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# Toolbox for Water Utility Energy and Greenhouse Gas Emission Management

Subject Area: Management and Customer Relations

# Toolbox for Water Utility Energy and Greenhouse Gas Emission Management

## About the Water Research Foundation

The Water Research Foundation is a member-supported, international, 501(c)3 nonprofit organization that sponsors research that enables water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.

The Foundation's mission is to advance the science of water to improve the quality of life. To achieve this mission, the Foundation sponsors studies on all aspects of drinking water, including resources, treatment, and distribution. Nearly 1,000 water utilities, consulting firms, and manufacturers in North America and abroad contribute subscription payments to support the Foundation's work. Additional funding comes from collaborative partnerships with other national and international organizations and the U.S. federal government, allowing for resources to be leveraged, expertise to be shared, and broad-based knowledge to be developed and disseminated.

From its headquarters in Denver, Colorado, the Foundation's staff directs and supports the efforts of more than 800 volunteers who serve on the board of trustees and various committees. These volunteers represent many facets of the water industry, and contribute their expertise to select and monitor research studies that benefit the entire drinking water community.

Research results are disseminated through a number of channels, including reports, the Website, Webcasts, workshops, and periodicals.

The Foundation serves as a cooperative program providing subscribers the opportunity to pool their resources and build upon each others' expertise. By applying Foundation research findings, subscribers can save substantial costs and stay on the leading edge of drinking water science and technology. Since its inception, the Foundation has supplied the water community with more than $460 million in applied research value.

More information about the Foundation and how to become a subscriber is available at **www.WaterRF.org**.

# Toolbox for Water Utility Energy and Greenhouse Gas Emission Management

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and

**Global Water Research Coalition (GWRC)**
Alliance House, 12 Caxton St., London SW1H 0QS, England

Published by:

Water Research Foundation℠

# DISCLAIMER

This study was jointly funded by the Water Research Foundation (Foundation), New York State Energy Research and Development Authority (NYSERDA), and the Global Water Research Coalition (GWRC). The Foundation, NYSERDA, and GWRC assume no responsibility for the content of the research study reported in this publication or for the opinions or statements of fact expressed in the report. The mention of trade names for commercial products does not represent or imply the approval or endorsement of the Foundation, NYSERDA, or GWRC. This report is presented solely for informational purposes.

ISBN 978-1-60573-185-8

Printed in the U.S.A.

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# FOREWORD

The Water Research Foundation (Foundation) is a nonprofit corporation dedicated to the development and implementation of scientifically sound research designed to help drinking water utilities respond to regulatory requirements and address high-priority concerns. The Foundation's research agenda is developed through a process of consultation with Foundation subscribers and other drinking water professionals. The Foundation's Board of Trustees and other professional volunteers help prioritize and select research projects for funding based upon current and future industry needs, applicability, and past work. The Foundation sponsors research projects through the Focus Area, Emerging Opportunities, and Tailored Collaboration programs, as well as various joint research efforts with organizations such as the U.S. Environmental Protection Agency and the U.S. Bureau of Reclamation.

This publication is a result of a research project fully funded or funded in part by Foundation subscribers. The Foundation's subscription program provides a cost-effective and collaborative method for funding research in the public interest. The research investment that underpins this report will intrinsically increase in value as the findings are applied in communities throughout the world. Foundation research projects are managed closely from their inception to the final report by the staff and a large cadre of volunteers who willingly contribute their time and expertise. The Foundation provides planning, management, and technical oversight and awards contracts to other institutions such as water utilities, universities, and engineering firms to conduct the research.

A broad spectrum of water supply issues is addressed by the Foundation's research agenda, including resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide a reliable supply of safe and affordable drinking water to consumers. The true benefits of the Foundation's research are realized when the results are implemented at the utility level. The Foundation's staff and Board of Trustees are pleased to offer this publication as a contribution toward that end.

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# ACKNOWLEDGMENTS

This project was funded by the Water Research Foundation, the New York State Energy Research and Development Authority (NYSERDA), and the Global Water Research Coalition (GWRC). This study would not have been possible without the insights, efforts, and dedication of many individuals and organizations. These include the members of the research team, project advisory committee (PAC) members (as listed below), and the project managers. Sincere thanks to the following personnel of MWH for contributing to the content and review of the document: Maria Chau, Adrian Johnson, Gillian Hand-Smith, Daniel Brooke, Meta Schouten, Kuang-Ping Chiu, Jeff Hlad, Mark Allen, Bert Wellens, Charlotte van Erp, Zakir Hirani, Arun Subramani, Luis Matheus, and Garrett B Hazelton.

The research team would like to thank the following utilities for their participation in the project proposal and report: District of Columbia Water and Sewer Authority, City of Batavia, Metropolitan Water Reclamation District of Greater Chicago, Sweetwater Authority, Metropolitan Water District of Southern California, City of Los Angeles Bureau of Sanitation, Coachella Valley Water District, Public Utilities Board - Singapore, Long Beach Water Department, City of San Diego, Denver Water, United Utilities, and the Los Angeles Department of Water and Power.

The research team would also like to thank the following organizations for providing information for the utility survey: Yorkshire Water, Northumbrian Water, Scottish Water, Southern Water, United Utilities, South East Water, Western Water, Melbourne Water, Water Corporation, Water Care, Palmerton North, Water Board Veluwe, Coachella Valley Water District, District of Columbia Water and Sewerage Authority, Denver Water, Los Angeles Bureau of Sanitation, Metropolitan Water District of Southern California, City of San Diego, and Tarrant Regional Water District, as well as the three utilities that requested anonymity. Special thanks also go to the following utility personnel for their help in providing the case study information: Adam Moke, Jose Gutierrez, Shahrouzeh Saneie, and Omar Moghaddam of LABOS; Michael Rojas of MWDSC, and Elizabeth Sala of West Basin MWD.

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# EXECUTIVE SUMMARY

## OBJECTIVES

The water industry is focusing efforts on optimizing water usage with minimal energy inputs. This shift toward more sustainable options is in response to the need to mitigate climate change and to manage associated regulatory, operational and cost challenges. Available energy management and greenhouse gas (GHG) accounting tools are proliferating in response to differing location and sector specific needs for reporting, carbon trading, and facility optimization strategies. In order to support the specific needs of the water sector, it is critical to assess the applicability of existing tools and develop an energy and GHG emissions toolbox that the water industry can utilize effectively on a global scale.

The primary objective of this project was to develop a globally harmonized framework for energy use and GHG emission assessments for the water industry. The study consisted of an international review focused on addressing the following questions:

- What tools are commonly used by water agencies to measure or track energy and GHG emissions across the urban water cycle and what are their capabilities relative to program reporting or process optimization needs?
- What underlying models and algorithms support these tools and what additional research is needed to improve their accuracy and specificity?
- What strategies are needed in order to work toward a common set of best practices that could be harmonized across utilities and geographic regions?

## BACKGROUND

The demand for energy is increasing in many treatment processes due to more stringent treatment requirements and/or poorer quality source water options, among other reasons. Greenhouse gases (GHGs) are a direct result of energy consumption and energy use is the principal source of GHG emissions at any water or wastewater treatment plant. The release of these GHGs is causing changes in our global climate, which are directly impacting the quantity and quality of both source and receiving waters, and may also impact process operations through unanticipated fluctuations of temperature and precipitation. The conflicting pressures of increased energy consumption and requirements to reduce GHG emissions are an increasing concern to water utilities.

There are numerous choices in methodologies, protocols and tools for GHG accounting and energy assessment and it can be challenging for a utility to understand which of these may be most applicable to their facility. This diversity in available resources is driven in part by the segmentation of research and regulation on a regional basis. Research has been conducted that is specific to the operating conditions of a given geography; methodologies have been tailored to the specific regulatory needs of a country or region; and tools have then been molded around that research, regulation and the specific units of measure (e.g., Metric or Imperial) in use in that area.

Given the above challenges and pressures, it is clear that the water industry needs a harmonized approach to energy and GHG accounting which would enable effective and comparable reporting and solutions identification. A harmonized framework can assist utilities in improving their GHG reporting, influencing the nature of existing or pending regulations, reducing the operating challenges and costs of reporting, and improving relations with their communities through accurate and transparent reporting.

## APPROACH

The following tasks were performed in order to address the objectives of this research effort:

- A literature review assessed the research related to GHG accounting and energy management for the water sector. A comprehensive list of tools applicable for energy use and GHG accounting for the water industry were assessed. Though many utilities use their own spreadsheet solutions, the tools reviewed included only complete, stand-alone solutions available either from commercial vendors or as free-ware through public agencies.
- A global utility survey was conducted in order to understand water sector reporting needs, how they are being met, and what tools and methodologies are being used. An assessment was made of the modeling needed for GHG accounting across the urban water cycle and the on-going research efforts in these areas.
- A framework was created for establishing comparability of the standards used in navigating across the range of GHG accounting inputs, outputs and associated impacts. This framework is intended for use by utilities in regions that lack regulatory clarity.
- Case studies were performed demonstrating how three different subsector water utilities have conducted GHG accounting.

## RESULTS/CONCLUSIONS

### *Water Sector Regulations for GHG & Energy Reporting*

Water utilities around the world are responding to energy use pressures and GHG reporting needs differently. This variability is driven by three fundamentally different situations that utilities are facing with respect to GHG reporting and energy use requirements: (i) regions with clearly mandated regulatory reporting requirement for either/both GHG and energy, such as the UK; (ii) regions with uncertain or complex regulatory reporting requirements, where some combination of national, state/provincial and voluntary requirements have created a mixture of standards and reporting requirements, such as in the US and the EU; and (iii) regions without regulatory reporting requirements but with some pressure to monitor or reduce GHGs or energy use, such as South Africa and Singapore. In the first type of environment the reporting standards are clear and tools are in place to enable this reporting. In the second and third types of environment the reporting requirements are unclear and present a variety of options for protocols, methodologies and available tools.

