environment Emissions Activities and Sources.

Finally, site-specific source test information using methods developed or approved by regulatory agencies is often better than any of these methods.

WW.4 Data Needs

- Measured mass of biosolids or sludges sent to incineration, wet weight (mt/day)

WW.4 Calculation Based on the Wet Weight of Material Combusted

The method presented consists of the following two steps:

Step 1: Determine the mass of residuals combusted per day. This is the total mass in kg of the wet weight of sludges or biosolids combusted.

Step 2: Enter above variables into *Equation WW.4*. Use the default emission factor for grams CH_4 per mt wet weight material combusted, GWP, and unit conversions. Enter these values into *Equation WW.4* to calculate stationary CH_4 emissions from the incomplete combustion of digester gas in $mtCO_2e$.

Equation WW.4 **CH_4 Emissions from the Combustion of Wastewater Treatment Plant Residuals on a Wet Weight Basis**		
Annual CH_4 emissions = (Wet Weight $\times EF_{CH4} \times 365.25 \times 10^{-6}) \times GWP$		
Where:		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by incomplete combustion ($mtCO_2e$)	Result
Wet Weight	= Wet weight of sludges or biosolids incinerated (mt/day)	User Input
EF_{CH4}	= CH_4 emission factor (g CH_4/mt)	9.7 g CH_4 per mt
365.25	= Conversion factor (day/year)	365.25
10^{-6}	= Conversion from g to mt	10^{-6}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[12]
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 5: Incineration and Open Burning of Waste, Section 5.4.2, page 5.20. See: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf		

[12] See Appendix GWP for value.

WW.5 Stationary Nitrous Oxide Emissions from Combustion of Biosolids and Sludges

Introduction

This section provides equations for calculating the stationary N_2O emissions from the combustion of biosolids and sludges produced by treatment plant processes based on site-specific data. There is no alternative method based solely on population. The method provides a description and appropriate default values (where applicable) for each term in the following equation.

As mentioned before, the CO_2 emissions from this source are part of the short-term carbon cycle. The methodologies to calculate these emissions are contained in the Power Generation chapter of this Protocol, and should be used when these fuels are used to generate power for export. When these fuels are burned to meet internal facility power needs or for purposes other than exporting power, the methods in this section should be used.

To calculate the stationary N_2O emissions from the combustion of treatment plant residuals please follow *Method WW.5 Stationary Nitrous Oxide Emissions from Combustion of Biosolids and Sludges* if process information is available. If no process information is available, it is not possible to calculate emissions from this source. Also, this factor is based on a wet weight basis. If the dry weight is reported and the percent by weight of water is known after the dewatering step, the user should back-calculate the wet weight and then perform the calculations.

Larger municipalities often employ a portfolio of methods to affect final disposal of their WWTP residuals. Incineration may be one of several options used by a municipality to diversify their options. Therefore, it is not always the case that 100% of the residuals will be incinerated. The user of this protocol should verify that the mass of material entered into the equation accurately reflects the mass incinerated and not just blindly assume all the facility's residuals are processed that way.

Please note that if you are generating power or heat at your wastewater treatment facility and the electricity and/or heat are consumed entirely within the facility, you should report the combustion emissions from generating that power in Appendix F: Wastewater Emission Activities and Sources, not in Appendix C: the Built Environment Emissions Activities and Sources. If you generate power that is distributed outside your facility, report those emissions in Appendix C: the Built Environment Emissions Activities and Sources.

Finally, site-specific source test information using methods developed or approved by regulatory agencies is often better than any of these methods. Please note that N_2O is NOT considered the same as NOx, which is a criteria pollutant[13], so a facility should <u>not</u> use NOx information to estimate their N_2O emissions.

WW.5 Data Needs

- Measured mass of biosolids or sludges sent to incineration, wet weight (mt/day.)

WW.5 Calculation Based on the Wet Weight of Material Combusted

The method presented consists of the following two steps:

Step 1: Determine the mass of residuals combusted per day. This is the total mass in kg of the wet weight of sludges or biosolids combusted.

Step 2: Enter above variables into *Equation WW.5*. Use the default emission factor for g N_2O per mt wet weight material combusted, GWP, and unit conversions. Enter these values into *Equation WW.5* to calculate stationary N_2O emissions from the combustion of treatment plant residuals in $mtCO_2e$.

Equation WW.5 N_2OEmissions from the Combustion of Wastewater Treatment Plant Residuals on a Wet Weight Basis

$$\text{Annual } N_2O \text{ emissions} = (\text{Wet Weight} \times EF_{N2O} \times 365.25 \times 10^{-6}) \times GWP$$

Where:

Description			Value
Annual N_2O emissions	=	Total annual N_2O emitted by residuals combustion ($mtCO_2e$)	Result
Wet Weight	=	Wet weight of sludges or biosolids incinerated (mt/day)	User Input
EF_{N2O}	=	N_2O emission factor (g N_2O /mt)	900 g N_2O per mt
365.25	=	Conversion factor (day/year)	365.25
10^{-6}	=	Conversion from g to mt	10^{-6}
GWP_{N_2O}	=	Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[14]

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 5: Incineration and Open Burning of Waste, Section 5.4.3, page 5.21 and 5.22. See: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf

[13] The South Coast Air Quality Management District in their Rule 1110.2 defines NOx as "*OXIDES OF NITROGEN (NOx) means nitric oxide and nitrogen dioxide.*" See: http://www.aqmd.gov/rules/reg/reg11/r1110-2.pdf, §(c)(13).

[14] See Appendix GWP for value.

Process Emissions[15]

WW.6 Process Methane Emissions from Wastewater Treatment Lagoons

Introduction

This section provides equations for calculating the process CH_4 emissions from lagoons based on site-specific data of the BOD_5 load. The method provides a description and an appropriate default value (where applicable) for each term in the following equations. This methodology is adapted from the LGO protocol and the EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2010)*.

Lagoons treat wastewater through a combination of biological, physical and chemical processes. Most of the treatment occurs naturally but some systems include aeration devices to increase the amount of oxygen in the water, thereby making the treatment more efficient. Both aerobic and anaerobic fermentation can occur in a lagoon environment. It is only during the anaerobic phase of this process that CH_4 is produced.

To calculate the fugitive CH_4 emissions associated with lagoons please follow *Method WW.6.* This is the recommended method. If the data for WW.6 is unavailable, follow the alternate *Method WW.6 (alt)* to estimate the emissions based on population served by the lagoon.

Regardless of the methodology used to determine CH_4 emissions, the user should also calculate N_2O emissions from any nitrogen discharged from the lagoon into the receiving waters using *Method WW.12*.a or *WW.12.b.*

WW.6 Data Needs

Below are the data inputs needed to collect in order to estimate the process CH_4 emitted by a community's wastewater treatment lagoons:

If Process Information is Available:	BOD_5 load (the amount of BOD_5 treated per day) AND Fraction of BOD_5 removed in primary treatment (FP), if applicable (*Method WW.6*)
If Only Population Served is Available:	Population (*Method WW.6.(alt)*)

[15] Note that this classification differs from the Clean Air Act, which considers emissions from these types of sources to be fugitive. According to 40 CFR Ch. I, section 70.2, fugitive emissions are defined as those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

WW.6 Calculation if BOD_5 Load and Fraction of BOD_5 Removed in Primary Treatment (if applicable) are Known

WW.6 Data Needs

- BOD_5 load (the amount of BOD_5 treated per day)
- Fraction of BOD_5 removed in primary treatment (FP), if applicable

WW.6 Calculation Method

The method presented consists of the following three steps:

Step 1: Determine the amount of BOD_5 treated per day. BOD_5 is the amount of dissolved oxygen consumed in five days of biological decomposition. Users should be able to obtain this value (in kg/day) from the agency that oversees the lagoon.

Step 2: Determine the fraction of BOD_5 removed in primary treatment. Lagoons may have a primary treatment process, which removes some of the biologically dissolved oxygen. In order to get an accurate emission estimation, users must determine the BOD_5 load sent to the lagoon by determining the fraction of BOD_5 removed in primary treatment (FP). If there is no primary treatment, FP is zero.

Step 3: Enter above variables into *Equation WW.6* Use the default values for B_o and MCF_a, GWP, and unit conversions. Enter these values into *Equation WW.6* to calculate CH_4 emissions from a community's lagoon(s) in $mtCO_2e$

Equation WW.6 **Methane Emissions from Lagoons**		
Annual CH_4 emissions = (BOD_5 load $\times$ (1-FP) $\times$ Bo x $MCF_a \times$ 365.25 $\times 10^{-3}$) $\times$ GWP		
Where:		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by lagoon ($mtCO_2e$)	Result
BOD_5 load	= Amount of BOD_5 treated per day ($kgBOD_5$/day)	User input
FP	= Fraction of BOD_5 removed in primary treatment	User input
Bo	= Maximum CH_4 producing capacity for domestic wastewater (kg CH_4/kg BOD_5 removed)	0.6
MCF_a	= CH_4 correction factor for anaerobic systems	0.8
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[16]
Source: As listed in LGO protocol Equation 10.3 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-7 (2009)		

[16] See Appendix GWP for value.

WW.6 Alternate Method for Methane Emissions from Lagoons if Only the Population is Known

If site-specific data on average BOD_5 load and fraction of BOD_5 removal during primary treatment are not available, the alternative methodology WW.6.b should be employed. The only data required for this methodology is the population served by the lagoon. The methodology also includes a factor for wastewater discharge from industrial or commercial sources – $F_{ind\text{-}com}$. This factor should only be used if the commerce or industries in a user's community are "significant industrial users," according to the EPA's National Pretreatment program.[17] A "significant" industrial user" includes:

1. All users subject to categorical pretreatment standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N, except those designated as 'non-significant categorical industrial users' (see Box. 1 on page 8 for non-significant definition); and
2. Any other industrial user that discharges an average of 25,000 gallons per day (gpd) or more of process wastewater (excluding sanitary, noncontact cooling, and boiler blowdown wastewater).

If a facility does not have significant industrial or commercial wastewater inputs, set the $F_{ind\text{-}com}$ term to 1 in these equations.

WW.6 (alt) Data Needs

- Population served by the lagoon (P)

WW.6 (alt) Calculation Method

The method presented consists of the following two steps:

Step 1: Determine the population served by the lagoon. Lagoon CH_4 emissions can be estimated based upon the size of the population that is served by the lagoon.

Step 2*:* Enter above variables into *Equation WW.6.b*. Use the provided default values for $F_{ind\text{-}com}$, BOD_5 FP, Bo MCF_a,GWP, and unit conversion factors. Enter these values into *Equation WW.6.b* to calculate CH_4 emissions from a community's lagoon(s) in $mtCO_2e$. If the lagoon does not treat wastewater from significant industrial or commercial sources, use 1 for $F_{ind\text{-}com}$.

[17] US EPA Introduction to the National Pretreatment Program. June 2011

***Equation WW.6.(alt)* Alternate Methane Emissions from Lagoons**			
Annual CH_4 emissions = $((P \times F_{ind\text{-}com}) \times BOD_5\ load \times (1\text{-}FP) \times Bo \times MCF_a \times 365.25 \times 10^{-3}) \times GWP$ Where:			
Description			Value
Annual CH_4 emissions	=	Total annual CH_4 emitted by lagoon ($mtCO_2e$)	Result
P	=	Population served by lagoon	User Input
$F_{ind\text{-}com}$	=	Factor for significant industrial and commercial co-discharge waste (see definition above)	1.25
Description			Value
BOD_5 load	=	Amount of BOD_5 treated per day (kg BOD_5/person/day)	0.090
F_P	=	Fraction of BOD_5 removed in primary treatment	0.325
Bo	=	Maximum CH_4 producing capacity for domestic wastewater (kg CH_4/kg BOD_5)	0.6
MCF_a	=	CH_4 correction factor for anaerobic systems	0.8
365.25	=	Conversion factor (day/year)	365.25
10^{-3}	=	Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	=	Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[18]
Source: *As listed in LGO protocol Equation 10.4 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-7 (2009); except F_p: Tchobanoglous, G., F.L. Burton, and H.D. Stensel, Wastewater Engineering: Treatment and Reuse, p. 396, 4th Edition (2003).*			

[18] See Appendix GWP for value.

WW.7 Process Nitrous Oxide Emissions from Wastewater Treatment Plants with Nitrification or Denitrification

Introduction

This section provides equations for calculating the process N_2O emissions from WWTPs based on the population served by the WWTPs. Use *Method WW.7* for centralized WWTPs that utilize nitrification or denitrification or decentralized systems that utilize aeration basins with nitrification or denitrification. This includes WWTPs or aeration basins that support transient (such as in the summer) or complete nitrification or denitrification. The method provides a description and an appropriate default value (where applicable) for each term in the following equation. If the WWTP (or aeration basin) does not support any nitrification or denitrification then follow *Method WW.8Process Emissions from All other Wastewater Treatment Plants*. If a user is uncertain whether or not a treatment plant employing nitrification or denitrification serves the user's community, the user should assume that it does not. In this case, skip this section and proceed to section *WW.8 Process Emissions from all other Wastewater Treatment Plants*.[19]

The $F_{ind\text{-}com}$ term accounts for industrial and commercial discharges into the WWTP in *Equations WW.7* and *WW.8*. This factor should only be used if the commerce or industries are considered 'significant industrial' users. According to the EPA's National Pretreatment program[20] a 'significant user' includes (1) all users subject to categorical pretreatment standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N, except those designated as 'non-significant categorical industrial users' (see Box.1 on page 8); and (2) any other industrial user that discharges an average of 25,000 gpd or more of process wastewater (excluding sanitary, noncontact cooling, and boiler blowdown wastewater). If the facility does not have wastewater inputs from significant industrial or commercial sources, then set the $F_{ind\text{-}com}$ term to 1 in these equations.

WW.7 Data Needs

- Population served by the WWTP (P)

[19] The vast majority of WWTP in the United States do not employ NDN. According to the U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2009, page 8-14, only 2.4 million people are served by nitrification/denitrification. See: http://www.epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Chapter-8-Waste.pdf

[20] US EPA Introduction to the National Pretreatment Program. June 2011

WW.7 Calculation Method
The method presented consists of the following three steps:

Step 1: Determine the population served by the WWTP (or aeration basin).
Step 2: Determine if significant amounts of industrial wastewater are discharged to the community's municipal treatment system (see definition of 'significant' above). If the community has wastewater from significant users then set the $F_{ind\text{-}com}$ term to 1.25.If the facility does not have significant levels of industrial or commercial nitrogen wastewater inputs then set the $F_{ind\text{-}com}$ term to 1.
Step 3*:* Enter above variables into *Equation WW.7.* Use the provided default values for $F_{ind\text{-}com}$, EF, GWP, and unit conversions to calculate N_2O emissions.

Equation WW.7 **N_2O Process Emission from Wastewater Treatment Plants (or aeration basin) that Uses Nitrification or Denitrification**		
Annual N_2O emissions = $((P \times F_{ind\text{-}com}) \times EF \times 10^{-6}) \times GWP$		
Where: Description		Value
Annual N_2O emissions	= Total annual N_2O emitted by WWTP processes ($mtCO_2e$)	Result
P	= Population served by the WWTP	User input
$F_{ind\text{-}com}$	= Factor for high nitrogen loading of industrial or commercial discharge	1.25
$F_{ind\text{-}com}$	= Factor for insignificant industrial or commercial discharge	1
EFnit/denit	= Emission factor for a WWTP with nitrification or denitrification (g N_2O/ person / year)	7
10^{-6}	= Conversion from g to mt (mt/g)	10^{-6}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[21]
Source: *As listed in LGO protocol Equation 10.7 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1890-2007, Chapter 8, 8-13 (2009)*		

[21] See Appendix GWP for value.