Many water organizations that exist in regions of the world that have mandatory reporting requirements do not have GHG emissions or energy usage levels high enough to trigger mandatory reporting. It is possible that the threshold levels will change and possibly become lower as reporting becomes more common and mitigation efforts drive a greater degree of scrutiny. Many facilities have also chosen to report on a voluntary basis as part of a stewardship program or in anticipation of future mandatory regulations.

GHG Standards and Equations for Measurement

GHG emissions in the potable water and wastewater sector are primarily a result of energy consumption, but non $CO_2$ emissions during wastewater process collection and treatment must not be neglected due to the higher $CO_2$ equivalency of $CH_4$ and $N_2O$. The release of GHGs due to energy consumption occurs from moving water great distances and treating water to achieve high quality standards.

At present, the equations for direct GHG emissions from water treatment processes are based on global averages and represent a 'top-down' approach to estimating GHG releases across the water industry. Significant research is being conducted into the actual release of GHGs from different water treatment processes at the facility level. This research is resulting in improved methodologies for GHG accounting that are based on a 'bottom-up' or facility level estimation. However, there are additional studies underway and there is research which is still needed in order to quantitatively understand the impact of treatment process design and operational variables on emission outputs. Continued research into this level of emissions, and consolidating this cumulative body of knowledge into a set of facility-level, bottom-up accounting methodologies is the essential work remaining for the water sector.

### *Tools for GHG and Energy*

A summary of key characteristics of available tools for GHG and energy in the water sector show that most were developed for wastewater applications and not for drinking water applications. Since the major source of GHG emissions from drinking water facilities is due to energy consumption, some of the energy management and estimation tools discussed in a subsequent section of this review may prove beneficial to carbon footprinting for water treatment facilities.

A review of Life Cycle Assessment (LCA) tools was also conducted, and although a significant amount of information is available on these tools, very little information is reported on the applicability of these tools for the water sector. Most of examples on the applicability of these tools for water are from European and Australian studies. The application of life cycle assessment is still not widely used by utilities in the US.

### *Industry Survey Results and Industry Needs*

Several industry needs to better fulfill mandatory and voluntary GHG emissions reporting were identified over the course of reviewing the survey responses:

- Better harmonization between international regulations or preparation of position papers that clearly specify the key differences that will impact the precision and/or accuracy of reported emissions.
- Better oversight of carbon emissions tools, particularly those internally developed by water utilities within countries without mandated approaches specified in regulations.
- Better communication and transparency amongst water industry professionals about tool development, perhaps through an industry-sponsored committee dedicated to the harmonization of GHG reporting protocols and tools.

- Translation of developed tools that calculate emissions as a function of processes, such as CHEApet, BEAM, and/or BioWin into industry-specific design and operational guidance documents. Currently, the ability to identify improvements and specific losses for each treatment step is missing because carbon emissions are not calculated individually within each process. This information is being generated and when available in the near future, should be consolidated into some sort of best practices compendium.

### *Framework for Analysis, and Case Studies*

The conclusions regarding a common framework for analysis focused on utilities that exist in the most difficult of regulatory circumstances: those without clear regulation. This includes either regions of the world that have pending regulations, have regulations which apply to some facilities but not others (typically due to an emissions threshold), regions with strong pressures for voluntary reporting but many options under which to do so, or regions of the world with no regulation but where the utlity may wish to report anyway. For regions of the world with clear and uniformly applicable standards set by a regulator, those are the only frameworks to use. Our analysis framework and case studies presents a systematic means by which utilities may work through the challenges of determining which standards and equations should be used for different asset profiles. Each situation is unique, so it is essential for any utility conducting a footprinting or energy baseline to rigorously research and document all standards and equations used.

## APPLICATIONS

The research presented in this report has applications for utilities in both regulated and non-regulated environments in the following areas:

***Improved GHG Reporting*** – The harmonized framework, guidance, tool review, and research review conducted in this work will enable water utilities to improve their GHG reporting, regardless of whether they are in a regulated or unregulated region.

***Influencing Emerging Regulations*** – The research presented in this work can inform the regulatory development process for either GHGs or energy efficiency. Specifically, this work presents the best practices for GHG accounting and reporting and the range of methodologies and protocols in use, presents an organizational and guidance framework for decision making, and summarizes both the state of research as well as select equations and reporting ranges.

***Reducing Facility Costs*** – Active management of both energy and GHGs can result in cost reductions through the decrease in resource consumption, assurance of proper billing practices, assessment of future options for improved energy price management, GHG regulatory compliance, and possible GHG mitigation cost recovery from trading of emission reductions.

***Improved Facility Management*** – Improving the active management of energy can directly result in better facility management. The co-benefits of energy management and facility management are typically realized in the total facility assessment approach needed in order to first assess baseline energy use, determine the means by which to reduce energy throughout the facility, and finally the systems that can then be put in place to monitor energy use on a real-time basis. These are discussed in detail in this report. Furthermore, GHG accounting provides a similar facility-wide perspective and often goes a level deeper with the possible consideration of full-life cycle emissions, all of which enables greater control of both facility operations and costs.

***Improved Customer Relations*** – The reporting of GHG emissions and energy efficiency measures on utility websites and through regulatory or voluntary reporting bodies demonstrates both environmental leadership and sound corporate social responsibility. These actions typically improve customer relations. This report provides the basis for understanding the full range of options for providing these reports.

***Understanding Further Research Needs*** – The review of literature, tools, protocols and methodologies presented in this report provides a sound basis for understanding what additional research is needed for GHG emission and energy use accounting in the water sector.

## RECOMMENDATIONS

The recommendations for additional work include the following four key items:

- Continue research efforts into the fundamental biological and chemical equations and process models that describe the release of process and conveyance related GHGs in the wastewater component of the urban water cycle, both anthropogenic and biogenic.
- Create a technical compendium of GHG emission methodologies that also provides guidance on the handling of calculation methodologies in remaining areas of uncertainty.
- Incorporate the full urban water cycle into a single GHG emission methodology, including all scopes of GHG emissions. At present most methodologies include only a given subset of GHG producing assets involved in the full urban water cycle.
- Incorporate full GHG emissions benchmarks into a combined energy and GHG benchmarking tool. At present most energy benchmarking tools include only GHGs that originate from the consumption of energy, and do not include other sources of GHGs.

## RESEARCH PARTNERS

This work has been made possible through a WaterRF partnership with the Global Water Research Coalition (GWRC) and the New York State Energy Research and Development Authority (NYSERDA).

## PARTICIPANTS

This research effort has realized contributions from the following participants: District of Columbia Water and Sewer Authority (DC Water), Washington; City of Batavia, Illinois; Metropolitan Water Reclamation District of Greater Chicago, Illinois; Sweetwater Authority (CA); Metropolitan Water District of Southern California (CA); Los Angeles Bureau of Sanitation, Regulatory Affairs Division (CA); Coachella Valley Water District (CA); PUB, Singapore; Long Beach Water Department (CA); The City of San Diego (CA); Denver Water, CO; United Utilities; Department of Water and Power, The City of Los Angeles.

# CHAPTER 1
# INTRODUCTION

The impacts of anthropogenic greenhouse gas emissions on the earth's climate system has been the subject of considerable study, legislation, debate, and international treaties over the past two decades; and anthropogenic releases of greenhouse gases (GHGs) into the atmosphere are now accepted as the cause of global changes in climate (Solomon et *al.* 2007). GHG emissions alter the climate system energy balance by absorbing infrared radiation that results in heat trapping within the surface troposphere (Karl and Trenberth 2003). The principle contributor of GHGs to the atmosphere stems from the consumption of fossil fuels to produce energy. However, many other sectors, including water, cause significant release of GHGs to the atmosphere both from their direct process emissions, their secondary emissions due to energy consumption, and their tertiary emissions due to the life cycle impact of their facility.

## CLIMATE CHANGE AND THE WATER SECTOR

Climate change is of great concern to the water industry because it can adversely alter the quantity and quality of source water available within a localized service area. Exacerbating this is the fact that the water industry is becoming increasingly energy intensive, resulting in the release of even more GHGs. This rising energy intensity is driven by the continually increasing stringency of water quality requirements within both the water and wastewater industry sectors, which often leads to larger process energy inputs.

The water and wastewater industry is currently one of the lower GHG emitting sectors, and as such does not fall under the majority of mandatory global reporting regulations. Estimates put emissions from the water sector at anywhere from 3-10% of the global total (IPCC 2007). In the United States, domestic and industrial wastewater treatment is cited as the sixth highest contributor to atmospheric $CH_4$ and human sewage is cited as the fourth highest contributor to atmospheric $N_2O$ (U.S. EPA 2006). As such, many regulators and rate payers are turning their attention to GHG's from this sector and anticipate future emission limits that will impact some portion of the water industry. Methods for accurate accounting of GHG emissions within the water and wastewater industry are necessary in order to adequately prepare for reporting under regulatory requirements or to better understand the economic opportunities to use methane gas as a resource for energy generation. These methodologies are needed not only to meet anticipated regulatory reporting requirements, but also to optimize the processes that would minimize GHG emissions, and either benefit from available carbon trading schemes or minimize potential carbon taxes. It is therefore important for the water and wastewater industry to be aware of the science, regulation, and accounting standards that support accurate GHG emission estimation reporting and the extent to which existing GHG emission tools adequately serve their specific estimation needs.