WW.8 Process Nitrous Oxide Emissions from Wastewater Treatment Plants without Nitrification or Denitrification

Introduction

This section provides equations for calculating the process N_2O emissions from all other WWTPs that do not support transient or complete nitrification or denitrification based on the population served by the WWTP. *Method WW.8* can be used to approximate the emissions from non-nitrifying or denitrifying systems, and similar cluster package systems, which mimic, on a smaller scale, non-nitrifying centralized WWTP. The approach in this section is the default condition if a user is uncertain if a plant supporting nitrification or denitrification serves the user's community.

Uncertainties in Calculations and Emerging Information:

A recent survey investigating N_2O emissions from select WWTPs supported by the Water Environment Research Foundation suggests that WWTPs not designed for nitrification but nitrified transiently could be potentially higher emitters of N_2O than WWTPs designed and operated to nitrify and denitrify[22]. These preliminary findings are in contrast to the relative magnitudes of the two emission factors used in the above section.

Additionally, a high degree of spatial and temporal variability in N_2O emissions has been consistently documented[23], which cannot be captured by single emission factors as used in the calculations above. This variability implies that the greatest accuracy will not be achieved with these formulas, but with either sophisticated computer models under development or through comprehensive on-site source testing.

WW.8 Data Needs

Below are the data inputs needed to collect in order to estimate the N_2O process emissions produced by a WWTP (or cluster package system) that does not use nitrification or denitrification:

- Population served by the WWTP (P)

WW.8 Calculation Method

The method presented consists of the following three steps:

Step 1: Determine the population size served by the WWTP (or aeration basin).

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[22] Ahn, J. H., Kim, S., Park, H., Rahm, B., Pagilla, K., Chandran, K. N_2O Emissions from Activated Sludge Processes, 2008-2009: Results of a National Monitoring Survey in the United States. *Environ. Sci. Technol.* 2010;44(12): 4505-4511. This study was derived from research that has yet to be finalized and thus has not been vetted.

[23] Ahn, J.-H., Kim, S., Pagilla, K., Katehis, D., Chandran, K. Spatial and temporal variability in N_2O generation and emission from full-scale BNR and non-BNR processes. *Wat. Environ. Res.* 2010;82(12): 2362-2372.

Step 2: Determine whether the user's facility has significant industrial or commercial wastewater inputs. According to the EPA's National Pretreatment program[24] a 'significant industrial user' includes (1) all users subject to categorical pretreatment standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N, except those designated as 'non-significant categorical industrial users' (see Box. 1 on page 8); and (2) any other industrial user that discharges an average of 25,000 gpd or more of process wastewater (excluding sanitary, noncontact cooling, and boiler blowdown wastewater). If the user's community does have significant industrial users then set the $F_{ind\text{-}com}$ term to 1.25. If the user's community does not have significant inputs, then set the $F_{ind\text{-}com}$ term to 1.

Step 3: Enter above variables into *Equation WW.8*. Use the provided default values for $F_{ind\text{-}com}$, EF, GWP and unit conversions to calculate N_2O emissions.

Equation WW.8 **N_2O Process Emissions from Wastewater Treatment Plants (or aeration basin) without nitrification or denitrification**

Annual N_2O emissions = $((P \times F_{ind\text{-}com}) \times EF \times 10^{-6}) \times GWP$

Where:

Description		Value
Annual N_2O emissions	= Total annual N_2O emitted by WWTP processes ($mtCO_2e$)	Result
P	= Population served by the WWTP	User input
$F_{ind\text{-}com}$	= Factor for high nitrogen loading of industrial or commercial discharge	1.25
$F_{ind\text{-}com}$	= Factor for insignificant industrial or commercial discharge	1
$EF_{w/o\ nit/denit}$	= Emissions factor for a WWTP without nitrification or denitrification(g N_2O/ person / year)	3.2
10^{-6}	= Conversion from g to mt (mt/g)	10^{-6}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[25]

Source: *As listed in LGO protocol Equation 10.7 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1890-2007, Chapter 8, 8-13 (2009)*

[24] US EPA Introduction to the National Pretreatment Program. June 2011

[25] See Appendix GWP for value.

WW.9 Process Carbon Dioxide Emissions from the Use of Fossil-Fuel-Derived Methanol for Biological Nitrogen Removal

Introduction
This section provides equations for calculating anthropogenic CO_2 emissions from the use of fossil-fuel-derived methanol for biological nitrogen removal. If the user's WWTP uses methanol in the treatment process, follow *Method WW.9* to estimate anthropogenic CO_2 emissions from the methanol. Some wastewater treatment plants use carbon sources other than methanol for nitrogen removal. These sources may be fossil derived or biomass derived. Evaluating emissions from these sources is an area for future development.

Under current protocols, natural gas purveyors do not account for having unsequestered natural gas CH_4; instead entities burning that gas are encouraged to account for its emission as a direct (Scope 1) GHG emission. The manufacturing Scope 3 emission factor of 0.67 kg CO_2e/kg of methanol (IPCC, 2006) is considerably lower than the stoichiometric factor of 1.37 (molecular weight of CO_2, 44.01, divided by the molecular weight of CH_3OH, 32.04) and as such cannot account for having unsequestered the fossil fuel carbon. As such entities may wish to account for the anthropogenic CO_2 emissions associated with the process use of fossil-fuel-derived methanol for denitrification or biological phosphorus removal.

If methanol is needed for nitrogen removal, please be aware that any changes to methanol use, without replacement with an alternate carbon source, may affect nitrogen discharged in the effluent. A portion of this effluent nitrogen will be converted to N_2O, so a decrease in methanol use may result in increased N_2O emissions. If the user calculates emissions from methanol use at the user's WWTP, the user must follow the recommended *Method WW.12.a* for *Fugitive Emissions from Effluent Discharge* based on N-Load. The alternate *Method WW.12.b* is based on population and will overestimate N_2O emissions because it does not take into account that N_2O emissions that may be reduced due to the addition of methanol in the WWTP.

Under this methodology, methanol carbon addition results in carbon disposition that is partitioned as follows:

- 80% is respired as anthropogenic CO_2 in the activated sludge process and the balance (20%; representative of a 20% net sludge value) is converted to cell mass. If a different actual sludge yield is known for a given WWTP, then that yield should be used, and a corresponding different percent respired CO_2 (respired percent CO_2 = 1 – percent sludge yield) should also be used.

- In plants with anaerobic digestion, 50% of the cell mass carbon (10% of the original methanol carbon) is converted to a combination of CO_2 and CH_4 with the CH_4 being fully oxidized and emitted as CO_2 in either CHP equipment or at waste gas flares.

- In plants with solids combustion (incineration, gasification or other thermal destruction technologies) 100% of the cell mass carbon (20% of the original carbon) is fully oxidized to CO_2.

- In plants with raw sludge disposal, no additional CO_2 emissions exist on site – instead some emissions may occur as scope 3 emissions off site.

WW.9 Data Needs

- Methanol load (methanol load); amount of chemical used per day in $mtCH_3OH$/day
- Treatment type (F), i.e. raw solids disposal, anaerobic digestion, or solids combustion

WW.9 Calculation Method

The following calculation is recommended to calculate the direct (Scope 1) CO_2 emissions from methanol use:

Step 1: Determine the amount of neat chemical in $mtCH_3OH$ used per day at the WWTP. This information should be available by contacting the treatment facility.

Step 2: Determine the type of sludge treatment at the facility—raw solids disposal, anaerobic digestion, or solids combustion. Each of these treatment options has a different factor associated with it. Choose the factor that matches the user's facility.

Step 3: Use *Equation WW.9* to estimate annual CO_2 emissions associated with the methanol used at the WWTP along with the values identified in steps 1 and 2. *Equation WW.9* provides conversion factors to complete this calculation.

Equation WW.9 **CO2 Emission from Methanol Use**

*Annual CO_2 emissions = Methanol Load *F *(44.01/32.04) *GWP *365.25*

Where:

Description		Value
Annual CO_2 emissions	= Total annual CO_2 emitted ($mtCO_2e$)	Result
Methanol load	= Amount of neat chemical used per day (mt CH_3OH/day)	User Input
F	= Factor to be applied based on WWTP's sludge treatment type: • Raw Solids Disposal 80% • Anaerobic Digestion 90% • Solids Combustion 100%	0.80, 0.90, 1.0
44.01/32.04	= Molecular weight ratio of 44.01 (for CO_2) to 32.04 (for CH_3OH)	1.37
GWP	= Global Warming Potential for CO_2	1
365.25	= Conversion factor from days to year	365.25

WW.10 Process Emissions from Cluster Package Systems

Cluster package systems operate like small-scale centralized WWTP that do not use nitrification or denitrification. If the community utilizes cluster package systems to treat its wastewater, follow method *WW.8 Process Emissions from all other Wastewater Treatment Plants* to calculate the N_2O emissions from a cluster package system.

Fugitive Emissions

WW.11 Fugitive Methane Emissions from Septic Systems

Introduction

This section provides equations for calculating the fugitive CH_4 emissions from septic systems based on BOD_5 load. The method provides a description and an appropriate default value (where applicable) for each term in the following equations.

Septic tanks collect wastewater on site and process it in underground tanks usually owned by private, residential owners. Conditions in the tank are anaerobic since the sewage in the system is not exposed to air. Under these anaerobic conditions, microorganisms biodegrade the soluble organic material found in waste. Some CH_4 produced during this degradation escapes from the septic systems into the atmosphere. The conversion to CH_4 is incomplete due to cold temperatures and other factors in the tanks. These systems are not optimized for CH_4 production and therefore are less efficient than theoretically possible.

To calculate the fugitive CH_4 emissions associated with the user's septic systems please follow *Method WW.11*. This recommended method is based on data on the BOD_5 load treated per day by the septic systems. Many communities may not have access to this data; if BOD_5 load data is not available then use alternate *Method WW.11.(alt)* to estimate the fugitive emissions based on population served by septic systems.

N_2O emissions from septic systems are negligible and therefore no method has been included here.

WW.11 Data Needs

Below are the data inputs needed to collect in order to estimate the fugitive CH_4 emitted by septic systems:

If Process Information is Available:	BOD_5 load (the amount of BOD_5 treated per day) (*Method WW.11*)
If Only Population Served is Available:	Population (*Method WW.1.(alt)*)

WW.11Fugitive Methane Emissions from Septic Systems if BOD_5 Load is Known

WW.11 Data Needs

- BOD_5 load (the amount of BOD_5 treated per day)

WW.11 Calculation Method

The method presented consists of the following two steps:

Step 1: Determine the amount of BOD_5 treated per day. BOD_5 is the amount of dissolved oxygen consumed in five days of biological decomposition. A user should be able to get this value (in kg/day) from the agency that oversees septic systems.

Step 2: Plug into *Equation WW.11* Use the default values for B_o and MCF_a,GWP, and unit conversions. Plug these values into *Equation WW.11* to calculate CH_4 emissions from septic system in $mtCO_2e$.

Equation WW.11 **Methane Emissions from Septic Systems**		
Annual CH_4 emissions = (BOD_5 load $\times$ Bo x $MCF_s \times$ 365.25 $\times 10^{-3}$) $\times$ GWP		
Where:		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by septic system annually ($mtCO_2e$)	Result
BOD_5 load	= Amount of BOD_5 produced per day ($kgBOD_5$/day)	User input
Bo	= Maximum CH_4 producing capacity for domestic wastewater (kg CH_4/kg BOD_5 removed)	0.6
MCF_s	= CH_4 correction factor for septic systems[26]	0.22
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[27]
Source: As listed in LGO protocol Equation 10.5 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-8 (2009).		

WW.11(alt)Alternative Method for Methane Emissions from Septic Systems if Only the Population is Known

If data on the BOD_5 load is not available, then follow *Method WW.11(alt)*. The only data collection required for this methodology is the population served by septic systems in the user's community.

WW.11(alt) Data Needs

- Population served by septic systems (P)

[26] Libia R Diaz-Valbuena, H.L. Leverenz, C. D. Cappa, G. Tchobanoglous, W.R. Horwath and J. L. Darby. 2011. "Methane, Carbon Dioxide, and Nitrous Oxide Emissions from Septic Tanks". Environmental Science and Technology.

[27] See Appendix GWP for value.

WW.11(alt) Calculation Method

The method presented consists of the following two steps:

Step1: Determine the population served by the septic system. Septic system CH_4 emissions can be estimated based upon the size of the population that is served by them. If the user does not have records of the population in the community served by the septic system, the method provides some guidance below to help determine that number.

- Table WW.11(alt).1 lists the number of people that use septic systems in 47 different metropolitan areas. If the user's community is one of those metropolitan areas, use Table WW.11(alt).2 to find population served by septic system (P).
- If the user's community is not included in Table WW.11(alt).1 then calculate the number of people served by septic systems by multiplying the population of the community by the rural/ urban default percentages for septic tanks from Table WW.11(alt).2. These default percentages are from IPCC 2006.
- NOTE: The US Census Bureau defines urban and rural areas as follows:
    - Urbanized Areas (UAs) of 50,000 or more people;
    - Rural encompasses all population, housing, and territory not included within an urban area.

Step 2: Enter above variables into *Equation WW.11(alt)*. Use the population served by septic systems and the provided default values for BOD_5, Bo MCF_s,GWP, and unit conversions. Enter these values into *Equation WW.11(alt)* to calculate CH_4 emissions from septic systems in $mtCO_2e$.

Box WW.11(alt).1 Septic Systems in Metropolitan Areas[28]				
Area	Year	Housing units with Septic System [in thousands]	Average number of people per household	**Population served by septic (P)**
Anaheim-Santa Ana, CA PMSA	2002	3.3	2.88	9.52E+03
Atlanta, GA MSA	2004	358.7	2.58	9.26E+05
Baltimore, MD MSA	2007	143.8	2.49	3.58E+05
Birmingham, AL MSA	1998	137.5	2.49	3.43E+05
Boston, CMSA	2007	175.7	2.41	4.23E+05
Buffalo, NY CMSA	2002	55	2.43	1.33E+05
Charlotte, NC-SC MSA	2002	178.7	2.52	4.51E+05
Chicago, IL PMSA	2009	138.5	2.61	3.61E+05
Cincinnati, OH-KY-IN PMSA	1998	85.5	2.51	2.15E+05
Cleveland, OH PMSA	2004	87.4	2.44	2.13E+05
Columbus, OH MSA	2002	75.4	2.50	1.89E+05
Dallas, TX PMSA	2002	82.5	2.73	2.26E+05
Denver, CO MSA	2004	31.5	2.53	7.96E+04
Detroit, MI PMSA	2009	219.2	2.50	5.48E+05
Ft. Worth-Arlington, TX PMSA	2002	32.2	2.71	8.72E+04
Hartford, CT MSA	2004	115.1	2.48	2.85E+05
Houston, TX PMSA	2007	177.6	2.73	4.85E+05
Indianapolis, IN MSA	2004	119.4	2.47	2.95E+05
Kansas City, MO-KS MSA	2002	61.9	2.44	1.51E+05
Los Angeles-Long Beach, CA PMSA	2003	42	2.89	1.21E+05
Memphis, TN-AR-MS MSA	2004	42.1	2.58	1.09E+05
Miami-Ft. Lauderdale, FL CMSA	2007	127	2.54	3.22E+05
Milwaukee, WI PMSA	2002	59.5	2.47	1.47E+05
Minneapolis-St. Paul, MN-WI MSA	2007	139.4	2.56	3.57E+05
New Orleans, LA MSA	2009	41.6	2.47	1.03E+05
New York-Nassau-Suffolk-Orange, NY PMSA	2009	383	2.43	9.29E+05
Norfolk-Virginia Beach-Newport News, VA MSA	1998	66.1	2.59	1.71E+05
Northern NJ PMSA	2009	196.5	2.56	5.03E+05
Oakland, CA PMSA	1998	12.7	2.60	3.30E+04
Oklahoma City, OK MSA	2004	81	2.47	2.00E+05
Philadelphia, PA-NJ PMSA	2009	171.4	2.48	4.25E+05
Phoenix, AZ MSA	2002	60.5	2.62	1.59E+05
Pittsburgh, PA MSA	2004	169	2.38	4.03E+05
Portland, OR-WA PMSA	2002	110.1	2.51	2.76E+05
Providence-Pawtucket-Warwick, RI-MA PMSA	1998	115.5	2.50	2.88E+05
Riverside-San Bernardino-Ontario, CA PMSA	2002	192.4	3.03	5.82E+05
Rochester, NY MSA	1998	96.9	2.52	2.45E+05

[28] If user believes numbers are not representative of their community, then they should use the default factors.

Box WW.11(alt).1 Septic systems in Metropolitan Areas (continued)				
Area	Year	Housing units with Septic System [in thousands]	Average number of people per household	**Population served by septic (P)**
Sacramento, CA PMSA	2004	78.3	2.63	2.06E+05
ST. Louis, MO-IL MSA	2004	118.3	2.42	2.86E+05
Salt Lake City, UT MSA	1998	10.5	3.01	3.16E+04
San Antonio, TX MSA	2004	75.7	2.69	2.04E+05
San Diego, CA MSA	2002	59.2	2.60	1.54E+05
San Francisco-Oakland, CA PMSA	1998	13.9	2.34	3.25E+04
San Jose, CA PMSA	1998	14.7	2.68	3.94E+04
Seattle-Everett, WA PMSA	2009	222.7	2.45	5.45E+05
Tampa-St. Petersburg, FL MSA	2007	155.9	2.31	3.60E+05
Washington, DC-MD-VA MSA	2007	195.6	2.51	4.90E+05
Source: *US Census Bureau,* See: *http://www.census.gov/hhes/www/housing/ahs/metropolitandata.html*				

Box WW.11(alt).2 Default proportion of population that utilizes septic tanks		
	Rural	Urban*
United States	0.90	0.05
*Definitions **Urban** is defined as areas of 50,000 or more people; **Rural** is defined as all population, housing, and territory not included within an urban area.		
Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 6, Table 6.5*		

***Equation WW.11(alt)* Alternate Methane Emissions from Septic Systems**		
Annual CH_4 emissions = (P x BOD_5 load x Bo x MCFs x 365.25 x 10^{-3}) x GWP		
Where:		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by septic system ($mtCO_2e$)	Result
P	= Population served by septic system	For some Metropolitan Areas see Table WW.11(alt) For all other areas multiply population of community by rural or urban default from Table WW.11(alt).2
BOD_5 load	= Amount of BOD_5 treated per day (kg BOD5/person/day)	0.090
Bo	= Maximum CH_4 producing capacity for domestic wastewater (kg CH4/kg BOD_5)	0.6
MCF_s[29]	= CH_4 correction factor for septic systems	0.22
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[30]
Source: *As listed in LGO protocol Equation 10.5 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006, Chapter 8, 8-8 (2008).*		

[29] Libia R Diaz-Valbuena, H.L. Leverenz, C. D. Cappa, G. Tchobanoglous, W.R. Horwath and J. L. Darby. 2011. "Methane, Carbon Dioxide, and Nitrous Oxide Emissions from Septic Tanks". Environmental Science and Technology.
Jeannie L. Darby, et. al. 2010. *Evaluation of Greenhouse Gas Emissions from Septic Systems*. Water Environment Research Foundation DEC1R09

[30] See Appendix GWP for value.

WW.12 Fugitive Nitrous Oxide Emissions from Effluent Discharge

Introduction

This section provides equations for calculating the process N_2O emissions from effluent discharge from WWTPs based on site-specific data or the population served by the WWTP. The method provides a description and an appropriate default value (where applicable) for each term in the following equations.

Effluent discharge is treated wastewater that flows out from a treatment facility or industrial plant and is discharged into waterways, lakes, or the ocean. Effluent discharge originating from a conventional wastewater treatment facility without advanced processes is treated to secondary treatment standards and is therefore called secondary effluent. Conventional WWTPs are not able to remove all of the nitrogen content in wastewater, leaving about 10% in the effluent (Scheehle 2001). However, N_2O is only present in trace amounts (if at all) in the effluent, and most of the nitrogen is in other forms. Only when this nitrogen containing effluent reaches a natural watershed will indirect N_2O emissions occur through side reactions. Using methodology from the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010, N_2O emissions through these side reactions could make up to 95% of the total N_2O generated from a WWTP.

To calculate the fugitive N_2O emissions associated with effluent discharge from WWTPs please follow *Method WW.12 Fugitive Nitrous Oxide Emissions from Effluent Discharge*. If significant amounts of industrial wastewater are discharged to a community's municipal treatment system, users should use the recommended method, *WW.12*. If the effluent nitrogen content is routinely measured by the user's facility, use that number with *Equation WW.12*; this is the most accurate approach. If the data for WW.12 is unavailable, follow *Method WW.12(alt)*to estimate the fugitive emissions based on population served by the WWTP.

If the user calculated the emissions due to methanol use in its WWTPs in *WW.9* please follow *Method WW.12 Fugitive N2O Emissions from Effluent Discharge*. Following *Method WW.12(alt)* will result in over-estimating emissions.

WW.12 Data Needs

Below are the data inputs needed to collect in order to estimate the fugitive CH_4 emitted by septic systems:

If Process Information is Available:	Average total nitrogen discharged per day (Total N-load) (*Method WW.12*)
If Only Population Served is Available:	Population AND Whether there is significant industrial or commercial input (*Method WW.12.(alt)*)

WW.12 Calculation if Average Total Nitrogen Discharged per Day (Total N-load) is Known

WW.12 Data Needs

- Average total nitrogen discharged per day (Total N-load)

WW.12 Calculation Method

The method presented consists of the following two steps:

Step 1: Determine the average nitrogen discharged per day by the facility. The facility should maintain records of the N-load in their discharge.

Step 2: Enter above variables obtained and default values into *Equation WW.12.* Use the provided default values for N-load, GWP, and unit conversions. Enter these values along with the procured data into *Equation WW.12* to calculate N_2O emissions from effluent in $mtCO_2e$

Equation WW.12 **N_2O Emission from Effluent Conversion**		
Annual N_2O emissions = (N-Load $\times EF_{effluent} \times$ 365.25 $\times 10^{-3} \times$ 44/28) $\times$ GWP		
Where: Description		Value
N_2O emissions	= Total annual N_2O emitted by effluent conversion ($mtCO_2e$)	Result
N-Load	= Average total nitrogen per day (kg N/day)	User input
$EF_{effluent}$	= Emission factor (kg N_2O-N/kg sewage-N discharged)	0.005 for river or stream discharge, 0.0025 for direct ocean discharge[31]
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
44/28	= Molecular weight ratio of N_2O to N_2	1.57
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[32]
Source: As listed in LGO protocol Equation 10.9 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-13 (2009)		

[31] Note, neither the IPCC nor the EPA have yet to distinguish between effluent conversion that occurs in rivers (and then subsequent conversion in estuaries), as opposed to conversion that only occurs in estuaries.

[32] See Appendix GWP for value.

Alternative WW.12(alt) Nitrous Oxide Emissions from Effluent Discharge if Only the Population is Known

An alternative methodology has been provided for communities without site-specific N-load data. This method is based on population, and uses a default total nitrogen load factor of 0.026 kg N/person/day that was derived from the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006 as used in the LGO Protocol[33]. If there is a significant industrial wastewater contribution to a user's municipal treatment system, the population input of this equation must be adjusted. As stated above, significant industrial users are defined as (1) all users subject to categorical pretreatment standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N, except those designated as 'non-significant categorical industrial users' (see Box. 1 on page 8); and (2) any other industrial users that discharges an average of 25,000 gpd or more of process wastewater (excluding sanitary, noncontact cooling, and boiler blowdown wastewater).

WW.12(alt) Data Needs

- Population served by the facility (P)
- Whether there is significant industrial or commercial input

WW.12(alt) Calculation Method

The method presented consists of the following three steps:

Step 1: Determine the population served by the facility. When the other data is unavailable, the population served by that WWTP could be used to estimate N_2O emissions from the effluent discharge. Where appropriate, a user may add the industrial-equivalent factor ($F_{ind\text{-}com}$ 1.25) to the domestic population if both are served by the WWTP. If a user's facility does not have industrial or commercial wastewater inputs then set the $F_{ind\text{-}com}$ term to 1.

Step 2: Determine whether the WWTP employs nitrification or denitrification. If a WWTP employs nitrification or denitrification then the fraction of N removed by the plant can be estimated to 0.7. If the WWTP does not employ nitrification or denitrification, then 0.0 N is removed from the WWTP.

Step 3: Enter above variables obtained and default values into *Equation WW.12(alt)*. Use the provided default values for $F_{int\text{-}com}$, N-load, N uptake, BOD_5, EF, F_{plant} (either with or with out nitrification/ denitrification), GWP, and unit conversions. Enter these values along with the procured data into *Equation WW.12(alt)*to calculate N_2O emissions from the effluent conversion of discharged nitrogen from a wastewater plant in $mtCO_2e$

[33] The default total nitrogen load value is derived based on the following default values from US EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006, Chapter 8, 8-14 and Table 8.11: Average US protein intake (41.9 kg/person-year) x default fraction of N in protein (0.16 kg N/kg protein) x factor for non-consumed protein added to water (1.4) / days per year (365.25) = 0.026 kg N/person/day.

Equation WW.12.(alt) N_2O Emission from Effluent Conversion when only Population Served by Wastewater Treatment Plant is Known		
Annual N_2O emissions = ((P × $F_{ind\text{-}com}$) × (Total N load - N uptake x BOD5 load) × EF effluent × 44/28 × (1 – Fplant nit/denite) × 365.25 × 10^{-3}) × GWP		
Where: Description		Value
N_2O emissions	= Total annual N_2O emitted by effluent (mtCO2e)	Result
P	= Population	User input
$F_{ind\text{-}com}$	= Factor for industrial or commercial discharge	1.25 (if applicable)
Total N-Load	= Average total nitrogen per day (kg N/person/day)	0.026[34]
N uptake	= Nitrogen uptake for cell growth in *aerobic* systems (kg N/kg BOD_5)	0.05
<u>OR</u>		
N uptake	= Nitrogen uptake for cell growth in *anaerobic or lagoon* systems(kg N/kg BOD_5)	0.005
BOD_5	= Amount of BOD_5 produced per person per day (kg BOD_5/person/day)	0.090
EF	= Emission factor (kg N_2O-N/kg sewage-N discharged)	0.005 for river or stream discharge, 0.0025 for direct ocean discharge[35]
44/28	= Molecular weight ratio of N_2O to N_2	1.57
F*plant nit/denit*	= Fraction of nitrogen removed from the WWTP with nitrification/denitrification	0.7
<u>OR</u>		
F*plant*	= Fraction of nitrogen removed from the WWTP without nitrification/denitrification	0.0
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[36]
Source: *As listed in LGO protocol Equation 10.10 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-13 (2009); except Grady, C.P. L., Jr., G. T. Daigger, and H. C. Lim, Biological Wastewater Treatment p. 108-109, 644 2nd Edition (1999)*		

[34] The default total nitrogen load value is derived based on the following default values from US EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006, Chapter 8, 8-14 and Table 8.11: Average US protein intake (41.9 kg/person-year) x default fraction of N in protein (0.16 kg N/kg protein) x factor for non-consumed protein added to water (1.4) / days per year (365.25) = 0.026 kg N/person/day.

[35] Note, neither the IPCC nor the EPA have yet to distinguish between effluent conversion that occurs in rivers (and then subsequent conversion in estuaries), as opposed to conversion that only occurs in estuaries.

[36] See Appendix GWP for value.

WW.13 Attribution of Wastewater Emissions Outside of Operational Control

Introduction

This section provides equations for attributing the portion of CH_4 and N_2O emissions from WWTPs to their respective communities based upon proportioning population of the given community in question to the total population served by the WWTP. If a user's community has a significant commercial and/or industrial contribution (especially if the nitrogen loading is high), this method could underestimate the actual emissions. The method provides a description and an appropriate default value (where applicable) for each term in the following equations.

To calculate attributed CH_4 emissions associated with a user's community, follow *MethodWW.13$_{CH4}$ Attribution of Wastewater CH4 Emissions*. To calculate attributed N_2O emissions associated with a user's community, follow *MethodWW.13$_{N2O}$*. Add the results from calculation *WW.13$_{CH4}$* and *WW.13$_{N2O}$*to get the total emissions attributed for a community's wastewater. Communities served by multiple wastewater treatment systems must apply *MethodWW.13$_{CH4}$* (for CH_4) and *MethodWW.13$_{N2O}$* (for N_2O) to each wastewater treatment system the community utilizes to get the total attributed emissions.

WW.13$_{CH4}$ Attribution of Wastewater CH_4 Emissions

WW.13$_{CH4}$ Data Needs

- Population of community served by given WWTP (P)
- Total population the WWTP serves (P_{tot})
- Total CH_4 emissions from WWTP in $mtCO_2e$ (E)

WW.13$_{CH4}$ Calculation Method

The method presented consists of the following four steps:

Step 1: Determine the population served by given WWTP. For communities that are entirely served by one wastewater treatment facility, then P is the entire population of the community. For those populations served by multiple facilities, then P is the number of people served by the given facility

Step 2: Determine the total population the given WWTP serves. The number of people served by the facility can be found by contacting a user's wastewater treatment provider.

Step 3: Determine the Total CH_4 emissions from the WWTP. The total CH_4 emissions can also be found by using methods described earlier in this document, or by contacting the user's wastewater treatment provider. They can implement this protocol to calculate their total emissions.