Accurate estimation of GHG emissions in the wastewater sector presents an interesting challenge because of the multitude of treatment processes that are designed to meet a variety of permitted effluent discharge and biosolids handling requirements. Unlike GHG emissions from the power sector, which can be fairly reliably estimated based on the input fuel, GHG emissions from the wastewater sector are still being studied in order to better understand design and process impacts on emission levels. By contrast, emissions from the water sector are principally due to energy consumption, and as such are highly predictable based on power consumption data.

The actual method of reporting GHGs for any sector of the economy is driven by two factors: (i) regulatory requirements, which are typically driven by either national legislation or international treaties; and (ii) utility or rate payer expectations. These two conditions have further sub-drivers: first, the degree of regulatory certainty; and outside of certainty, the level of expectation for sustainable environmental action/leadership or specific GHG reporting within the community serviced by any given water utility. As such, there is actually a very high degree of variability in the reporting protocols for GHG emissions around the world, and the degree to which actual accounting and reporting is conducted.

## ENERGY AND THE WATER[1] SECTOR

There is a very close link between energy and water consumption, the oft-discussed water-energy nexus. For many components of the urban water cycle, energy is the number one operational cost after staff, and is the number one source of GHG emissions. An increasing level of study has been given to the topic of energy conservation in the water sector, particularly as energy pricing continues to increase and drivers for energy consumption rise due to: increased water treatment requirements, increased demand for clean water, decreased availability of high quality source water. Actual monitoring of energy consumption varies considerably between the different points in the urban water cycle, and also varies considerably around the world. In some cases, energy consumption is measured at such a high level that specific attribution to a particular component in the treatment cycle can be quite challenging. At the other end of the spectrum, sub-metering and data collection can be quite specific and enable process and system optimization for energy consumption.

As a result, the methodologies being used to quantify energy usage and GHG emissions in the water sector can vary widely in terms of performance indicators, input and output metrics, underlying algorithms, applicability to water industry processes, and level of accuracy.

## THE URBAN WATER CYCLE

The urban water cycle shown in Figure 1.1 depicts the movement of water into, within, and out of defined urban boundaries. In this example, the boundaries capture the engineered potable water systems that convey, store, and extract raw water for treatment and distribution as well as the wastewater systems that collect, treat, and reclaim wastewater and handle wastewater residuals. The energy usage and GHG emissions associated with the elements within this generic urban water cycle can differ widely, depending upon daily flows and travel distances, hydraulic head considerations (topography), water storage requirements, and the treatment technologies needed to achieve final water quality requirements (Reiling et *al.* 2009).

Throughout this report we will refer to the urban water cycle as we guide the reader through an understanding of GHG emissions and energy use. We will also discuss the different levels of reporting that are currently possible based on a review of current research and discussions with utilities, in order to provide an understanding of the best available information for measuring, estimating and reporting both GHGs and energy.

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[1] In this paper, the authors use the term “Water Sector” to refer to the full urban water cycle and all utilities and services therein. We use the terms Drinking Water and Wastewater uniquely to refer to those specific segments of the urban water cycle.

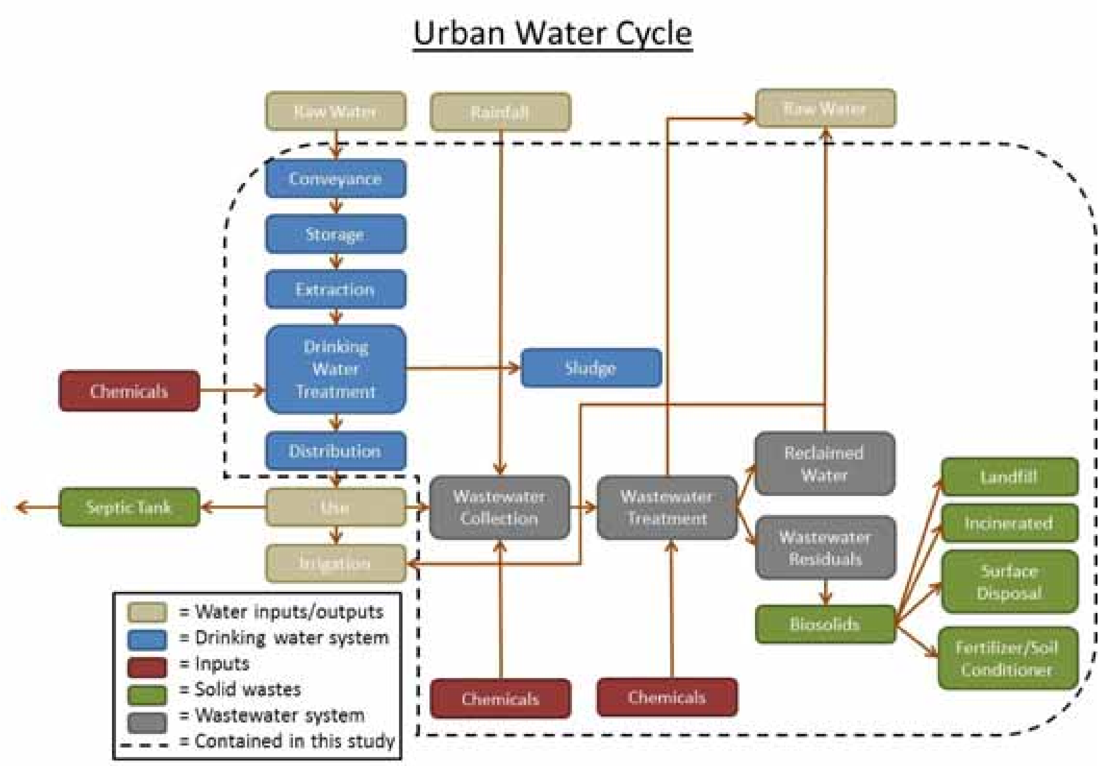


**Figure 1.1 Water and wastewater components of a typical urban water cycle**

## PROJECT OBJECTIVES

The principal goal of this study was to compare available methodologies for GHG and energy measurement against those needed for the various infrastructure components of the urban water cycle. We provide a detailed assessment of the relevance, completeness, consistency, transparency, and accuracy of the tools which are currently available to measure energy and GHGs. This assessment was then translated into a discussion of the current state of research, and the needs to fill identified gaps, provide higher levels of accuracy in estimations, or achieve harmonization in approaches used in different regions of the world.

The primary objective of this project was to develop a globally harmonized framework for energy use and GHG emission assessments for the water industry. The study consisted of an international review focused on addressing the following questions:

- What tools are commonly used by water agencies to measure or track energy and GHG emissions across the urban water cycle and what are their capabilities relative to program reporting or process optimization needs?
- What underlying models and algorithms support these tools and what additional research is needed to improve their accuracy and specificity?
- What strategies are needed in order to work toward a common set of best practices that could be harmonized across utilities and geographic regions?

This report is not intended as a beginners guide to GHG emissions, energy use or the water cycle; however, several references are provided which contain basic information in these areas. This report is designed for utility managers and staff who wish to augment their understanding of best practices in minimizing GHG emissions and energy in the urban water cycle, so that they may more efficaciously monitor, estimate and report these values during facility planning and operation.

## ORGANIZATION OF REPORT

The report is organized into chapters that focus on clarifying the portion of existing GHG emissions accountancy practices of potential relevance to the water and wastewater industry. Chapter 1 is a general introduction and overview of the topic; Chapter 2 discusses the science and regulation behind GHG emissions; Chapter 3 provides a discussion on protocols and methodologies supporting GHG accounting standards; Chapter 4 focuses on energy usage, energy management and monitoring principles for water utilities; Chapter 5 enumerates the tools available for energy and GHG emission estimations; Chapter 6 describes the findings obtained from a survey of 22 water/wastewater utilities regarding their drivers for GHG emissions reporting, the GHG emission tools utilized, the range of observed GHG emission estimates, the degree of harmonization in reporting strategies, and the remaining knowledge gaps preventing achievement of an industry-wide framework. Chapter 7 provides a water/wastewater specific decision framework for GHG emissions reporting and then evaluates usage of this framework in the reporting of case studies for a water, wastewater, and water reuse facility. Chapter 8 provides a study summary and recommendations for the water industry relative to energy and GHG emission accountancy practices. It should be noted that this report is intended to further inform readers who have a basic understanding of the urban water cycle, energy use in the water sector, and GHG accounting. For readers who may not possess this background, we suggest first reading some of the foundational work included in the reference section of this document. Values reported in this report are in International System of Units (SI), the modern metric system of measurement, or Unites States customary units of measurement, depending upon the country of origin.

# CHAPTER 2
# GREENHOUSE GAS BACKGROUND SCIENCE & REGULATION

## SCIENCE

The Intergovernmental Panel on Climate Change (IPCC) is a scientific body responsible for reviewing and assessing global scientific information relevant to climate change. The IPCC was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) and endorsed by the United Nations General Assembly (IPCC 2012). The IPCC reviews and assesses the most recent scientific, technical and socio-economic information provided by member countries relevant to the understanding of climate change. Fundamental research is conducted around the world by environmental agencies, national and university laboratories; this research is fed into and consolidated by the IPCC into periodic reports on the state of climate change and climate science.