Step 4: Enter above variables into *Equation WW.13$_{CH4}$*. Use these values in *Equation WW.13$_{CH4}$* to calculate the annual emissions attributed to the community from the given wastewater treatment facility

Equation WW.13$_{CH4}$ Attributed CH_4 Emissions		
*Attributed CH_4 Emissions = P/P_{tot} * E*		
Where:		
Description		Value
Attributed CH_4 Emissions	= Annual CH_4 credited to the community ($mtCO_2e$)	Result
P	= Population of community served by the given WWTP	User input
P_{tot}	= Total population the WWTP serves	User input
E	= Total CH_4 produced by WWTP ($mtCO_2e$)	User input
Source: Developed by ICLEI Staff and Wastewater Technical Advisory Committee		

WW.13$_{N2O}$ Attribution of Wastewater N_2O Emissions

This section provides equations for attributing the portion N_2O emissions from WWTPs to their respective communities based upon proportioning population of the given community in question to the total population served by the WWTP. If the user's community has a significant commercial and/or industrial contribution (especially if the nitrogen loading is high), this method could underestimate the actual emissions. The method provides a description and an appropriate default value (where applicable) for each term in the following equation.

WW.13$_{N2O}$ Data Needs

- Population of community served by given WWTP (P)
- Total population the WWTP serves (P_{tot})
- Total N_2O emissions from WWTP in $mtCO_2e$ (E)

WW.13$_{N2O}$CalculationMethod

The method presented consists of the following four steps:

Step 1: Determine the population served by given WWTP. For communities that are entirely served by one wastewater treatment facility, then P is the entire population of the community. For those populations served by multiple facilities, then P is the number of people served by the given facility

Step 2: Determine the total population the given WWTP serves. The number of people served by the facility can be found by contacting the community's wastewater treatment provider.

Step 3: Determine the Total N_2O emissions from the WWTP. The total N_2O emissions can also be found by using method described earlier in this document, or by contacting the user's wastewater treatment provider. They can implement this protocol to calculate their total emissions.

Step 4: Enter above variables into *Equation WW.13$_{N2O}$*. Use these values in *Equation WW.13$_{N2O}$* to calculate the annual emissions attributed to the community from the given wastewater treatment facility

Equation WW.13$_{N2O}$ Attributed N_2O Emissions		
Attributed N_2O Emissions = $P/P_{tot} * E$		
Where:		
Description		Value
Attributed N_2O Emissions	= Annual N_2O credited to the user's community ($mtCO_2e$)	Result
P	= Population of community served by the given WWTP	User input
P_{tot}	= Total population the WWTP serves	User input
E	= Total N_2O produced by WWTP ($mtCO_2e$)	User input
Source: Developed by ICLEI Staff and Wastewater Technical Advisory Committee		

WW.14 Energy-related Emissions Associated with Water Delivery and Treatment

Introduction

The consumption of water by a community's residents and businesses can have significant GHG implications depending on the source of water, distances and topography traversed in conveyance, and the treatment processes that occur before and after the end-use phase. Incorporating the relationship between water consumption and energy consumption in a GHG inventory allows a community to use water conservation measures as a GHG emissions reduction strategy.

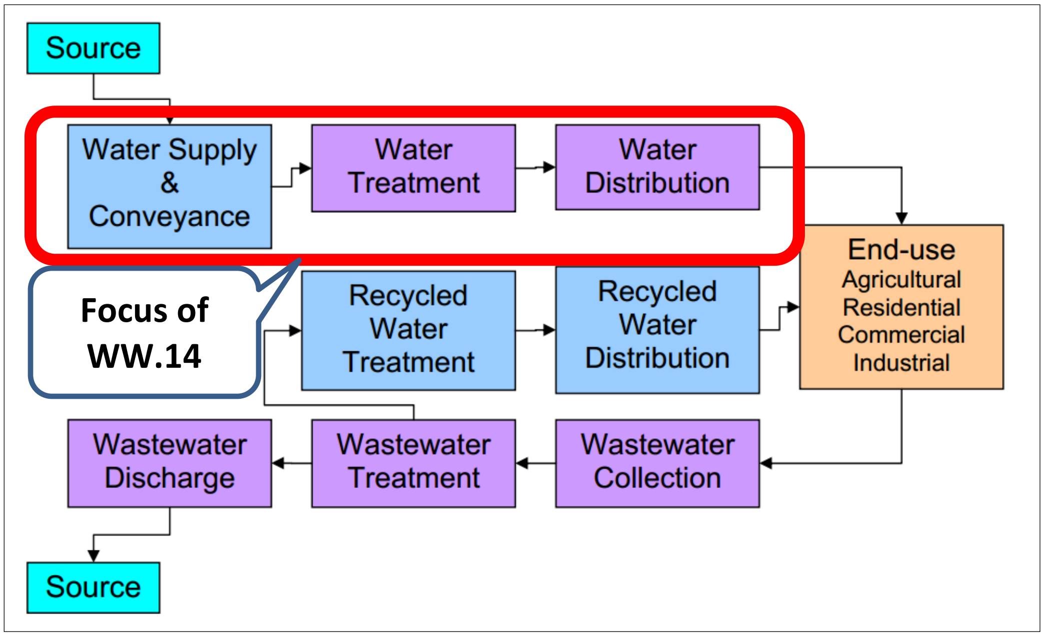
The methods described in this section first account for the embodied energy and the subsequent GHG emissions impact of water consumption in a community inventory, the first steps in the community water cycle. Methods are implemented from a water use perspective. Therefore, double counting with GHG emission sources accounted for in other sectors may be likely. For example, stationary energy consumption at water treatment and distribution facilities within a community's boundary may be at risk for double counting. For this reason, GHG emissions from water consumption should not be summed with GHG emissions from other direct sources (i.e. stationary energy consumption).

Several processes exist which, when combined, provide for the total GHG emissions of a community's management of its potable water. Figure WW.14.1 illustrates the different energy consuming processes involved in the delivery and treatment of water. Note this method will address the first three elements of that cycle. The energy intensity of each of these processes and the volume of water passing through each will need to be known in order to accurately inventory emissions associated with water consumption. The degree to which each of the processes used to deliver your community's water is identified, and the energy intensity of each of those processes is known, will define the accuracy of the methods for determining the GHG emissions from water consumption.

Different water sources can have different fates in the cycle. In many states, a significant percentage of water comes from on-site sources. On-site sources of water often meet the needs of users in very close proximity to the source; hence the extraction/conveyance demands are insignificant. Also, for these systems, treatment is minimal and the water is consumed on-site so there are no distribution impacts. Therefore, the focus is centered on that fraction of the population served by public supplies from surface and groundwater.

It is common for communities to draw from a mixture of both groundwater and surface water. Groundwater sources require energy to extract the water from wells; surface waters require no extraction energy. Also, surface waters generally require more treatment than groundwater to bring the surface waters to drinking water standards. For the purposes of this method, the distribution energy demands for both supplies are the same.

Figure WW.14.1 Energy Consuming Processes in the Delivery and Treatment of Water[37]



Water supply requires energy for extraction in the case of ground water. Surface water does not require energy to supply. Energy use for conveyance applies to both ground water and surface water.

Water conveyance can be the most impactful element in the cycle. In California, communities in the south draw significant amounts of water from vast distances over elevated terrain. Nevertheless, even communities in Northern California can have a high energy demand associated with their water supply and distribution. Because of California's unique energy demands, California users should refer to *Embedded Energy in Water Studies, Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles,* Appendix B[38] if data is not available directly from your local water agency.

Energy consumption and resulting GHG emissions from the end-use phase are excluded. End Use consists of the electricity or fossil fuels used at community residences, commercial buildings or industrial facilities for heating, cooling, and final dispersal of water (when these require additional power inputs). End Use emissions will already be contained in calculations done in Appendix C: Built Environment Emission Activities and Sources. Emissions from water supply/conveyance, treatment and distribution *might* be accounted for in Appendix C (or

[37] Klein, Gary, Ricardo Amon, Shahid Chaudhry, Loraine White, et al. California's Water-Energy Relationship: Final Staff Report. Nov. 2005. California Energy Commission. Available at: http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

[38] Prepared by GEI Consultants/Navigant Consulting for the California Public Utilities Commission, August 31, 2010. ftp://ftp.cpuc.ca.gov/gopher-data/energy%20efficiency/Water%20Studies%202/Appendix%20B%20-%20Agency%20Profiles%20-%20FINAL.pdf.

maybe just in part) if your water facilities are located within your community, however, in most cases, these facilities are spread out across numerous jurisdictions.

The water system components in each process in your water system that should be accounted for in this section may include:

- Water Supply & Conveyance:
    - Pumps to extract water from either a surface body of water or groundwater and to move the raw water any significant distance.
- Water Treatment:
    - Pumps and equipment to provide purification treatments such as UV disinfection, ozone treatment, membrane filtration, or chlorination.
- Water Distribution:
    - Pumps to send out and pressurize water in the local distribution system.

Methods for calculating the energy intensity for Wastewater Collection, Treatment and Distribution are found in WW.15.

Each of the processes listed above occur in facilities that consume energy for activities that are not directly related to or dependent on the volume of water processed at that facility. This includes things like lighting or other building energy functions. Properly benchmarking your water delivery system will help to ensure that these functions are accounted for such that process energy is readily available for this type of GHG inventory calculation. Many resources are available for benchmarking your system through the EPA Energy Star Program.[39] The end-use phase is excluded because energy consumption from that phase is captured in the stationary energy and electricity consumption sector, primarily from water heating.

Uncertainties and Limitations

For users without site-specific information, this method combines state level usage with nation-wide energy intensities and regional energy to GHG emission conversions, each with different vintages and different degrees of reliability. Users should be cautioned against using WW.14 to meet regulatory requirements such as those in federal or state mandatory reporting rules or, in California, CEQA. Although Lead Agencies in CEQA have the discretion to choose their preferred emissions estimation method, they must be able to justify why that method is the best for their project. Thus, tools designed to meet regulatory requirements such as EPA's Energy Star

[39] US EPA ENERGY STAR for Wastewater Plants and Drinking Water Systems. http://www.energystar.gov/index.cfm?c=water.wastewater_drinking_water

Portfolio Manager or CalEEMod[40] for CEQA may be more appropriate for that purpose. Other tools that are more comprehensive such as WESim[41] may be more suitable as well. The best results are from site-specific values that are better than any model regardless of the source.

Recommended Approach

The recommended approach for calculating GHG emissions for water consumption, including water supply and wastewater treatment, utilizes community-specific energy consumed per unit of water for each process of the water system for a community's water consumption.

For communities without significant influence over these activities or those without resources to obtain specific information should use the method outlined below. Default values and assumptions for each required input are provided in Tables WW.14.1 – WW.14.5.

Method WW.14 Calculation of Upstream Emissions Associated with Water Supply, Conveyance, Treatment and Delivery

WW.14 Data Needs

- Water Supply and Conveyance:
    - Percentage of self-supplied, groundwater and surface water
    - Population
    - Water use per capita
    - Default factor for groundwater energy intensity
    - Community specific energy to GHG emissions
    - General knowledge of water source (inside or outside community)

The method considers the energy intensity of groundwater extraction, and groundwater and surface water conveyance.

- Water Treatment:
    - Percentage of self-supplied, groundwater and surface water
    - Population
    - Water use per capita
    - Default factors for water treatment
    - Community specific energy to GHG emissions

The method considers only the energy intensity of surface water treatment since the energy intensities for self-supplied water and groundwater treatment are negligible.

- Water Distribution:

[40] CalEEMod was developed by the California Air Pollution Control Officers Association for purposes of estimating impacts of projects under CEQA and thus is valid only for California users. See: http://caleemod.com/

[41] http://pacinst.org/resources/wesim/index.htm

- Percentage of self-supplied, groundwater and surface water
- Population
- Water use per capita
- Default factor for groundwater energy intensity
- Community specific energy to GHG emissions

The method considers only the energy intensity of groundwater and surface water distribution since it is assumed that self-supplied is mainly used on-site and is not distributed to remote users.

WW.14 Calculation Method

The method presented considers each element of the water cycle highlighted in Figure WW.14.1 individually and sums the conveyance, treatment, and distribution emissions at the end. Note the method assumes self-supplied waters have negligible emissions. These waters are generally obtained and used on-site with little need for treatment.

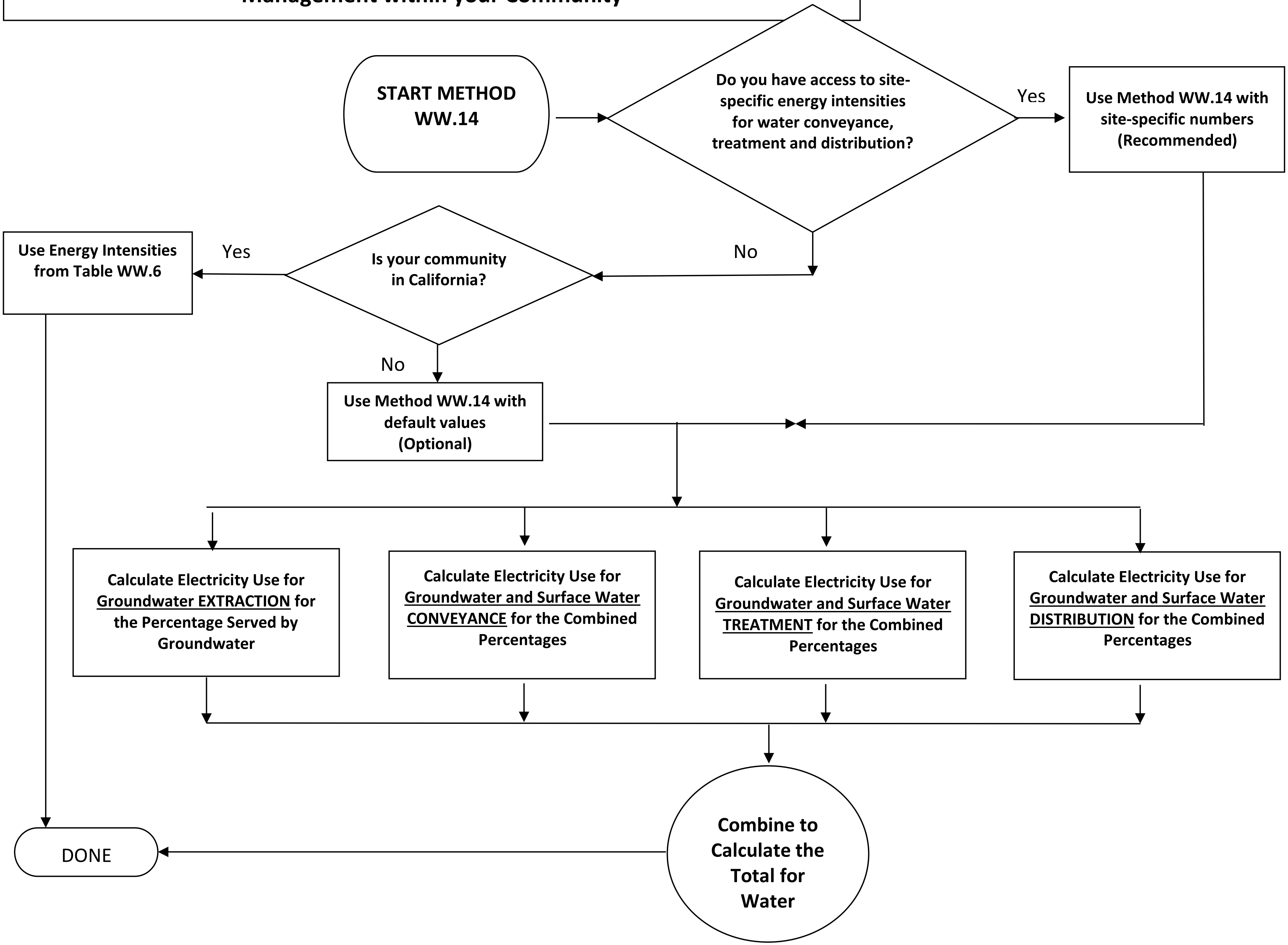
California users should refer to the report *Embedded Energy in Water Studies, Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*, Appendix B.[42] For most included water agencies, this report provides number of customers and population served, total water supplied, percentage of water from different sources, and energy intensity of these sources. Note that annual water supply in this report is often provided in units of AF, or Acre-feet. One acre-foot is equal to 325,851 gallons.

Figure WW.14.2 can guide the user through the steps required to calculate emissions from the management of water by a community.

In these methods, if a table or method calls for a size in units of million gallons (MG), that metric can be obtained by multiplying the per capita generation by the population and dividing by one million.

[42] Prepared by GEI Consultants/Navigant Consulting for the California Public Utilities Commission, August 31, 2010.
ftp://ftp.cpuc.ca.gov/gopher-data/energy%20efficiency/Water%20Studies%202/Appendix%20B%20-%20Agency%20Profiles%20-%20FINAL.pdf.

FIGURE WW.14.2: Decision Tree for Reporting Electricity Use from Water Management within your Community



WATER SUPPLY: EXTRACTION AND CONVEYANCE

Step 1: Obtain the proportions of groundwater and surface water.
Refer to Table WW.14.1 for a state-by-state distribution if the community specific distribution is not known or obtainable.

Step 2: Multiply the total population of the community by the fraction receiving groundwater and surface water and the per capita use, (defaults available in table WW.14.1) to get the actual volume.

Step 3: Multiply the volume of groundwater for the community by the appropriate process energy consumed per unit of groundwater to calculate total energy consumed for groundwater extraction. Refer to Table WW.14.2 for groundwater extraction default energy intensities if the community specific value is not known. The low value in the table is the default since there is no median value. If the water table depth is known, multiply the depth in feet by 4.5 to yield energy intensity in kWh/million gallons.[43] The extraction energy for self-supplied and surface waters are assumed to be negligible.

Step 4: Multiply the volume of groundwater and surface water by the process energy consumed per unit of groundwater and/or surface water to calculate total energy consumed for its conveyance to the treatment facility. Refer to Table WW.14.3 for conveyance default energy intensities if the community specific value is not known. For water sourced within the community geographic boundary, use the median value of 110 kWh/MG. For waters sourced from beyond the geographic boundary of the community, use the median value of 3000 kWh/MG. Energy requirements for conveyance depend greatly on distance pumped and the change in elevation so low and high values can be used based on the judgment of the user[44]. Only deviate from the median if absolutely certain. The conveyance energy for self-supplied waters are assumed to be negligible.

California users should refer to the report *Embedded Energy in Water Studies, Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*, Appendix B for defaults.

Step 5: Multiply total energy consumed for extraction and conveyance by the appropriate GHG emissions factor for the community from Table WW.14.7, WW.14.8, or WW.14.9. See Appendix C, section BE.2 for guidance on choosing the appropriate factor.

WATER TREATMENT

[43] Value/foot is calculated as an average of the values in Table WW.14.2.

[44] Implications of Future Water Supply Sources for Energy Demands, WateReuse Research Foundation, 2012. See: http://www.pacinst.org/resources/wesim/report.pdf, page 22.

Step 1: Obtain the percentage of surface water.
Refer to Table WW.14.1 for a state-by-state distribution if the community specific distribution is not known or obtainable.

Step 2: Multiply the total population of the community by the fraction receiving surface water and the per capita use, (defaults available in table WW.14.2) to get the actual volume.

Step 3: Multiply the volume of surface water for the community by the appropriate process energy consumed per unit of treated surface water to calculate total energy consumed. Refer to Table WW.14.4 for treatment default energy intensities if the community specific value is not known. Assume that the treatment energy intensities for groundwater are negligible. In general, use the median values based on population multiplied by per capita water use. Facilities for pressure filtration and oxidation use the high values. For sand filtration use the low values. Only deviate from the median if absolutely certain

Step 4: Multiply total energy consumed for water treatment by the appropriate GHG emissions factor for the community from Table WW.14.7, WW.14.8, or WW.14.9. See Appendix C, section BE.2 for guidance on choosing the appropriate factor.

WATER DISTRIBUTION

Step 1: Obtain the proportions of groundwater and surface water.
Refer to Table WW.14.1 for a state-by-state distribution if the community specific distribution is not known or obtainable.

Step 2: Multiply the total population of the community by the fraction receiving groundwater and surface water and the per capita use, (defaults in table WW.14.1) to get the actual volume.

Step 3: Multiply the volume of groundwater and surface water for the community by the appropriate process energy consumed per unit of distributed groundwater and/or surface water to calculate total energy consumed for distribution. Refer to Table WW.14.5 for distribution default energy intensities if the community specific value is not known. Distribution energy is highly dependent on distribution network topography and distance pumped. Assume distribution energy intensity is the same for water sourced from groundwater and surface water. High and low values are supplied for use based on the best judgment of the user. Only deviate from the median if absolutely certain.

Step 4: Multiply total energy consumed for water distribution by the appropriate GHG emissions factor for the community from Table WW.14.7, WW.14.8, or WW.14.9. See Appendix C, section BE.2 for guidance on choosing the appropriate factor.

For the total emissions for water consumption, sum the three elements of extraction, conveyance, treatment and distribution. This total should be reported separately from the wastewater total calculated in WW.15, and from the wastewater combustion, fugitive and process emissions calculated in Appendix F. Also, this total does not include emissions associated with electricity transmission and distribution losses. If you apply the method in Appendix C, Section BE.4 to other electricity use in your inventory, you should also apply it to this total.

***Equation WW.14.1* Total Energy-related Emissions as a Result of Water Consumption**
Annual CO_2e emissions = Extraction + Conveyance + Treatment + Distribution

Extraction = *[(Source Percentage Groundwater x Population x per capita Use x Process Energy Intensity-Groundwater **Extraction**) x Unit Conversions+*

Conveyance =*∑ (Source Percentage x Population x per capita Use x Process Energy Intensity-**Conveyance**)$_{surface\ water\ only}$]x Energy Emissions Factor x Unit Conversions*

Treatment = *∑ (Source Percentage x Population x per capita Use x Process Energy Intensity-**Treatment**)$_{groundwater,\ surface\ water\ only}$ x Energy Emissions Factor x Unit Conversions*

Distribution = *∑ (Source Percentage x Population x per capita Use x Process Energy Intensity-**Distribution**)$_{groundwater,\ surface\ water}$ x Energy Emissions Factor x Unit Conversions*

Where:

Description			Value
Annual CO_2e emissions	=	Total annual emissions from water extraction, conveyance, distribution and treatment	Result
Source Percentage	=	Percentage of population drawing from either groundwater or surface water	User Input
Population	=	Total population of the community	User Input
Per capita use	=	Amount of water used by each member of the community on average. Includes all possible end uses for the water.	User Input
Water Processed	=	Annual volume of water processed in an individual process (million gallons)	User Input
Process Energy Intensity	=	Energy consumed per unit water processed (kWh/million gallons)	User Input
Energy Emissions Factors	=	Standard electricity emissions factors from eGRID, or other verified source	User Input

Table WW.14.1 Public Water Supply Sources and per Capita Use[45]				
State	per Capita Water Use Non-Self Supplied gal/d/capita	Percent Served by Self-Supply	Percent Served by Groundwater Supplies	Percent Served by Surface Water Supplies
Alabama	199	11	30.7	58.3
Alaska	177	35	22.2	42.8
Arizona	205	4	46.5	49.5
Arkansas	157	7	31.8	61.2
California	209	7	17.0	76.0
Colorado	198	6	11.1	82.9
Connecticut	180	24	12.0	64.0
Delaware	126	10	47.9	42.1
Florida	158	10	78.0	12.0
Georgia	158	18	17.7	64.3
Hawaii	218	6	89.7	4.3
Idaho	244	30	62.6	7.4
Illinois	147	9	21.7	69.3
Indiana	145	26	39.0	35.0
Iowa	163	18	64.3	17.7
Kansas	155	5	37.7	57.3
Kentucky	160	17	10.3	72.7
Louisiana	181	12	43.3	44.7
Maine	129	44	16.0	40.0
Maryland	146	17	11.7	71.3
Massachusetts	135	8	23.6	68.4
Michigan	158	29	16.2	54.8
Minnesota	134	22	54.0	24.0
Mississippi	156	19	72.4	8.6
Missouri	168	15	24.9	60.1
Montana	224	32	32.2	35.8
Nebraska	228	18	58.6	23.4
Nevada	303	8	18.4	73.6
New Hampshire	132	42	21.6	36.4
New Jersey	123	11	38.1	50.9
New Mexico	185	20	69.7	10.3
New York	145	10	17.9	72.1

[45] Adapted from Table 5, Public Supply Withdrawals, 2005, USGS Estimated Use of Water in the United States in 2005. See: http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf

Table WW.14.1 Public Water Supply Sources and per Capita Use - Continued				
State	per Capita Water Use Non-Self Supplied gal/d/capita	Percent Served by Self-Supply	Percent Served by Groundwater Supplies	Percent Served by Surface Water Supplies
North Carolina	144	26	12.5	61.5
North Dakota	126	16	39.9	44.1
Ohio	151	17	28.3	54.7
Oklahoma	199	8	16.2	75.8
Oregon	181	19	12.4	68.6
Pennsylvania	144	20	11.8	68.2
Rhode Island	121	8	12.4	79.6
South Carolina	217	30	16.3	53.7
South Dakota	150	14	56.7	29.3
Tennessee	168	9	33.1	57.9
Texas	207	10	25.5	64.5
Utah	245	3	55.6	41.4
Vermont	105	30	21.0	49.0
Virginia	167	22	6.7	71.3
Washington	184	14	46.8	39.2
West Virginia	135	23	15.2	61.8
Wisconsin	143	30	38.7	31.3
Wyoming	227	17	42.9	40.1
National Average[46]	171	14	28.4	57.6

[46] National average includes use in the states, the District of Columbia, Puerto Rico and the U.S. Virgin Islands.

Table WW.14.2: Energy Intensities for Groundwater Extraction[47]

	Groundwater Extraction (kWh/MG)	Water Table Depth (feet)
Low Value (default)	540	120
High Value	2270	500

Table WW.14.3: Energy Intensities for Water Conveyance[48]

	Local Water (kWh/MG)	Imported Water (kWh/MG)
Low Value	88	1900
Median Value	110	3000
High Value	330	5300

[47] From Energy Down the Drain: The Hidden Costs of California's Water Supply, NRDC and The Pacific Institute, 2004, page 11

[48] Adapted from Implications of Future Water Supply Sources for Energy Demands, WateReuse Research Foundation, 2012. See: http://www.pacinst.org/resources/wesim/report.pdf, Table 4.2.

Table WW.14.4: Energy Intensities for Water Treatment[49]

	<1 MGD (kWh/MG)	1-5 MGD (kWh/MG)	5-20 MGD (kWh/MG)	>20 MGD (kWh/MG)
Low Value	620	300	180	120
Median Value	1500	750	560	210
High Value	2000	1300	1100	2000

Table WW.14.5: Energy Intensities for Water Distribution[50]

	Distribution Intensity (kWh/MG)
Low Value	360
Median Value	540
High Value	860

[49] Adapted from Implications of Future Water Supply Sources for Energy Demands, WateReuse Research Foundation, 2012. See: http://www.pacinst.org/resources/wesim/report.pdf, Table 4.3.
[50] Adapted from Implications of Future Water Supply Sources for Energy Demands, WateReuse Research Foundation, 2012. See: http://www.pacinst.org/resources/wesim/report.pdf, Table 4.8.

Table WW.14.7 Utility-Specific Verified Electricity CO_2 Emission Factors (lbs CO_2/MWh)

	Year										
	2000[a]	2001[a]	2002[a]	2003[a]	2004[a]	2005[a]	2006[a]	2007[a]	2008[a]	2009[a,b]	2010[b]
Anaheim Public Utilities						1,399.80	1,416.74	1,543.28			
Austin Energy						1,127.37	1,077.97	1,117.37			
City and County of San Francisco								76.28			
City of Palo Alto Public Utilities						320.94	39.02	426.82			
City of Vernon, Light and Power											775.83
Glendale Water & Power								1,065.00			
Los Angeles Department of Water & Power	1,407.44	1,403.39	1,348.48	1,360.07	1,360.60	1,303.58	1,238.52	1,227.89			
Modesto Irrigation District, Retail Power										1,036.17	942.99
Modesto Irrigation District, Wholesale Power										2,048.09	2,026.12
Newmont Nevada Energy Investment											2,055.79
Pacific Gas & Electric Company					566.20	489.16	455.81	635.67		575.38	444.64
PacifiCorp					1,811.00	1,812.22	1,747.30	1,775.28			
Pasadena Water & Power							1,409.65	1,664.14			
Platte River Power Authority						1,970.93	1,955.66	1,847.88			
Riverside Public Utilities						1,333.45	1,346.15	1,325.65			
Roseville Electric							565.52	793.80			
Sacramento Municipal Utility District					769.00	616.07	555.26	714.31			526.47
Salt River Project							1,546.28	1,469.90			
San Diego Gas & Electric					613.75	546.46	780.79	806.27	739.05	720.49	
Seattle City Light								17.77			
Sierra Pacific Resources								1,442.78			
Southern California Edison					678.88	665.72	641.26	630.89			

Data Source Notes:

[a]*Data from the California Climate Action Registry Power/Utility Protocol public reports, http://www.climateregistry.org/CARROT/public/reports.aspx*

[b]*Data from the Climate Registry Electric Power Sector Protocol public reports, http://www.climateregistry.org/carrot/public/reports.aspx*

Table WW.14.8 California Grid Average Electricity Emission Factors (1990-2007) (lbs/MWh)

Year	CO_2	CH_4	N_2O	CO_2e
1990	1031.14	0.040	0.014	1036.19
1991	994.03	0.037	0.013	998.72
1992	984.42	0.040	0.012	988.87
1993	1007.26	0.037	0.013	1011.95
1994	1071.19	0.040	0.013	1075.94
1995	929.77	0.031	0.012	934.03
1996	827.65	0.029	0.011	831.57
1997	874.96	0.029	0.011	878.88
1998	941.54	0.029	0.011	945.46
1999	917.60	0.031	0.011	921.56
2000	829.50	0.029	0.009	832.82
2001	1009.75	0.033	0.011	1013.75
2002	865.28	0.031	0.010	868.94
2003	888.41	0.031	0.011	892.37
2004	958.49	0.029	0.011	962.41
2005	948.28	0.030	0.011	952.22
2006	889.75	0.031	0.009	893.11
2007	919.64	0.029	0.010	923.26
Sources: Calculated from total in-state and imported electricity emissions divided by total use in MWh. Emissions from California Air Resources Board, Greenhouse Gas Inventory, 1990 – 2004 (November 17, 2007 version), available on line. CO_2e calculated using current 100-yearGlobal Warming Potentials (GWPs)from US EPA.(GWP_{CO2} = 1, GW_{CH4} = 21, GWP_{N2O} = 310).				