The IPCC has created a globally accepted methodology for country-level estimation of GHGs from each major sector of the economy, including the water sector. This methodology is based on research conducted around the world, and has resulted in generalized equations with lookup factors for specific countries and other factors. Each participating country provides an annual report of their GHG emissions to the IPCC; typically this report is provided by the country's national environmental agency. Among other critical scientific information, the IPCC updates the global GHG reporting standards for all nations reporting under the United Nations Framework Convention on Climate Change (UNFCCC), as well as the global warming potential (GWP) of each GHG which is calculated based on its heat-trapping capability relative to $CO_2$.

The IPCC's role is critical in contributing toward a globally harmonized protocol for high level GHG emissions accounting that can be utilized throughout the world. In fact, the IPCC GHG methodology is perhaps the closest to a globally harmonized approach. Nonetheless, while the IPCC methodology is considered to be adequate for high level government reporting it is only a starting point for assessing actual GHG emissions from specific sectors and facilities.

## REGULATION

Around the world many countries and regions have put in place or are discussing legislation which requires GHG reporting. The foundation for nearly all of the methodologies provided in the resulting regulations find their origin in the work of the UNFCCC and IPCC.

The UNFCCC is an international treaty adopted in 1992 and ratified in 1994 that recognized the problem and encouraged industrialized countries to curtail emissions to levels that would prevent interference with the climate system. As of September 2011, 194 countries plus the European Union (EU) have ratified the Convention. The UNFCCC strengthened the engagement of industrialized nations interested in meeting their GHG targets to a higher level of commitment with the ratification of the Kyoto Protocol in 2005.

The Kyoto Protocol requires all signatory countries to monitor, at a national scale, their emissions of six key GHGs: (1) carbon dioxide ($CO_2$), (2) methane ($CH_4$), (3) nitrous oxide ($N_2O$), (4) hydrofluorocarbons (HFCs), (5) perfluorocarbons (PFCs), and (6) sulfur hexafluoride ($SF_6$). As discussed above, these are emissions reported annually by each participating country to the IPCC using the IPCC GHG methodology.

As the UNFCCC work has progressed, all of the ratifying countries have conducted work of their own on measures to both measure and to curtail GHG emissions and comply with the Kyoto Protocol. These efforts typically originate from the country's environmental agency, and have generally been specific to the highest GHG generating sectors of that country's economy. In some cases this work has been delegated to the agencies responsible for regulating the individual sectors.

As subsequently discussed in this report, global reporting regulations for the water and wastewater industry are highly regionalized with reporting mandated in some regions (e.g., Ofwat in England and Wales), voluntary in a majority of countries provided that emissions remain below a specified trigger level (e.g., Canada, USEPA, European Union, Australia, Japan), or mandated for specific portions of the economy and certain types of facilities (e.g., USEPA coverage of municipal wastewater treatment facility operated landfills).

## Regulatory Reporting Requirements by Region

GHG reporting requirements are established by political entities and lack uniformity across geopolitical regions. A brief summary of regulatory GHG reporting requirements in the United States, European Union, United Kingdom, Australia, New Zealand, Japan, South Africa, and Singapore are provided below. While reporting is required for all government entities and large industry emitters, mandatory reporting across the water industry sector is not required and typically only occurs for the larger entities that exceed the minimum emissions threshold or choose to report voluntarily.

### *Australia*

In Australia the Clean Energy Regulator is responsible for administering legislation relating to carbon reduction and clean energy, and administers the Carbon Pricing Mechanism, the National Greenhouse and Energy Reporting (NGER) scheme, the Carbon Farming Initiative and the Renewable Energy Target. The NGER Act introduced a single national framework for the reporting and dissemination of information about greenhouse gas emissions, greenhouse gas projects, and energy use and production of corporations. Corporations that meet an NGER threshold must report their: greenhouse gas emissions, energy production, energy consumption, and other information specified under NGER legislation.

NGER includes two types of thresholds under which corporations are required to participate: 'facility' thresholds and 'corporate' thresholds. As a guide, entities emitting more than 25,000 tonnes of CO2 equivalent, or consuming more than 25,000 MWh of electricity or 2.5 million litres of fuel in a financial year are expected to report. NGER includes two tools for wastewater utilities:

- NGER wastewater (Domestic and Commercial) calculator (NGER, 2011)
- NGER wastewater (Industrial) calculator (NGER, 2011)

The Online System for Comprehensive Activity Reporting (OSCAR) is a web–based data tool for entities required to report under NGER to record energy and emissions data. OSCAR allows both the government and community members to gain a clear picture of an organization's emissions, and enables automatic calculations of an organization's GHGs based on energy and emissions data.

### *Canada*

The Canadian government has developed several non-binding, voluntary frameworks on GHGs and climate change. These frameworks are designed to encourage reductions in GHG emissions in areas not currently covered by existing air emissions regulations. The industrial GHG framework provides a standard that the provinces and territories can implement to have a uniform approach.

Otherwise, activities related to climate change are set at the provincial level. Some provinces, like British Columbia, have goals for carbon neutrality and are supposed to be carbon neutral by 2012. In addition, a number of provinces and territories are members or observers of the Western Climate Initiative (WCI). British Columbia, Manitoba, Ontario and Quebec are full members; while the Yukon Territory, Saskatchewan, and Nova Scotia are observer members. The WCI outlines activities that would set GHG reduction goals, put a cap on total emissions, and establish a trading scheme for allowances and offsets.

Water utilities across Canada have varied carbon footprints due largely to regional variations in water availability and water quality. However, Canada produces the world's second largest amount of hydroelectricity, which has a much lower carbon footprint than electricity generated using hydrocarbons. As a result the relative carbon footprint of Canada's water utilities is low.

### *European Union*

The EU Member States agreed in December 2008 to a climate and energy package known as the '20-20-20' targets to be achieved by 2020. The first target is for 20% reduction in GHG emissions below 1990 levels; the second target is for utilization of renewable sources for 20% of the energy consumption, and the third target is for a 20% reduction in primary energy use from projected levels through energy efficiency. The package includes strengthening of the Emissions Trading System (ETS), the EU's key tool for cutting emissions which includes reliance upon an emission allowance cap that is reduced annually. The ETS targets heavy industries with the largest emissions. Other pieces of legislation that are part of the climate and energy package deal with the following: a framework for carbon capture and storage, binding national targets for renewable energy, and binding national emissions limitation targets for sectors not covered by the ETS. None of this legislation is directly applicable to the water and wastewater industry.

### *France*

In 2000, France produced its first National Programme for Tackling Climate Change, synthesizing specific objectives and measures which were then either inscribed in laws or regulations. The program was updated with the Climate Plan 2004 and the Climate Plan 2006, and there is now a requirement that the climate plan be updated every two years (Townshed et al 2011). The state also encourages local authorities to produce local climate plans.

The main objective of the climate change regulation is to create an obligation on large emitters to report their carbon footprint, report and action plan. Companies with more than 500 employees will have to calculate their carbon footprint following specific requirements, and municipalities with more than 50,000 people will have to calculate their carbon footprint and make local climate action plans in order to reduce it and to adapt to the changes in water patterns. Companies and municipalities can also receive government assistance from the French Agency for the Environment and the Energy Savings (ADEME). ASDEME has set up a specific website and some government bodies/agencies may subsidize emissions reduction projects.

In October 2007 the 'Grenelle de l'environnement' process was initiated. The process gathers environmental stakeholders to reach a series of agreements which are then translated into laws and regulations. One of the six working groups focused specifically on climate and energy, with measures adopted in the 2010 Grenelle II law, including a carbon tax. However, this policy was postponed in favor of a European border carbon tax, before implementing a carbon tax at the national level.

Another source of climate legislation in France comes from the adoption of the CO2 EU Emissions Trading Scheme. Water utilities can use efficiency gains to generate credits for use by other industries. However, France increased the restrictions on efficiency credits with new legislation, and as a result water utilities must apply through their energy provider to obtain efficiency certificates (Mansoz et al 2010).

The carbon footprint of French water utilities is lower than comparable nations due primarily to the fact that the majority of France's electricity comes from low-emission nuclear power plants.

### *Germany*

Germany launched its first national climate change and energy program in 2007. However, the integration of climate change mitigation into the legal system has been primarily focused on energy efficiency and renewable energy. Germany has introduced a range of statutory regulations on energy efficiency in key sectors including industrial, transportation, district heating and buildings. In addition, the use of renewable energy is of fundamental importance in German climate change legislation. The Renewable Energy Sources Act of 2008 sets a target to generate 30% of electricity supply from renewable energy resources by 2020 (Townshed et al 2011).

### *Italy*

Italy has ratified the Kyoto protocol and adopted regulations regarding emission trading, and created a national committee to implement the Kyoto protocol. This committee is responsible jointly to the Ministry of Environment and the Ministry of Economic Development, and publishes the majority of the guidance on adapting to climate change. However, the joint committee is not responsible for defining the guidelines on GHG emission reductions; this responsibility is carried by the Ministry of Environment.

Italy has promoted sustainable resource development through several national goals, including guidance on water conservation and protecting water ecosystems, and acknowledging the effect climate change has on water resources. In addition, a series of laws and decrees have been adopted to promote energy efficiency and renewable energy.

Though Italy has some of the most abundant supplies of fresh water in Europe, these freshwater sources are generally considered more polluted than freshwater in other EU countries. In addition, the southern regions suffer from considerable drought (Rilascatiati et al 2002). As a result, Italy uses a relatively high amount of energy to transport water where it is needed and to treat drinking water, resulting in a higher associated carbon footprint .

### *Japan*

Workshops on GHG inventories in Asia (WGIA) have been convened annually since 2003 under the support of the Japanese government. These workshops focus on identification of common issues and solutions by sector, reporting country inventory practices, and verification of the UNFCCC reporting requirements to meet the Kyoto Protocol targets (Umemiya 2006). Methodology in Japan for methane and nitrous oxide emissions from wastewater facilities are derived from the IPCC methodology with some minor modifications.