Table WW.14.9 eGRID Sub-region 2009 CO_2e Emission Rates

Region	eGRID Sub-region Acronym	eGRID Sub-region Name	Annual CO2 Equivalent Electricity Emission Rate (lb/MWh)
Alaska	AKGD	ASCC Alaska Grid	1,283.82
Alaska	AKMS	ASCC Miscellaneous	523.05
Eastern	FRCC	FRCC All	1,181.63
Eastern	MROE	MRO East	1,600.54
Eastern	MROW	MRO West	1,637.82
Eastern	NYLI	NPCC Long Island	1,353.86
Eastern	NEWE	NPCC New England	734.29
Eastern	NYCW	NPCC NYC/Westchester	612.04
Eastern	NYUP	NPCC Upstate NY	500.35
Eastern	RFCE	RFC East	952.63
Eastern	RFCM	RFC Michigan	1,668.76
Eastern	RFCW	RFC West	1,528.76
Eastern	SRMW	SERC Midwest	1,759.15
Eastern	SRMV	SERC Mississippi Valley	1,006.12
Eastern	SRSO	SERC South	1,332.59
Eastern	SRTV	SERC Tennessee Valley	1,364.92
Eastern	SRVC	SERC Virginia/Carolina	1,041.73
Eastern	SPNO	SPP North	1,825.15
Eastern	SPSO	SPP South	1,606.26
ERCOT	ERCT	ERCOT All	1,186.14
Hawaii	HIMS	HICC Miscellaneous	1,357.46
Hawaii	HIOA	HICC Oahu	1,602.30
Western	CAMX	WECC California	661.20
Western	NWPP	WECC Northwest	823.40
Western	RMPA	WECC Rockies	1,833.41
Western	AZNM	WECC Southwest	1,196.58
Source: eGRID2010 Version 1.0 Sub-region data (Year 2009 Data), http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html			

WW.15 Energy-related Emissions Associated with Wastewater Collection and Treatment

Introduction

The energy demands for collection and treatment of wastewater can be on par with the energy demands for water conveyance, treatment and distribution for many communities. There are many communities where the wastewater emissions may be dwarfed by emission from water conveyance due to extensive pumping requirements over long distances. Conversely, other communities may have significant energy demands from wastewater treatment if those facilities are required to meet stringent effluent discharge requirements and/or they choose not to capitalize on renewable energy opportunities associated with wastewater treatment. Thus, there is no nexus between the energy requirements of water and wastewater management.

The methods described in this section account for the final stages in the water cycle; those associated with wastewater treatment. As with the methods in Appendix F, no consideration is given for renewable energy opportunities within the treatment process. As in method WW.14, methods are implemented from a water cycle perspective. Therefore, double counting with GHG emission sources accounted for in other sectors may be likely. For example, stationary energy consumption at wastewater treatment facilities within a community's boundary may be at risk for double counting. For this reason, GHG emissions from wastewater collection and treatment should not be summed with GHG emissions from other direct sources (i.e. stationary energy consumption).

Several processes exist which, when combined, provide for the GHG emissions of a community's wastewater management strategy. Figure WW.15.1 highlights the different energy consuming processes involved in the collection and treatment of wastewater. The energy intensity of each of these highlighted processes and the volume of wastewater passing through each will need to be known in order to accurately inventory emissions associated with wastewater management. The degree to which each of the processes used for collection and treatment of your community's wastewater is identified, and the energy intensity of each of those processes is known, will define the accuracy of the methods for determining the GHG emissions from wastewater collection and treatment.

Communities may employ a mix of strategies to manage their wastewater needs. It is more common for rural communities, for example, to employ on-site treatment systems. However, these may be found in some urban environments as well, and some rural communities may also be served by a centralized system. The EPA maintains a database (The Clean Watershed Needs Survey - CWNS)[51] that documents the major processes employed, and through this database, state-by-state information is available and reported here. Although the energy demand for on-

[51] http://water.epa.gov/scitech/datait/databases/cwns/index.cfm

site systems is negligible, it is important to identify the percentage in the community that uses these systems so that only those populations that employ the other processes with significant energy demands be considered.

The CWNS database also can be used to determine the percent of the population that employs various degrees of centralized treatment. Generally, as the treatment needs become more stringent, the energy demand increases[52]. The energy demand for each major process modality should be considered and weighted against the population served by that kind of process.

The per capita use of water is rarely equal to the per capita generation of wastewater. Not all water use ends up in the wastewater collection system; waters needed for irrigation and agricultural use are important examples. Conversely, wastewater collection systems in some states may be "combined" systems that include stormwater drainage. Additionally, there may be infiltration in some collection systems. Thus, a table is presented to report default values for the per capita generation of wastewater for each state, again based on the EPA's CWNS database.

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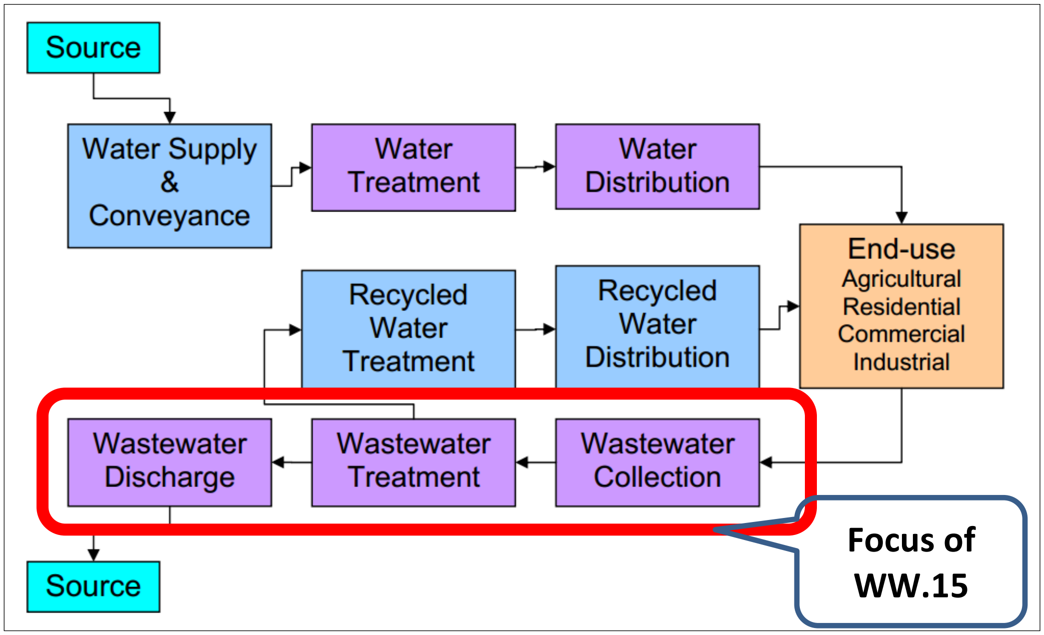
[52] A possible exception to this is the use of some facilities to achieve combined nitrification/denitrification (NDN). Some facilities are reporting *lower* energy demand for NDN than for conventional secondary treatment. Nevertheless, the energy needs for this level of advanced treatment are assumed to be consistent with those described in the CWNS for Advanced Treatment II technologies, which may include other energy intensive processes such as UV disinfection, and microfiltration or reverse osmosis..

Figure WW.15.1 Energy Consuming Processes in the Collection and Treatment of Wastewater[53]



Energy consumption and resulting GHG emissions should be accounted for in each wastewater process highlighted from Figure WW.15. The end-use phase is excluded from analysis. End Use consists of the electricity or fossil fuels used at community residences, commercial buildings or industrial facilities for heating cooling, and final dispersal of water (when these require additional power inputs). End Use emissions will already be contained in calculations done in Appendix C: Built Environment Emission Activities and Sources. Emissions from water supply/conveyance, treatment and distribution *might* be accounted for in Appendix C (or maybe just in part) if your water facilities are located within your community, however, in most cases, these facilities are spread out across numerous jurisdictions.

The wastewater system components in each process in your wastewater system that should be accounted for in this section may include:

- Wastewater Collection:
    - Pumps used to move wastewater to a treatment facility. Much wastewater collection is gravity fed, however lift-station pumps are used when elevation gain is needed.

[53] Klein, Gary, Ricardo Amon, Shahid Chaudhry, Loraine White, et al. California's Water-Energy Relationship: Final Staff Report. Nov. 2005. California Energy Commission. Available at: <http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF>.

- Wastewater Treatment:
  - Pumps within the wastewater treatment plant, plus specific treatment equipment that may include aeration blowers or mixers, pressurized filtration, mechanical dewatering and thickening, heating, digestion equipment.
- Wastewater Discharge:
  - Pumps used to convey treated wastewater back to a receiving body of water or underground injection site. This energy demand may be small and/or may be difficult to consider separately from the demands for treatment if the discharge pumping occurs at the facility.

Uncertainties and Limitations

Like WW.14, for users without site-specific information, this method combines state level usage with nation-wide energy intensities and regional energy to GHG emission conversions, each with different vintages and different degrees of reliability. Such users should be cautioned against using WW.14 or WW.15 to meet regulatory requirements such as those in federal or state mandatory reporting rules or, in California, CEQA. Although Lead Agencies in CEQA have the discretion to choose their preferred emissions estimation method, they must be able to justify why that method is the best for their project. Thus, tools designed to meet regulatory requirements such as EPA's Energy Star Portfolio Manager or CalEEMod[54] for CEQA may be more appropriate for that purpose. Other tools that are more comprehensive such as WESim[55] may be more suitable as well. The best results are from site-specific values that are better than any model regardless of the source.

The results from the 2008 CWNS reported here differ from accounts reported elsewhere based on the 2004 survey such as in the annual EPA National GHG Inventory. The Inventory, for example, suggests that septic systems account for as much as 20% of the nation's treatment for wastewater, lagoons 10% and nitrification/denitrification (NDN) only served 2.4 million people[56]. The results reported in Table WW.15.1 based on the 2008 CWNS instead state that nationwide, septic systems account for 11% of treatment, lagoons 1% and NDN serves a much higher population. Although it is certain that the NDN population is greater than that referenced in the Inventory, the CWNS has other inconsistencies that make any conclusions drawn from it questionable. For example, the CWNS for several states only accounts for roughly 60% nearly half the population and there is a shortfall nationwide of roughly 40 million people between the census estimate for 2008 and the population accounted for in the CWNS. Additionally, it's not clear how accurate the process designations are or if they have been updated with each new survey. EPA has plans to improve the reliability of the database for its 2012 report.

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[54] CalEEMod was developed by the California Air Pollution Control Officers Association for purposes of estimating impacts of projects under CEQA and thus is valid only for California users. See: http://caleemod.com/

[55] http://pacinst.org/resources/wesim/index.htm

[56] http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Chapter-8-Waste.pdf, see page 8-10.

Recommended Approach

The recommended approach for calculating GHG emissions for wastewater collection and treatment, utilizes community-specific energy consumed per unit of wastewater for each process of the wastewater system. If you are not able to obtain community-specific energy intensities, use default factors as outlined below.

Method WW.15 Calculation of Upstream Emissions Associated with Wastewater Collection and Treatment

WW.15 Data Needs

- Wastewater Collection:
  - Proportion of centralized treatment (all treatment modalities except on-site)
  - Population
  - Wastewater generation per capita
  - Default factor for wastewater collection energy intensity
  - Community specific energy to GHG emissions

The method considers only the energy intensity of centralized treatment since on-site systems require no collection energy expenditure.

- Wastewater Treatment:
  - Percentage of on-site treatment systems and split between the centralized system treatment modalities
  - Population
  - Wastewater generation per capita
  - Default factors for each wastewater treatment modality
  - Community specific energy to GHG emissions
  - (See Box WW.15 in the appendix of this document for an example calculation.)

The method considers only the energy intensity of centralized wastewater treatment systems since the energy intensities for on-site septic tanks is negligible. Septic tanks are assumed to comprise most of the on-site systems.

Wastewater discharge energy intensities are assumed to be negligible. Typically, flow exits the facility by gravity into the receiving watersheds. Additionally, for those facilities that do require discharge pumping, often that pumping occurs within the treatment facility and that electricity use is difficult to separate from the treatment plant as a whole.

WW.15 Calculation Method

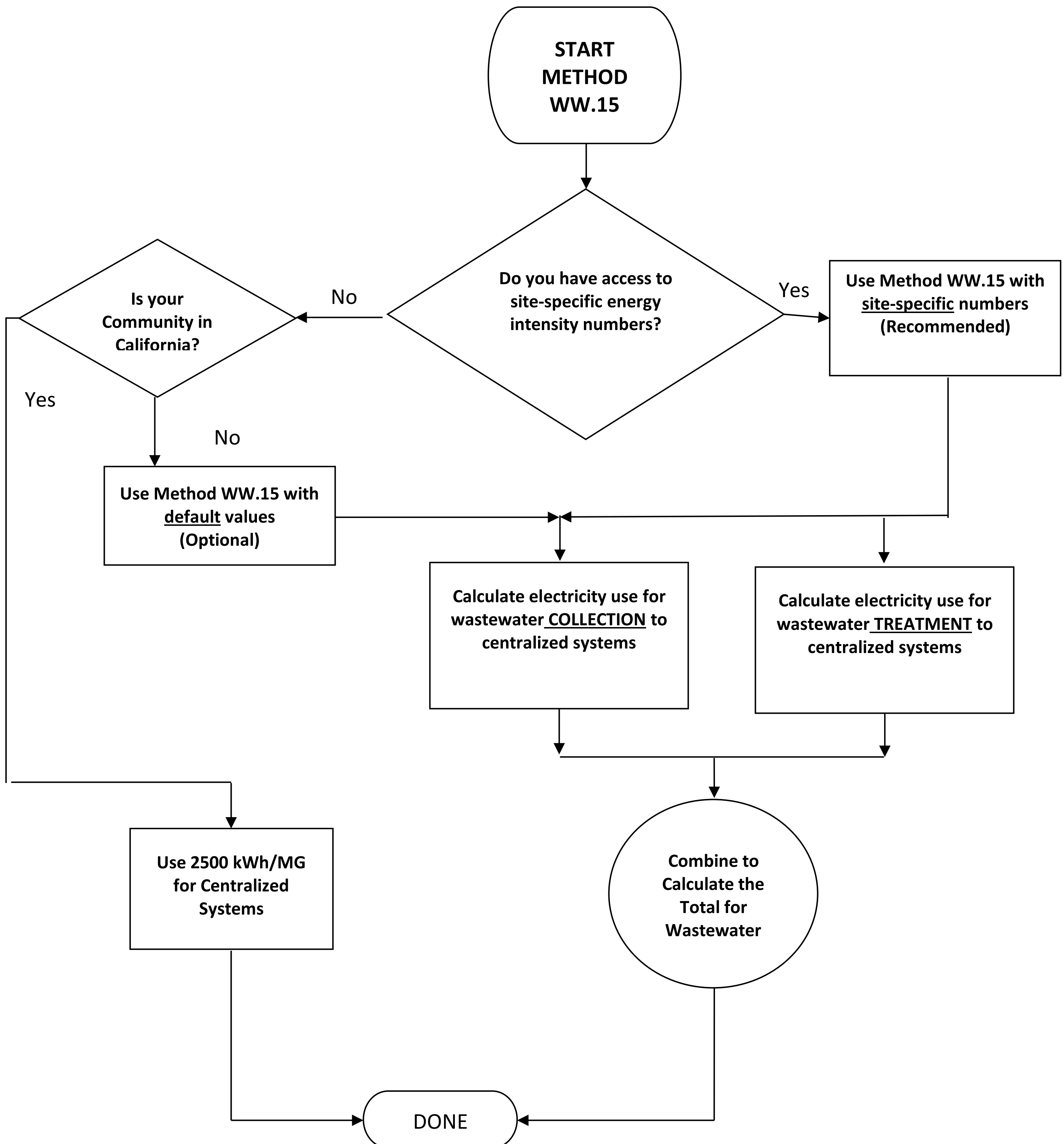
The method presented considers each wastewater element of the water cycle individually and sums the conveyance, treatment and distribution emissions at the end. Note the method assumes on-site treatment has negligible emissions.

Special energy intensities are reported for California because of the unique challenges that accompany that state's water needs. For the wastewater elements, apply 2500 kWh/MG to the population served by centralized systems for California; exclude the on-site systems (e.g., septic tanks) for this analysis.

Figure WW.15.2 can guide the user through the steps required to calculate electricity use from the management of wastewater by a community.

In these methods, if a table or method calls for a size in units of million gallons (MG), that metric can be obtained by multiplying the per capita generation by the population and dividing by one million. Use this approach only if you are certain what type of treatment process is being used and if the population (from all communities, not just yours) served by that process is known. Otherwise, refer to the energy intensities for the default treatment plant sizes.

FIGURE WW.15.2: Decision Tree for Reporting Electricity Use from Wastewater Management within your Community



WASTEWATER COLLECTION

Step 1: Obtain the proportion of centralized treatment. Refer to Table WW.15.1 for a state-by-state distribution if the community specific distribution is not known or obtainable.

Step 2: Multiply the total population of the community by the fraction receiving centralized treatment and the state's per capita wastewater generation, found in table WW.15.1 to get the actual volume sent to the collection system.

Step 3: Multiply the volume sent to the collection system for the community by the energy intensity per unit of wastewater collected. Refer to Table WW.15.2 for wastewater collection default energy intensities if the community specific value is not known. The collection energy intensity for on-site systems is assumed to be negligible. Variability in the energy requirements for wastewater collection is dependent upon local geography and pump efficiency, with flatter topography associated with the lower end of the range[57]. Only deviate from the median value if certain that your terrain and pumping is at either end of the range.

Step 4: Multiply total energy consumed for wastewater collection by the appropriate GHG emissions factor for the community from Table WW.14.7, WW.14.8, or WW.14.9. See Appendix C, section BE.2 for guidance on choosing the appropriate factor.

WASTEWATER TREATMENT

Step 1: Obtain the proportions of on-site and centralized treatment. Refer to Table WW.15.1 for a state-by-state distribution if the community specific distribution is not known or obtainable.

Step 2: Further break down the proportions of the flow sent to centralized systems by the percentages for each system type. Use the defaults for each state found in Table WW.15.2 if community specific distributions are not known or obtainable. Make sure you have accounted for all treatment types present. If you know a particular type is NOT present, you may recalculate the percentages in Table WW.15.2 to reflect that.

Step 3: Multiply the percentages of the total population of the community serviced by each treatment modality by the state's per capita use, found in table WW.15.2 to get the actual volume. Note that trickling filters and rotating biological contactors are considered to be attached growth processes in this table. If the size of the treatment process is not known or cannot be determined, use the default values in Table WW.15.3.

[57] http://pacinst.org/resources/wesim/index.htm, see Table 4.10 on page 35.

Step 4: Multiply the volume sent to each treatment modality by the appropriate process energy consumed per unit of treated wastewater to calculate total energy consumed. Refer to Table WW.15.3 for treatment default energy intensities if the community specific value is not known. Note that trickling filters and rotating biological contactors are considered to be attached growth processes in this table.

Step 5: Multiply total energy consumed for wastewater treatment by the appropriate GHG emissions factor for the community from Table WW.14.7, WW.14.8, or WW.14.9. See Appendix C, section BE.2 for guidance on choosing the appropriate factor.

For the total emissions for wastewater collection and treatment, sum the two elements of collection and treatment. This total should be reported separately from the water total calculated in WW.14, and from the wastewater combustion and process emissions calculated in Appendix F. Also, this total does not include emissions associated with electricity transmission and distribution losses. If you apply the method in Appendix C, Section BE.4 to other electricity use in your inventory, you should also apply it to this total.

***Equation WW.15.1* Total Energy-related Emissions as a Result of Wastewater Collection and Treatment**

Annual CO_2e emissions = Collection + Treatment + Distribution

Collection *= [(Percentage Using Centralized Treatment x Population x per capita Use x Process Energy Intensity- **Collection**) x Energy Emissions Factor x Unit Conversions*

Treatment *= ∑ (Modality Percentage x Population x per capita Use x Modality Specific Process Energy Intensity-**Treatment**)$_{\textit{all centralized treatment modalities}}$ x Energy Emissions Factor x Unit Conversions*

Distribution *= Assumed to be negligible*

Where:

Description		Value
Annual CO_2e emissions	= Total annual emissions from wastewater collection and treatment	Result
Percentage Using Centralized Treatment	= Percentage of wastewater flow not sent to on-site systems like septic tanks	User Input
Population	= Total population of the community, regardless of treatment modality	User Input
Per Capita Use	= Total contributions of wastewater from all sources divided by total population	User Input
Collection Process Energy Intensity	= Energy consumed per unit wastewater processed in the centralized system (kWh/million gallons)	User Input
Modality Specific Process Energy Intensity	= Energy consumed per unit wastewater processed in each treatment modality (kWh/million gallons)	User Input
Energy Emissions Factors	= Standard electricity emissions factors from eGRID, or other verified source	User Input

Table WW.15.1 Wastewater Decentralized Septic and Centralized Treatment Modalities Sources and per Capita Use[58]						
		Centralized Treatment				per Capita Generation
State	Decentralized Septic	Lagoon	Attached Growth	Activated Sludge	NDN	gal/day/capita
Alabama	12%	0%	6%	68%	13%	177
Alaska	29%	0%	0%	71%	0%	202
Arizona	5%	2%	3%	66%	24%	86
Arkansas	3%	4%	3%	88%	1%	166
California	3%	1%	4%	86%	6%	100
Colorado	6%	3%	6%	78%	6%	125
Connecticut	38%	0%	1%	38%	23%	188
Delaware	0%	41%	0%	59%	0%	138
Florida	30%	0%	1%	56%	12%	119
Georgia	1%	0%	1%	76%	22%	145
Hawaii	0%	0%	23%	77%	0%	169
Idaho	2%	17%	12%	54%	15%	123
Illinois	2%	1%	1%	95%	1%	194
Indiana	17%	4%	12%	58%	10%	186
Iowa	1%	3%	12%	73%	11%	147
Kansas	16%	10%	9%	44%	21%	139
Kentucky	5%	0%	13%	82%	1%	149
Louisiana	3%	0%	18%	78%	0%	150
Maine	46%	1%	2%	47%	4%	226
Maryland	23%	0%	0%	27%	49%	118
Massachusetts	18%	0%	1%	43%	37%	165
Michigan	4%	2%	3%	88%	3%	186
Minnesota	22%	1%	0%	34%	42%	129
Mississippi	20%	13%	3%	55%	9%	138
Missouri	26%	3%	25%	42%	3%	187
Montana	7%	3%	3%	72%	15%	151
Nebraska	2%	0%	29%	53%	15%	146
Nevada	1%	0%	23%	38%	38%	83
New Hampshire	4%	0%	0%	96%	0%	176
New Jersey	1%	1%	8%	85%	5%	150
New Mexico	9%	0%	0%	91%	0%	75

[58] Adapted from http://water.epa.gov/scitech/datait/databases/cwns/index.cfm, EPA, 2008.

Table WW.15.1 Continued Wastewater Decentralized Septic and Centralized Treatment Modalities Sources and per Capita Use						
		Centralized Treatment				per Capita Generation
State	Decentralized Septic	Lagoon	Attached Growth	Activated Sludge	NDN	gal/day/capita
New York	17%	0%	1%	64%	17%	178
North Carolina	7%	0%	4%	72%	17%	155
North Dakota	7%	0%	0%	93%	0%	94
Ohio	13%	0%	7%	72%	8%	205
Oklahoma	0%	9%	13%	77%	1%	136
Oregon	1%	1%	3%	60%	34%	118
Pennsylvania	2%	0%	3%	91%	4%	140
Rhode Island	30%	0%	2%	68%	0%	183
South Carolina	16%	1%	0%	81%	2%	218
South Dakota	15%	0%	74%	11%	0%	112
Tennessee	7%	3%	7%	83%	0%	184
Texas	3%	1%	0%	88%	8%	114
Utah	2%	10%	36%	41%	11%	129
Vermont	27%	1%	5%	66%	0%	142
Virginia	8%	0%	1%	53%	38%	121
Washington	16%	1%	1%	66%	16%	161
West Virginia	39%	0%	1%	60%	0%	185
Wisconsin	1%	2%	4%	85%	8%	153
Wyoming	0%	29%	22%	48%	0%	107
Total Population (50 states + DC + Territories)	11%	1%	5%	72%	11%	144

Table WW.15.2 Range of Energy Intensities for Wastewater Collection[59]	Collection Energy Intensity (kWh/MG)
Low Value	140
Median Value	280
High Value	440

Table WW.15.3 Range of Energy Intensities for Wastewater Treatment

Size: / Treatment Modality	Default Size 1-5 MGD (kWh/MG)	5-20 MGD (kWh/MG)	20-50 MGD (kWh/MG)	50+ MGD (kWh/MG)
Conventional Aerobic[60]	2300	2000	1600	1400
Lagoon[61]	Use 1150 for all sizes			
Attached Growth[62]	1500	1400	1200	960
NDN[63]	3300	3000	2400	1800

[59] http://pacinst.org/resources/wesim/index.htm, see Table 4.10 on page 35.
[60] Ibid. See Table 4.11 on page 36, median values used.
[61] Energy Index Development for Benchmarking Water and Wastewater Utilities, AWWA Research Foundation, et al., page 141. 2007
[62] http://pacinst.org/resources/wesim/index.htm, see Table 4.11 on page 36., low values used.
[63] Ibid., see Table 4.13 on page 36., median values used.

Example Calculations for Wastewater and Water Activities and Sources Emissions

Box WW.1.a below gives an example of how to calculate the CH_4 emission from devices designed to combust digester gas using the methodology consistent with the EPA and California Air Resources Board mandatory reporting rules if the CH_4 fraction of the gas is known.

Box WW.1.a Example Calculation of CH_4 Emissions from the Incomplete Combustion of Anaerobic Digester Gas with Fraction of CH_4 Known		
A wastewater facility generates 1,000,000 ft^3 per day of digester gas containing 65% CH_4. The BTU content of the digester gas is not available. Based on this scenario the CH_4 emissions from the incomplete combustion of digester biogas can be calculated as follows		
Description		Value
CH_4 emissions	= Total CH_4 emitted by incomplete combustion ($mtCO_2e$)	Result
Digester gas	= Measured standard cubic feet of digester gas produced per day (std ft^3/ day)	1,000,000
fCH_4	= Fraction of CH_4 in biogas	0.65
BTU_{CH4}	= Default BTU content of CH_4, higher BTU content (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{CH4}	= CH_4 emission factor (kg CH_4/MMBTU)	3.2×10^{-3} kg CH_4 per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2e	GWP[64]
Sample Calculation: *Annual CH_4 emissions* = $(1{,}000{,}000 \times 0.65 \times 1028 \times 10^{-6} \times (3.2 \times 10^{-3}) \times 365.25 \times 10^{-3}) \times 21$ = 18 $mtCO_2e$		

- If a facility's BTU content is known, it's acceptable for use. *Equation WW.1.b* should be utilized; this entails conducting *Equation WW.1.a* with the exception of replacing the fraction of CH_4 in biogas (fCH_4) and the default BTU content of CH_4 (BTU_{CH4})with the facility's specific values ($BTU_{digester\ gas}$).

[64] See Appendix GWP for value.

- If only the population served is known, it's acceptable for use. *Equation WW.1.(alt)* should be utilized; this entails conduction *Equation WW.1.*a with the exception of replacing the measured standard cubic feet of digester gas produced per day (Digester gas), from *Equation WW.1.a*, with the population served by anaerobic digester (P) multiplied by the measured standard cubic feet of digester gas produced per person per day (1.0).

Box WW.3 below gives an example of how to calculate biogenic CO_2 emissions from the combustion of digester gas.

Box WW.3 **Example Calculation of Biogenic CO_2 Emissions from Digester Gas Combustion**		
A wastewater facility generates 1,000,000 ft^3 per day of digester gas. The BTU content of the gas is not available. Based on this scenario the biogenic CO_2 emissions from the combustion of digester biogas can be calculated as follows:		
Description		Value
CO_2 emissions	= Total annual biogenic CO_2 emitted by combustion of biogas ($mtCO_2e$)	Result
Description		Value
Digester gas	= Standard cubic feet of digester gas produced per day (std ft^3/day)	1,000,000
BTU_{CO2}	= BTU content of biogas (MMBTU/scf)	0.000841
EF_{CO2}	= Emission factor for CO_2 (kg CO_2/ MMBTU)	52.07
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion factor kg to mt	10^{-3}
Sample Calculation *Annual CO2 emissions = Digester gas * BTU_{CO2} * EF_{CO2} * 365.25 * 10^{-3}* *=1000000*0.000841*52.07*365.25*10^{-3}* =15995 $mtCO_2$		

Box WW.4 below gives an example of how to calculate the CH_4 emissions from the combustion of WWTP residuals on a wet weight basis.

Box WW.4 **Example Calculation of CH_4 Emissions from the Combustion of WWTP Residuals on a Wet Weight Basis**		
A wastewater facility sends out to incineration 2,000 wet tons per day of residuals. Based on this scenario the CH_4 emissions from the combustion of WWTP residuals on a wet weight basis can be calculated as follows		
Description		Value
CH_4 emissions	= Total CH_4 emitted by residuals combustion ($mtCO_2e$)	Result
Wet Weight	= Wet weight of sludges or biosolids incinerated (ton/day)	User Input
EF_{CH4}	= CH_4 emission factor (g CH_4/ton)	9.7 g CH_4 per ton
365.25	= Conversion factor (day/year)	365.25
10^{-6}	= Conversion from g to mt	10^{-6}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2e	GWP[65]
Sample Calculation: *Annual CH_4 emissions = $(2{,}000 \times 9.7 \times 365.25 \times 10^{-6}) \times 21$* *= 163 $mtCO_2e$*		

- *Equation WW.5* should be utilized to calculate the N_2O emissions from the combustion of WWTP residuals on a wet weight basis. This entails conducting *Equation WW.4* with the exception of replacing the CH_4 emission factor (EF_{CH4}) with the N_2O emission factor (EF_{N2O}) and replacing the GWP of CH_4 (21) with GWP of N_2O (310).

[65] See Appendix GWP for value.