### *New Zealand*

New Zealand ratified the Kyoto protocol and adopted regulations regarding emission trading and GHG reporting. The trading scheme is developed by the Ministry of the Environment and implemented by the Ministry of Economic Development for all sectors subject to the scheme except the forestry sector. The emission trading scheme for the forestry sector is designed and implemented by the Ministry of Agriculture and Forestry.

New Zealand also maintains a GHG emission inventory. The emission inventory is done to comply with New Zealand's obligations under the Kyoto Protocol and the United Nations Framework Convention on Climate Change. The inventory maintains information on six sectors: energy; industrial processes; solvents; agriculture; land use, land-use change and forestry; and waste (Gledhill et al, 2012). The emission-trading scheme is reviewed every 12 months to ensure it is working appropriately.

New Zealand's energy mix comes primarily from renewable resources. The large use of renewable resources for electric production helps to keep the overall carbon footprint of New Zealand low in comparison to countries with a greater reliance on fossil fuels.

### *Netherlands*

The Netherlands has passed legislation on climate change, and has adopted EU measures on climate change. The official targets set by climate change legislation in the Netherlands are as follows: a 30 percent decrease in GHG emissions compared to 1990 by 2020, 20 percent renewable energy target by 2020, and an energy saving rate of two percent per year in 2020. Emission goals in the Netherlands are mandatory for some sectors, including electricity, but not for the drinking water industry. The drinking water industry voluntarily complies with emission standards. Because the industry is not mandated to meet them, there is flexibility to adapt when these goals come into conflict with other obligations of the industry.

Generally, efforts in the Netherlands have focused on energy savings programs, capping emissions of GHGs, innovative technology solutions such as carbon capture and sequestration, and use of the EU's carbon trading scheme.

In the Netherlands, there are several additional regulations with respect to GHG emissions and energy efficiency for the water sector. These include: (1) The Climate Agreement between the Union of Water Stewardship Councils and the National Government; (2) Long term agreements (LTA3); (3) Sustainable procurement; and (4) Environmental Management Act. These target reduction in GHG emissions, energy usage from renewable energy research to better understand $N_2O$ and $CH_4$ formation in wastewater treatment processes, achieving increased energy efficiency, and procurement of sustainably produced goods/products/services.

### *Singapore*

Singapore is a non-annex (developing nation) member party of the UNFCCC. As such it is currently not required to reduce its GHG emissions, and at the same time it is eligible to receive assistance from Annex II countries to help reduce its emissions and adapt to climate change. Nonetheless, Singapore's urbanization and industrialization levels resemble those of a developed country –with the obvious difference of scale. Furthermore, the emission levels and carbon intensity (tonnes of $CO_2e$ / $ GDP) of its economy are very high and in par with many Annex II countries.

Still, and perhaps due to its small size and relative insignificant contribution to global emissions (<0.2%), Singapore has made the case and remains firm in being treated as a "least developed country" and not part of any of UNFCCC's Annex groups. In Singapore's National Climate Change Strategy, released in 2008, the goal was set to decrease the carbon intensity of its economy by 25% over 1990 levels by 2012. The country achieved this goal in advance, but at the same time, managed to almost double its total emissions. This achievement was in great part due to the conversion of the power matrix (98% based on fossil fuels and accounting for 55% of total emissions) to natural gas. Other contributing efforts came from energy efficiency improvements in industrial, transportation, building and residential sectors. New efforts seem to be underway that may assume more significant goals.

There are no GHG reporting requirements or emissions limitations for wastewater operations. Even waste operations do not represent a significant source of emissions given the high recycling rates and the common practice of incineration of waste that takes place in Singapore (waste-to-energy systems provide 2% of the country's electricity capacity). All focus areas to achieve reductions in emissions are concentrated on the power, transportation, industrial, building and residential sectors, with the exception of the Clean Development Mechanism (CDM) project listed in Table 2.1 (for a description of the CDM mechanism, see chapter 3.)

**Table 2.1**
**CDM sewage project in Singapore (CDM 2012)**

| Registered | Title | Methodology * | Reductions ** |
|---|---|---|---|
| 13 Sep 10 | Dehydration and incineration of sewage sludge in Singapore | AM0025 ver. 11 | 101577 |

* AM - Large scale, ACM - Consolidated Methodologies, AMS - Small scale

** Estimated emission reductions in metric tonnes of $CO_2$ equivalent per annum (as stated by the project participants)

### *South Africa*

South Africa is a non-annex (developing nation) member party of the UNFCCC. As such, it is currently not required to reduce its GHG emissions, and at the same time it is eligible to receive assistance from Annex II countries to help reduce its emissions and adapt to climate change.

Outside of the UNFCCC process, little additional regulatory activities have taken place to curb GHGs or reduce energy consumption. Recognizing that the nation is both a significant contributor to anthropogenic carbon emissions, and is at significant risk for the impacts of altered climate patterns, South Africa has taken a few first steps towards assuming its "fair share" of responsibility in climate change mitigation and also planning adaptation strategies.

The country has done its first national GHG inventory. It has also stated a goal for leveling and subsequently reducing its GHG emissions (dubbed the peak, plateau, decline scenario) in a way that still allows for sustainable development. The culmination of all the country's efforts so far is a strategic policy white paper titled the National Climate Change Response, released in late 2011 by the Water and Environmental Affairs Minister Edna Molewa (Molewa 2011).

The white paper is still far from setting emission restrictions or assigning reduction targets by activities, but it starts by defining a "Carbon Budget" (CB). The CB is to be released within two years (2013) and will first focus on the "significant emitting" industries, namely major energy supply (electricity and liquid fuels) and use (mining, industry and transport) sectors. The idea of the CB is to provide the greatest flexibility and lowest cost alternative for reaching the emission reduction targets for each sector of the economy.

According to the document "each significantly emitting economic sector or sub-sector will be required to formulate mitigation and lower-carbon development strategies. These strategies will specify a suite of mitigation programs and measures appropriate to that sector or sub-sector. They will also provide measurable and verifiable indicators for each program and measure to monitor their implementation and outcome." To jump-start the effort, the document also defines a number of Near-term Priority Flagship Program, one of which is the Waste Management Flagship Program:

***The Waste Management Flagship Program.*** Led by the DEA, the Waste Management Flagship Program will establish the GHG mitigation potential of the waste management sector including, but not limited to, investigating waste-to-energy opportunities available within the solid-, semi-solid- and liquid-waste management sectors, especially the generation, capture, conversion and/or use of methane emissions. This information will be used to develop and implement a detailed Waste-Related GHG Emission Mitigation Action Plan aimed at measurable GHG reductions aligned with any sectorial carbon budgets that may be set. This Action Plan will also detail the development and implementation of any policy, legislation and/or regulations required to facilitate the implementation of the plan.

The GHG accounting activities that South Africa has taken related to the urban water and wastewater cycle are all for qualifying CDM projects under the Kyoto Protocol. Table 2.2 is a list of wastewater or waste CDM projects in South Africa:

**Table 2.2**

**Clean development mechanism water and wastewater projects in South Africa (CDM 2012)**

| Registered | Title | Methodology * | Reductions ** |
|---|---|---|---|
| 29 Sep 06 | PetroSA Biogas to Energy Project | AMS-I.D. ver. 9 | 29933 |
| 15 Dec 06 | Durban Landfill-gas-to-electricity project – Mariannhill and La Mercy Landfills | AM0010 | 68833 |
| 27 Apr 07 | EnviroServ Chloorkop Landfill Gas Recovery Project. | AM0011 ver. 2 | 188390 |
| 26 Mar 09 | Durban Landfill-Gas Bisasar Road | AM0010 | 342705 |
| 24 Aug 09 | Alton Landfill Gas to Energy Project | AMS-I.D. ver. 13<br>AMS-III.G. ver. 6 | 25893 |
| 26 Oct 10 | Ekurhuleni Landfill Gas Recovery Project – South Africa | ACM0001 ver. 11 | 282349 |
| Rejected | New England Landfill Gas to Energy Project | ACM0001 ver. 11 | 51052 |

* AM - Large scale, ACM - Consolidated Methodologies, AMS - Small scale

** Estimated emission reductions in metric tonnes of $CO_2$ equivalent per annum (as stated by the project participants)

***United Kingdom.*** The UK Government has committed to an 80% reduction in UK GHG emissions by 2050 from 1990 levels and at least a 34% reduction by 2020 under the Climate Change Act of 2008. The Scottish Government has also set an 80% reduction target through the Climate Change (Scotland) Act 2009, with an interim goal of 42%. Water companies are required to report GHG emissions, and many UK water companies have set their own voluntary targets for reducing carbon emissions from their operations and Scottish Water is required to understand its contribution to Scotland's carbon emissions and take steps to mitigate these emissions. Specific legislation that directly impacts the water industry are described below.

***Climate Change Levy and Climate Change Agreements.*** The UK government operates a Climate Change Levy (CCL) under pre-existing legislation which takes the form of a per unit tax on the commercial use of electricity, natural gas, petroleum, coal, and coke. The use of oil and road fuel gas is excluded. Climate Change Agreements (CCAs) allow companies to obtain a discount on the CCL by agreeing to meet challenging targets for improving energy efficiency or reducing carbon emissions. Water companies are subject to the CCL and a few UK water companies hold CCAs.