Box WW.6.(alt) below gives an example of how to calculate emissions from a lagoon facility when the only data obtainable is population served by lagoon

Box WW.6(alt) **Example Calculation of CH_4 emissions from a Lagoon when only Population Served by Lagoon is Known**		
A lagoon collects sewage from a nearby town. The population served by this lagoon is 10,000. They have an industrial factory that discharges more than 25,000 gpd of wastewater. Based upon this scenario, the inputs are as follows		
Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by lagoon ($mtCO_2e$)	Result
P	= Population served by lagoon	10,000
Description		Value
$F_{ind\text{-}com}$	= Factor for industrial and commercial discharge waste	1.25
BOD_5 load	= Amount of BOD_5 treated per day (kg BOD5/person/day)	0.090
F_P	= Fraction of BOD_5 removed in primary treatment	0.325
Bo	= Maximum CH_4 producing capacity for domestic wastewater (kg CH_4/BOD_5 removed)	0.6
MCF_a	= CH_4 correction factor for anaerobic systems	0.8
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2e	GWP[66]
Sample Calculation: *Annual CH_4 emissions = ((10000 x 1.25) $\times$ 0.090 $\times$ (1-0.325) $\times$ 0.6 $\times$ 0.8 $\times$ 365.25 $\times 10^{-3}$) $\times$ 21* *=3062.1 $mtCO_2e$*		

- If the BOD_5 load is known, it's acceptable for use. *Equation WW.6* should be utilized; this entails conduction *Equation WW.6.(*alt) with the exception of replacing the population served by lagoon (P), the factor for industrial and commercial discharge waste ($F_{ind\text{-}com}$), and the amount of BOD_5 treated per day (BOD_5 load) with the known amount of BOD_5 load treated per day (BOD_5 load).

[66] See Appendix GWP for value.

Box WW.8 below gives an example of how to calculate N_2O emissions from a WWTP without nitrification/denitrification.

Box WW.8 **Example Calculation of N_2O Process Emissions from WWTP without Nitrification or Denitrification**		
A WWTP serves a population of 10,000 people. This WWTP does not use nitrification/denitrification and receives a significant amount of industrial waste demonstrated to have high nitrogen. Based upon this scenario, the inputs are as follows		
Description		Value
N_2O emissions	= Total annual N_2O emitted by WWTP processes ($mtCO_2e$)	Result
P	= Population served by WWTP	10,000
$F_{ind\text{-}com}$	= Factor for industrial or commercial discharge	1.25
$EF_{w/o\ nit/denit}$	= Emission factor for a WWTP without nitrification/denitrification	3.2
Person equivalent	= 100 gallons per day	
10^{-6}	= Conversion from g to mt (mt/g)	10^{-6}
GWP_{N_2O}	= Global Warming Potential	GWP[67]
Sample Calculation: Annual N_2O *emissions* $= ((10000 \times 1.25) \times 3.2 \times 10^{-6}) \times 310$ $= 12.4\ mtCO_2e$		

- WWTPs with nitrification or denitrification should utilize *Equation WW.7*; this entails conducting *Equation WW.8* with the exception of replacing the emission factor for a WWTP without nitrification/denitrification ($EF_{w/o\ nit/denit}$=3.2) with the emission factor for a WWTP with nitrification/denitrification ($EF_{nit/denit}$=7).

[67] See Appendix GWP for value.

Box WW.9 below gives an example of how to calculate CO_2 emissions from methanol use.

Box WW.9 **Example Calculation of CO_2 Emissions from Methanol Use**		
A WWTP uses 10 mt/day of methanol for nitrogen removal and employs anaerobic digestion. Based upon this scenario, the inputs are as follows:		
Description		Value
Annual CO_2 emissions	= Total annual CO_2 emitted ($mtCO_2e$)	Result
Methanol load	= Amount of neat chemical used per day (mt CH_3OH/day)	10
F	= Factor to be applied based on WWTP's sludge treatment type: • Raw Solids Disposal 80% • **Anaerobic Digestion 60%** • Solids Combustion 100%	0.80
44.01/32.04	= Molecular weight ratio of 44.01 (for CO_2) to 32.04 (for CH_3OH)	1.37
365.25	= Conversion factor from days to year	365.25
Sample Calculation: *Annual CO2e emissions assuming anaerobic digestion = (10 x 0.80 x 1.37 x 365.25)* *= 4,000 $mtCO_2e$*		

Box WW.11(alt) below gives an example of how to calculate emission from a septic system when the only data the user can obtain is the population served by septic system.

Box WW.11(alt)
Example Calculation of CH_4 emissions from a Septic System when only Population Served by System is Known

The residential areas of a small town are served by septic systems. The population of the town is 2,000 people and thus considered rural. Based upon this scenario, the inputs are as follows:

Description		Value
CH_4 emissions	= Total CH_4 emitted by septic systems ($mtCO_2e$)	Result
P	= Population served by septic systems	2000 * 0.90
BOD_5 load	= Amount of BOD_5 treated per day (kg BOD5/person/day)	0.090
Bo	= Maximum CH_4 producing capacity for domestic wastewater (kg CH_4/BOD5 removed)	0.6
MCF_s	= CH_4 correction factor for septic systems	0.22
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2e	21[68]
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}

Sample Calculation:

*P = total population * default rural*

*P = 2000*0.90*

P = 1800

Annual CH_4 emissions $=(P \times BOD_5\ load \times Bo \times MCFs \times 365.25 \times 10^{-3}) \times GWP$

$= (1800 \times 0.090 \times 0.6 \times 0.22 \times 365.25 \times 10^{-3}) \times 21$

$= 180\ mtCO_2e$

- If the BOD_5 load is known, it's acceptable for use. *Equation WW.11.a* should be utilized; this entails conduction *Equation WW.11.b* with the exception of replacing the population served by septic system (P) and the amount of BOD_5 treated per day (BOD_5 load) with the known amount of BOD_5 treated per day (BOD_5).

[68] See Appendix GWP for value.

Box WW.12(alt) below gives an example of how to calculate N_2O emissions from the effluent conversion from a WWTP.

Box WW.12(alt) **Example Calculation of N_2O Emissions from Effluent Conversion**		
A WWTP serves a population of 10,000 people. This WWTP also employs nitrification/denitrification in its treatment process; however, the amount of nitrogen in the effluent discharge is unknown. The community has a significant industrial base. Based upon this scenario, the inputs are as follows:		
Description		Value
N_2O emissions	= Total annual N_2O emitted by effluent conversion of discharged nitrogen ($mtCO_2e$)	Result
P	= Population served by WWTP	10,000
$F_{ind\text{-}com}$	= Factor for industrial or commercial discharge	1.25
Total N-Load	= Average total nitrogen per day (kg N/day)	0.026
N uptake	= Nitrogen uptake for cell growth (kg N/kg BOD_5)	0.05
BOD_5	= Amount of BOD_5 produced per person per day (kg BOD_5/person/day)	0.090
EF	= Emission factor (kg N_2O-N/kg sewage-N discharged)	0.005
44/28	= Molecular weight ratio of N_2O to N_2	1.57
F*plant*	= Fraction of nitrogen removed from the WWTP with nitrification/denitrification	0.7
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[69]
Sample Calculation: Annual N_2O *emissions* $= ((10000 \times 1.25) \times (0.026 - 0.05 \text{ x } 0.090) \times 0.005 \times 1.57 \times (1 - 0.7) \times 365.25 \times 10^{-3}) \times 310$ $= 7.17\ mtCO_2e$		

- If the total N-load is known, it's acceptable for use. *Equation WW.12.a* should be utilized; this entails conduction *Equation WW.12.(alt)* with the exception of replacing the population served by WWTP (P), the factor for industrial or commercial discharge ($F_{ind\text{-}com}$), the average total nitrogen per day (total N-load), the nitrogen uptake for cell growth (N uptake) and the amount

[69] See Appendix GWP for value.

of BOD_5 produced per person per day (BOD_5) with the known average total nitrogen per load (total N-load).

Box WW.13$_{CH4}$ below gives an example of how to calculate attributed CH_4 emissions from a community.

Box WW.13$_{CH4}$ **Example Calculation of attributed CH_4 emissions**		
A entire community of 10,000 people is served by a centralized WWTP. This treatment plant serves a total population of 50,000 people and produces 500 $mtCO_2e$ in CH_4 a year. Based upon this scenario, the following inputs are as follows		
Description		Value
Attributed CH_4 Emissions	= Annual CH_4 credited to the community ($mtCO_2e$)	Result
P	= Population of the community served by the given WWTP	10,000
P_{tot}	= Total population the WWTP serves	50,000
E	= Total CH_4 produced by WWTP ($mtCO_2e$)	500
Sample Calculation: *Attributed CH_4 emissions = (10000/50000)*500* *= 100 $mtCO_2e$*		

- *Equation WW.13$_{N2O}$* should be utilized to calculate the attributed N_2O emissions. This entails conducting *Equation WW.13$_{CH4}$* with the exception of replacing the population of community served by given WWTP (P), the total population the WWTP serves (P_{tot}) and the total CH_4 produced by WWTP (E) with the scenario-specific factors.

Box WW.14 below gives an example of how to calculate the energy-related emissions from water supply and treatment from a community.

Box WW.14

Energy-related Emissions from Water Distribution and Treatment

The residential sector of a city in Indiana has a population of 50,000 people. Water is imported from outside this community. Assume default values to calculate the energy intensity of water extraction/conveyance, treatment and distribution.

Description		Value
Annual CO_2e emissions	= Total annual emissions from water distribution and treatment	Result
Population	= Population in the community	50,000 people
per Capita Water Use	= Water use in gallons per day per capita from user supplied value or Table WW.14.1	145 gal/d/capita
Groundwater Supplied	= Fraction of the population served by groundwater from user supplied value or Table WW.14.1	0.39
Surface Water Supplied	= Fraction of the population served by surface water from user supplied value or Table WW.14.1	0.35
Groundwater Extraction Energy Intensity	= Electricity required to pump the groundwater from the water table depth to the surface from user supplied value or Table WW.14.2	540 kWh/MG
Water Conveyance Energy Intensity	= Electricity required to pump either groundwater or surface water from the source to the water treatment facility from user supplied value or Table WW.14.3	3000 kWh/MG
Daily Flow to Treatment Plant	= Average daily flow to the surface water treatment plant, needed if Table WW.14.4 is used	2.5 MGD
Surface Water Treatment Energy Intensity	= Electricity required to treat the water to drinking water standards either from user supplied value or Table WW.14.4	750 kWh/MG
Water Distribution Energy Intensity	= Electricity required to pump the treated groundwater or surface water from the treatment facility to the end user from user supplied value or Table WW.14.5	540 kWh/MG

Description		Value
Electricity Emission Factors	= Standard electricity emissions factors from eGRID (Table BE.10), or other verified source.	1,528.76 lb CO_2 eq./MWh (693.44 kg CO_2 eq./MWh)
10^{-6}	= Conversion from gallons to million gallons (MG/gal)	0.000001
10^{-3}	= Conversion from kWh to MWh (MWh/kWh)	0.001
10^{-3}	= Conversion from kg to MT (MT/kg)	0.001

Annual CO_2e Emissions**= **Extraction + Conveyance + Treatment + Distribution

Sample Calculation:

Annual Groundwater Extraction Emissions	*= (50,000 x 145 x 365.25 x 0.39 x 0.000001 x 540 x 693.44 x 0.001 x 0.001)* *=* ***387 mtCO_2e***
Annual Groundwater and Surface Water Conveyance Supply Emissions	*= (50,000 x 145 x 365.25 x (0.39 + 0.35) x 0.000001 x 3000 x 693.44 x 0.001 x 0.001)* *=* ***4073 mtCO_2e***
Annual Surface Water Treatment Emissions	*= (50,000 x 145 x 365.25 x 0.35 x 0.000001 x 750 x 693.44 x 0.001 x 0.001)* *=* ***482 mtCO_2e***
Annual Groundwater and Surface Water Distribution Emissions	*= (50,000 x 145 x 365.25 x (0.39 + 0.35) x 0.000001 x 540 x 693.44 x 0.001 x 0.001)* *=* ***737 mtCO_2e***
Total Emissions from Residential Water Consumption	*= 387 + 4073 + 482 + 737* *=* ***5679 mtCO_2e***

Box WW.15 Example Calculation of Energy-Related Emissions from Wastewater Collection and Treatment

The residential sector of a city in Indiana has a population of 50,000 people. The community does not operate its own wastewater treatment nor does it have the resources to determine site-specific results. Assume default values to calculate the energy intensity of wastewater collection and treatment.

Description		Value
Annual CO_2e emissions	= Total annual emissions from wastewater collection and treatment	Result
Population	= Population in the community	50,000 people
per Capita Wastewater Generation	= Wastewater generation in gallons per day per capita from user supplied value or Table WW.15.1	186 gal/d/capita
Centralized Percentage	= Fraction of the population served by all centralized systems from user supplied value or Table WW.15.1	0.84
Percentage Served by Lagoons	= Fraction of the population served by centralized lagoon or pond systems from user supplied value or Table WW.15.1	0.04
Percentage Served by Attached Growth	= Fraction of the population served by centralized trickling filters or rotating biological contactors from user supplied value or Table WW.15.1	0.12
Percentage Served by Conventional Activated Sludge	= Fraction of the population served by centralized conventional activated sludge systems from user supplied value or Table WW.15.1	0.58
Percentage Served by NDN	= Fraction served by centralized Nitrification or Nitrification/Denitrification activated sludge systems from user supplied value or Table WW.15.1	0.1

Process Energy Intensity for Wastewater Collection	= Electricity needed to convey untreated sewage from its various sources to a centralized treatment facility from user defined value or Table WW.15.2	280 kWh/MG
Process Energy Intensity for Wastewater Treatment by Lagoons	= Electricity needed to treat sewage to effluent standards by a centralized lagoon or pond from user defined value or Table WW.15.3	1150 kWh/MG
Process Energy Intensity for Wastewater Treatment by Attached Growth System	= Electricity needed to treat sewage to effluent standards by a centralized attached growth system from user defined value or Table WW.15.3	1500 kWh/MG
Process Energy Intensity for Wastewater Treatment by Conventional Activated Sludge Sample Calculation:	= Electricity needed to treat sewage to effluent standards by a centralized conventional activated sludge from user defined value or Table WW.15.3	2300 kWh/MG
Annual Surface Supply Emissions	= ***mtCO$_2$e***	
Process Energy Intensity for Wastewater Treatment by NDN	= Electricity needed to treat sewage to effluent standards by a centralized NDN plant from user defined value or Table WW.15.3	3300 kWh/MG
Annual Groundwater Supply Emissions	= ***mtCO$_2$e***	

Sample Calculation:	
Annual Collection Emissions	*= (50,000 x 186 x 365.25 x 0.84 x 0.000001 x 280 x 693.44 x 0.001 x 0.001)* *=* ***558 mtCO_2e***
Annual Wastewater Treatment Emissions	*= (50,000 x 186 x 365.25 x 0.000001 x ((0.04 x 1150) + (0.12 x 1500) + (0.58 x 2300) + (0.1 x 3300)) x 693.44 x 0.001 x 0.001)* *=* ***4,451 mtCO_2e***
Total Emissions from Residential Wastewater Management Water Consumption	*= 558 + 4451* *=* ***5,300 mtCO_2e***