***Carbon Reduction Commitment (CRC) Energy Efficiency Scheme.*** All public and private organizations using more than 6,000 MWh/yr of electricity are required to participate in the CRC scheme. The scheme covers the carbon emitted from the combustion of fossil fuels and electricity used on fixed sites, but does not cover direct process emissions or emissions from transportation and other sources. While originally designed as a cap-and-trade system, the scheme now operates as a carbon tax, with permit payments now going to the Treasury instead of being recycled back to participants. Since fixed site electricity use exceeds 6,000 MWh/yr for all water facilities in country, all water companies are participants in the scheme.

***GHG Emissions Reporting.*** Reporting of annual GHG emissions to the Government is currently voluntary, and reporting is expected to become mandatory in 2013. The Water Services Regulation Authority, Ofwat, is the water industry economic regulator that requires water companies in England and Wales to annually report their operational GHG emissions and provides the format for this reporting. Though Scotland does not come under Ofwat requirement they do conduct detailed GHG reporting and post that information online. Ofwat reporting utilizes the UK Water Industry Research "Methodology for Estimating Operational Emissions" (08/CL/01/5) and relies upon Government published emission factors for the use of fossil fuels, electricity, transport, and other activities that generate GHG emissions. Further research is being conducted by UKWIR and others to develop protocols for direct process emissions of methane and nitrous oxide from water industry operations. Ofwat also requires water companies to take account of GHG emissions in investment appraisal by applying carbon prices set by the Government and including carbon costs in cost benefit analysis. The UKWIR has published guidance to assist water companies in undertaking whole life carbon accounting for this purpose.

### *United States*

The United States' legal system enables regulation to occur both nationally at the federal level and/or regionally at the state level. Regulations crafted at the state level must meet or exceed regulatory requirements at the federal level.

***Federal Regulations.*** The United States Environmental Protection Agency (USEPA) has instituted two broad regulations covering nationwide mandatory GHG reporting. Neither regulation, briefly described below, directly impacts the water and wastewater treatment industry.

*Greenhouse Gas Mandatory Reporting Rule (40 CFR Part 98).* This rule, effective December 29, 2009, mandates annual reporting of GHG emissions for certain sectors of the economy. The rule applies to direct GHG emitters, fossil fuel suppliers, and industrial gas suppliers that exceed a threshold of 25,000 metric tons or more of carbon dioxide ($CO_2$) equivalent per year. The rule does not include municipal water and wastewater treatment facilities; however, industrial wastewater treatment was included in an addendum to the original Code of Federal Regulations (CFR) publication and municipal wastewater treatment facilities must report emissions from operated landfills. EPA has published technical support documentation for each source category of emissions, including both industrial and municipal wastewater treatment. Equations and emissions factors are provided based upon the standards set by the IPCC but tailored to US factors. The drawback of this rule is that it relies upon IPCC methodology that it is designed for top-down, nationwide GHG reporting, while the purpose of this rule is to accomplish bottom-up GHG accounting through use of the monitoring methodologies spelled out in the rule.

*Title II CFR 40 – The Clean Air Act.* EPA issued an amendment to the Clean Air Act requiring all sectors which must file under Title II of the Clean Air Act to report their GHG emissions. These sectors will report here in lieu of the 40 CFR Part 98 requirements. Since Title II is focused on moving sources, it has no direct impact on water and wastewater facilities.

***State Regulations.*** Nearly all US States have a voluntary GHG Registry with the exception of Alaska, Arkansas, Indiana, Kentucky, Louisiana, Mississippi, Nebraska, North Dakota, South Dakota, and Texas. Mandatory GHG reporting rules have been implemented by

California, Washington, Wisconsin, Iowa, Florida, North Carolina, and West Virginia. California has the most stringent reporting requirements and the California Air Resources Board (CARB) mandatory reporting regulation (sections 95100-95133 of Title 17, California Code of Regulations) covers municipal and industrial sites with a threshold that was recently lowered from 25,000 MT GHG/year to 10,000 MT GHG/year of anthropogenic emissions. Most water and wastewater utilities will fall below the 10,000 MT/year GHG emission threshold, but some of the largest utilities will fall into the 10,000-25,000 range.

### A Summary of Regulations Relating to the Water Sector

Many organizations within the water industry sector do not have GHG emissions or energy usage levels high enough to trigger mandatory reporting. Table 2.3 provides a listing of global and national regulations that could directly impact reporting requirements for the water sector in the future, if not now. It is possible that the threshold levels will change and possibly become lower as reporting becomes more common and mitigation efforts drive a greater degree of scrutiny. Many facilities have also chosen to report on a voluntary basis as part of a stewardship program or in anticipation of future mandatory regulations.

## Table 2.3
## Global regulations that may trigger reporting requirements for the water sector

| Country and Agency | Regulation | Trigger | Potential Water Sector Impact |
|---|---|---|---|
| United States Environmental Protection Agency | Greenhouse Gas Reporting Program (GHGRP) (40 CFR Part 98; 64 FR 56260) | Owners or operators of facilities where aggregate annual GHG emissions are equal to or more than 25,000 metric tons of $CO_2e$ must report to EPA under the Clean Air Act. | Any water facility exceeding threshold must report as of September 30, 2011. The following EPA tool can be used to assess whether a facility must report: http://www.epa.gov/climatechange/emissions/GHG-calculator/index.html. Presently, EPA is not planning on requiring permits for sources that emit less than a 50,000 metric ton threshold until sometime after April 30, 2016. |
| United States, California Air Resources Board | California GHG Mandatory Reporting Program (95100-95133 Title 17, California Code of Regulations) | Reporting threshold of 25,000 annual metric tonnes of carbon dioxide ($CO_2$) for most industrial sectors. | Water facilities emitting below threshold must report emissions if they utilize cogeneration system that individually has a nameplate generating capacity ≥ 1MW and emits > 2,500 MT $CO_2$ per calendar year. |
| United States California Department of Water Resources (DWR) Grant Program | California Environmental Quality Act (CEQA) Guideline Amendments (Title 14 of California Code of Regulations) | CEQA applies to governmental action either for direct participation, whole or partial financing of activities, or approval of private activities. | Any water project activity subject to CEQA must include quantitative accounting for GHG sources to the extent possible as part of the environmental impact report (CEQA Guidelines: Article 1. 2011). |
| Environment Canada | Greenhouse Gas Emissions Reporting Program | Reporting threshold lowered to 50,000 metric tonnes of $CO_2e$. | Any water facility exceeding threshold must report. |
| European Union | EU Emissions Trading System Directive 2003/87/EC plus amendments of the European Parliament and of the Council | Stationary sources in excess of 25,000 metric tonnes of $CO_2e$ per year and low emissions installations below this trigger level | Section 4, Article 47 allows stationary installations with low emissions to submit a simplified monitoring plan in accordance with Article 13. Tier 1 reporting (lowest accuracy requirement) is acceptable for activity data and calculation factors for all sources unless higher accuracy is achievable without additional effort for the operator. Combustion process emissions include boilers, burners, turbines, heaters, furnaces, incinerators, kilns, ovens, dryers, engines, flares, scrubbers, and any other equipment or machinery using fuel exclusive of those for transportation purposes. Fuel emission factors derived from IPCC 2006 GL. |
| United Kingdom Environment Agency Department of Energy and Climate Change (DECC) | CRC Energy Efficiency Scheme | All public and private organizations exceeding 6,000 MWh/yr of electricity must participate. | All water companies fall under this scheme and reporting of annual GHG emissions is required in England and Wales by the water industry economic regulator, Ofwat. |

(continued)

## Table 2.3 (Continued)
## Global regulations that may trigger reporting requirements for the water sector

| Country and Agency | Regulation | Trigger | Potential Water Sector Impact |
|---|---|---|---|
| Scotland | Climate Change Act 2009 | Not specified at local sector level | Scottish Water provides GHG reporting on a voluntary basis. |
| Australia | National Greenhouse and Energy Reporting (NGER) Act | Facilities where aggregate annual GHG emissions are equal to or more than 25,000 metric tons of $CO_2e$ or electricity consumption exceeds 25,000 MW. | Any water facility exceeding threshold must report. |
| Japan | Kyoto Protocol Target Achievement Plan (KPTAP) 2005 | Facilities where aggregate annual GHG emissions are equal to or more than 3,000 metric tons of $CO_2e$ | The Keidanren Voluntary Action Plan (VAP) specifies GHG reductions to various sectors and covers 35 industries which do not include the water/wastewater sector |

# CHAPTER 3
# GHG ACCOUNTING STANDARDS

Establishing global standards consisting of protocols and methodologies for accounting and reporting of greenhouse gas emissions within all contributing sectors of the economy, including water, has been recognized as a critical need. At present there are an abundance of standards related to GHG accounting in the water sector. In this chapter we navigate through many of these, and describe the specific research that has been conducted to improve the water sector's ability to accurately account for GHG emissions at the facility level.

## PROTOCOLS AND METHODOLOGIES IN GHG STANDARDS

Within this report, the term 'protocol(s)' refers to a set of general guidelines as to how GHG emission sources should be identified and assessed. The term 'methodology(ies)' refers to standardized sets of equations, algorithms, and lookup approaches for obtaining the values needed to quantify the GHG emissions from contributing sources.

### Protocol

A protocol is a broad framework that embodies best practices in the steps an organization should undertake to collect an accurate representation of their GHG footprint. Typically, protocols do not include specific equations, instead these are contained in the methodologies which are often tailored according to industry or region. The universal appeal of this Protocol lies in its flexibility for use by any type of organization that wishes to report voluntarily.

The most widely used foundational protocol is "The Greenhouse Gas Protocol" which was created by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (WRI/WBCSD 2005). This protocol establishes a broad framework guideline specifically for organizational GHG accounting, including how to define GHG emission ownership (scopes), draw organizational boundaries, and address other complexities of categorizing all types of GHGs.

### Methodology

Methodologies typically include a set of specific accounting standards and equations which are tailored to meet a specific regulatory need.

The UNFCCC and IPCC, the most widely used global standards, include both a methodology and a protocol. The IPCC methodology is tailored to nations that must report carbon under the UNFCCC system. It is the foundational international methodology from which all national environmental agencies have originated their individual accounting methodologies.

The UNFCCC GHG accounting rules, designed for the quantification and trade of carbon under Kyoto, have the advantage of being extremely project specific since they are designed to provide a specific accounting methodology with associated verification, validation and monitoring of the subsequent emissions reductions which occur as a result of the project. As such these methodologies are specific to the sector, country and project types. This occurs only for sectors and countries which trade carbon under Kyoto, and are specific to the approved project-types and projects themselves. There are two types of projects: those which are created under the Clean Development Mechanism (CDM) and are carbon exchanges between developing and developed nations; and Joint Implementation (JI) projects, which are between developed and emerging economies as defined in Kyoto.

Under the UNFCCC CDM and JI process, specific methodologies and protocols have been established so that a GHG reduction project can be defined and approved GHG emission savings estimated, the GHG emissions sold, and the actual GHG emission reductions can be verified for each year of the subsequent project. The methodology is quite precise, and even though relatively few water sector projects have gone through the CDM or JI process, they do serve as interesting case studies. This short description does not fully capture the very prescriptive process projects must follow. The Kyoto Protocol expires in 2012 and a new international agreement has yet to take full form. Regardless of the outcomes of these discussions, the standards themselves stand as important proxies for GHG accounting, and have resulted in significant additional legislative/regulatory action and research within the participating countries.

More specific methodologies exist within each country's environmental agency, according to each sector of the economy which is or may be regulated. For example, in the United States the US EPA's Mandatory Greenhouse Gas Reporting Rule (MRR) and all of the documentation associated with the development of the rule is the dominant guiding methodology. The specific methodologies are most precise in those countries which mandate GHG reporting, and the associated regulations, thresholds, and applicability have been described in the previous chapter.

It is important to understand that the IPCC methodologies are for 'top-down' consolidated reporting of emissions within each sector from a national perspective, and this reporting is provided by each participating agency. Whereas the UNFCCC methodologies contained in the CDM and JI documents are for project-specific, or 'bottom-up' reporting from a specific facility. Similarly, the regulations promulgated by national agencies for reporting from within their countries are designed for facility- or organizational-level reporting from the 'bottom-up'.

Since several national environmental agencies have utilized the IPCC methodologies as the foundational set of equations, the reporting from the facility-level using this methodology can represent an estimation based on global averages. It is far preferable to have methodologies and equations which represent the actual emissions levels from the specific facility, whether these are from actual monitoring or from a set of equations more specific to bottom-up accounting within that type of facility.

## Activity Data Emission Factor Algorithm

The IPCC captures emissions categorized under five broad sectors utilizing a methodology that entails multiplication of activity data (AD) representing level of emitting activity by human activity by an appropriate emissions factor (EF) as presented in the equation below. $CO_2$ emissions from decay of short-lived biogenic material are not included because those emissions are considered to be balanced by the carbon uptake occurring prior to harvest (IPCC 2006).

$$\text{Emission Rate} = \text{Emission Factor (EF)} \times \text{Activity Data (AD)} \qquad \text{(Equation 1)}$$

The estimation of GHG emissions for inventory development is usually based upon an emission factor approach where the emission rate is considered equal to the multiplication product of an emission factor with the associated activity data.

GHG emissions based upon direct measurement obtained from engineering data and/or mass balance approaches are more accurate, but require a considerably higher level of effort and cost and therefore are best approached through industry-wide foundation supported research. The four main quantification methods identified by the World Resources Institute are: (i) the emission factor – activity level method; (ii) the mass balance method; (iii) the predictive emissions monitoring system (PEMS); and (iv) the continuing emissions monitoring system (CEMS) (WRI 2002). PEMS and CEMS are typically only utilized in sectors that must meet air emission performance standards and therefore have not been directly applied to the water sector.

## LEVELS OF GHG REPORTING

The global GHG reporting landscape is complex, and this is particularly true for the water sector. This complexity is driven by the variable degree of reporting requirements around the world. Generally, there are three states of reporting requirement: first are those countries which have mandatory reporting for water sector facilities; in these countries the standards are clear; second are countries in which there is ongoing discussion on the possibility of regulatory reporting requirements at the facility or organizational level; in these countries the standards may be in varying states of development and facilities may need to report to more than one entity to adequately cover their bases. Finally are those countries which have no reporting requirements at all. In the absence of clear regulatory standards, voluntary standards have arisen. In addition, the foundational methodologies for GHG accounting in the water sector from the IPCC are largely based on global mean averages, and are not designed to incorporate the variability of treatment processes around the world, and this has driven considerable research efforts.

In this study, the different levels at which standards for GHG accounting exist were investigated. The segregation of levels goes from the most generally applicable protocols and top-down methodologies to the most specific and bottom-up approaches. A comprehensive description of each level and sub-level is included in Appendix A. This report has not included specific information on the actual content of any of the standards themselves, such as equations and look-up factors, but rather the focus of the discussion is on how to determine which standards are most applicable to any given facility.

### Context for the Levels

#### *From Top-Down to Bottom-Up Accounting*

All countries that are signatories to the Kyoto Protocol report their National GHG Inventory to the UNFCCC. For example, the US is a signatory to Kyoto and even though they never ratified the treaty, the US EPA still provides a national GHG inventory to the UNFCCC and participates in the IPCC. The IPCC creates the guidance for national reporting under the UNFCCC. The resulting methodologies reflect the need to estimate emissions for each sector of a nation's economy. This type of top-down accounting is very important in the absence of any reports available from the individual contributors to each sector's emissions, such as companies or local governments. The result is that the equations use broadly generalized functions and look up constants, based on data that were collected from a sampling of representative industries and then normalized into an 'averaged' set of equations and constants that fit the data. An example of this is in wastewater treatment plant equations in the 2006 IPCC Guidelines, where data for emissions factor lookups have been broadly generalized according to the source of wastewater and whether the treatment process is anaerobic or aerobic (IPCC 2006). This is also clearly reflected in the methodology put forward by the U.S. EPA in 2009 for wastewater treatment, where they show the sample locations and types (U.S. EPA 2009).

As GHG reporting and emissions credit trading progresses, with the imposition of strict requirements on specific industries, the impacted sectors have developed more accurate accounting based on actual collected data at specific sites. This research has often been funded by industrial research associations, which for the water industry has included work done by the Water Environment Research Foundation (WERF), the Water Environment Federation (WEF), the Water Research Foundation, the International Water Association (IWA), the WateReuse Research Foundation and the Global Water Research Coalition (GWRC), and often by regional bodies such as the New York State Energy Research and Development Authority (NYSERDA). This work represents data collected at water and wastewater treatment plants that are currently being aggregated into what could be referred to as 'bottom-up' accounting methodologies, and is much more representative of the emissions which are actually taking place based on the specifics of the processes in use. In limited cases, very specific methodology for the water and wastewater sector has been developed through the UNFCCC for projects that have generated tradable GHG emissions credits in the sector. Obviously, the most accurate 'bottom-up' data will be that which is specifically collected on-site. But where this is a somewhat feasible and cost-effective approach for 'smoke-stack' emissions industries such as the power sector, this is much more challenging for the non-smoke-stack processes in the water sector. The body that is the most active in updating methodologies and equations for the wastewater sector is the International Council for Local Environmental Initiatives (ICLEI) working group on wastewater (ICLEI 2009).

### *Industry-Driven Standards*

Many countries that have developed individual GHG standards have been slow to provide final clarity as to which sectors of the economy will ultimately be regulated, and to clarify whether reporting will be mandatory and trading systems will be established. Many entities have therefore sprung up to provide clarity for the particular sector(s) that they serve. These entities have established a variety of standards, protocols, methodologies and algorithms with which to conduct GHG accounting. While this has resulted in a multitude of standards, most still track back to the two fundamental protocols and methodologies provided by the IPCC and WRI, which were mentioned above.

Within a number of countries and industries a set of focused standards have been established which are not governed by the UNFCCC or the National environmental agencies. These standards have arisen for two very disparate reasons: (1) **Regulatory-Influenced**: in countries or industries where regulation has been slow to emerge or where the industry wishes to influence the international standard for regulation, certain organizations have initiated a set of voluntary standards, and (2) **Regulatory-Driven**: in countries that have been very proactive about their regulation, the governance of the regulation has devolved to the agency responsible for that sector of the economy.

*ICLEI* - An example of a sector-specific protocol that has arisen in the relative vacuum of accounting standards or regulations for municipalities is ICLEI's International Local Government GHG Emissions Analysis Protocol (IEAP, commonly referred to as the Local Government Operations Protocol or LGOP, 2010). ICLEI is an international association consisting of over 1,220 local governments and national and regional local government organizations committed to sustainable development. The LGOP is a high level emissions accountancy that addresses three major components of emissions reporting: (1) approach to inventory assessment of sources responsible for GHG emissions within defined operational boundaries and reporting periods; (2) framework for assigning degree of entity control over each reported emission source through proposed usage of the WRI Scope 1, Scope 2, and Scope 3 system; and (3) framework for assigning methodological complexity in estimating the activity level and associated emission factors through use of a three-tiered system. Calculations in the document specific to estimation of emissions from wastewater treatment systems reference the IPCC model.

*API* - There have been industry specific efforts to develop consistent methodologies for estimation of GHG emissions within an industry sector. One example is the American Petroleum Institute (API). Though the API methodology does not apply to the water sector, it provides an example of what an industry association can do to provide a standard, harmonized protocol and methodology for reporting (API 2009). The API formed a Greenhouse Gas Emissions Methodology Working Group to produce the API Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry, 2009. The Compendium protocols were compared with other widely used GHG emission estimation protocols and quantitative emission comparisons were made for oil and gas sources identified in six hypothetical facilities. GHG emission sources were identified for the six industry oil and gas exploration, production, and distribution sectors in the same manner that the water treatment industry can be organized around the urban water cycle. For each oil and gas sector within the API Compendium, the GHG emitted by each source is defined and cross-referenced to emissions estimation methods. These emissions estimating methodologies are the platform on which SANGEA$^{\text{TM}}$, an automated electronic data management information system is utilized by petroleum companies to estimate, manage, and report their GHG emissions and energy consumption. SANGEA$^{\text{TM}}$ was developed by Chevron Corporation with assistance from Battelle experts who then donated ownership to API to make the software available free of charge across the oil and gas industry as a standardized method of GHG emissions estimation and reporting. A comprehensive set of methodologies and associated software tailored to the urban water industry has not yet been developed.

## Description of the Levels of GHG Reporting Available For the Urban Water Cycle

There are several different levels at which GHG accounting standards exist as shown in Table 3.1. Each level represents a category of reporting body or standard of accounting and is defined from the highest level to the lowest level based on its global applicability. In this case the term global applicability means that the levels go from the broadest possible guidance which could apply to the greatest number of entities – be they public or private, local or multi-national – to those levels which are specific to a more limited number of entities, and finally to the level which is extremely specific to an individual facility and/or treatment process.

The relevance of this presentation of levels to a water utility is that in the absence of site-specific data or even methodology that is specifically designed for one's facility type and geography, one must then go up a level to search for the standard that provides equations which are the most applicable. The way in which a utility can navigate through the decision process is shown in Chapter 7. But first, it is essential to understand the levels of standard to which any given utility may be guided.

Each level can be segregated into distinct groupings based on the type of reporting and the specificity of the methodologies to the actual technologies in use at a facility level.

## Table 3.1
## Levels of GHG standard and reporting

| Level | Entity | Examples | Key Features | Applicability to the Urban Water Cycle |
|---|---|---|---|---|
| **1** | Global Accounting Standard | WRI, ISO, ANSI | Recognized protocols and certification standard for global, multi-sector, organization-wide management & accounting framework. Organizations may use these standards and report to almost any registry. | Framework can be used for any water utility. WRI is the foundational protocol for all organizational-wide reporting. |
| | Global Voluntary Registrations | GRI, CDP | Registry with global, multi-sector, organization-wide protocols. Protocols dictate the methodology to be used. | Water utilities may report to these entities, reports from utilities that have chosen to do so are on each registry's web site. |
| | United Nations | IPCC/ UNFCCC, Kyoto Protocol CDM & JI | For signatories, multi-sector, top-down (IPCC) and project specific (CDM/JI). Methodologies serve as the general foundation for much of the global regulation of GHGs. | IPCC methodology for wastewater and combustion. Several CDM & JI projects have focused on the water sector, and are available on the UNFCCC website. |
| **2** | National Governmental Regulatory Agency | US EPA | Regulatory: Focus on top GHG sectors, facility-specific, methodology tailored to national needs, but equations may have top-down legacy from IPCC. | In certain countries the water sector may be covered (Appendix A). |
| | Regional Voluntary Registries or Standards | TCR, ICLEI/ LGOP | Voluntary: Focus on top GHG sectors; methodology tailored to national, regional, sectoral needs. Efforts in process for improvement of methodologies to become bottom-up. | The LGOP has gone to great lengths to create a comprehensive methodology for wastewater GHG accounting. Most voluntary reporting bodies use LGOP. |
| | Region- or Sector-Specific Government Agency | DEFRA | Regulatory: Focus on own sector, facility-specific, methodology tailored to national & sectoral needs, equations may reflect bottom-up data & research. | Excellent precedents have been set in the UK for how to tailor a methodology to the water sector. |
| **3** | Industry Association Standards and Research Papers | WRF, WEF, WERF, GWRC, IWA, UKWIR | Research efforts to understand and model bottom-up data. | Wide disparities have been shown between reported data and the top-down equations put forth by IPCC and national regulators. This research may pave the way to more accurate equations & models. |
| | Facility-Specific | | The best single source of data. Some regulatory entities require actual monitoring for top emitters, but not in the water sector. | Actual, measured data is the best means of reporting. But often cost prohibitive, and challenging due to the fugitive nature of many GHG emissions. |

## GHG EMISSION REPORTING: SCOPES

Most of the equations for estimating GHG emissions are adaptations of the IPCC/UNFCCC ***methodology*** established for national reporting. Similarly, nearly all reporting traces back to the WRI GHG ***protocol***. As such, our discussion of the fundamentals of GHG accounting methodologies will focus on the IPCC and WRI 'foundational' equations and approach.

The WRI GHG Protocol allows for the attribution of GHG emissions according to different levels of ownership. These procedures introduce the concept of scope of emissions, which distinguishes direct facility ownership emissions from emissions resulting from broader company activities. Scope 1 emissions are owned or controlled by the company (producer) and include, for example, onsite emissions from boilers, furnaces, and vehicles. Scope 2 (consumer) encompasses emissions during the generation of purchased electricity. Scope 3 (consumer) includes offsite emissions during extraction and production of purchased materials, transportation of workers and supplies, and end product use. Scope 3 emissions do not have to incorporate a full life cycle assessment, but need to practically assess the major indirect emissions attributable to the company's activities (Kennedy et *al.* 2011). Many organizations such as the California Climate Action Registry (CCAR), The Chicago Climate Exchange (now defunct), The Colorado Carbon Fund (CCF) and the North American Climate Registry (CR) have adopted the WRI / WBSCD scope framework.

### Scope/Ownership for Water/Wastewater Utilities

A summary of the universally accepted scope definitions from the WRI standard is provided in Table 3.2. Linkage of these generic definitions to each of the engineered water and wastewater system components within the Figure 1.1 urban water cycle are provided in Table 3.3. The level of understanding of process specific GHG emissions within each scope and each part of the urban water cycle varies tremendously, and is discussed in detail in the next section of this chapter.

**Table 3.2**
**Universally accepted scope definitions (WRI/WBCSD 2005)**

| Scope Designation | Ownership Level | Contributing Sources |
|---|---|---|
| 1 | Direct | Fuel combustion<br>Process emissions<br>Facility owned vehicles<br>HVAC & Refrigeration |
| 2 | Indirect | Purchased electricity or steam for owner use |
| 3 | Indirect | Production of purchased materials<br>Employee business travel<br>Waste disposal<br>Outsourced activities<br>Contractor owned vehicles<br>Product use |

## Table 3.3
## Sources and type of GHG emissions from water/wastewater treatment facilities

| Sources | GHG | Scope |
|---|---|---|
| **Drinking Water Facilities** | | |
| Conveyance (Pumping) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Storage (Pumping) | $CO_2$, $CH_4$, $N_2O^1$ | Facility construction & maintenance = 3 and company owned vehicle usage = 1 |
| Extraction (Pumping) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage = 1 |
| Treatment (Coagulation/Floc/Sed) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Treatment (Filtration) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Treatment (Carbon) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Treatment (Ozone) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1; ozone generation of nitrous oxide = 1 |
| Treatment (Chlorine/Chloramines) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Treatment (UV) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Treatment (Lime Softening/Recarb) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Sludge to landfill | $CH_4$ | Waste disposal = 3 |
| Sludge applied to land | $CH_4$, $N_2O$ | Waste disposal = 3 |
| Distribution | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| **Wastewater Facilities** | | |
| Collection System (Pumping) | $CO_2$, $CH_4$, $N_2O^1$ | Power for pumping = 2 if electricity or 1 if on-site fuel; pumping facility construction & maintenance = 3 and company owned vehicle support =1; methane release from sewer = 1 |
| Treatment (Headwork) | $CH_4$ | Methane release from untreated wastewater = 1; headwork facility construction & maintenance = 3 |
| Treatment (Primary) | $CH_4$ | Methane release from untreated wastewater = 1; primary facility construction & maintenance = 3 |
| Treatment (Activated Sludge) | $CO_2$; $N_2O$ | Aeration power = 2 if electricity or 1 if on-site fuel; Nitrous oxide release during N/dN treatment or wastewater effluent discharge without N/dN treatment = 1; facility construction & maintenance = 3 |
| Treatment (Filters) | $N_2O$ | Nitrous oxide release from N/dN treatment = 1 |
| Treatment (Ozone) | $N_2O$ | Nitrous oxide release from treatment = 1 |
| Treatment (Chlorine) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Treatment (UV) | $CO_2$, $CH_4$, $N_2O^1$ | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |

(continued)

**Table 3.3 (Continued)**
**Sources and type of GHG emissions from water/wastewater treatment facilities**

| Sources | GHG | Scope |
|---|---|---|
| **Wastewater Facilities** (continued) | | |
| Treatment (Reclaimed Potable) | $CO_2$, $CH_4$, $N_2O$[1] | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Distribution (Nonpotable Reclaimed) | $CO_2$, $CH_4$, $N_2O$[1] | Power = 2 if electricity or 1 if on-site fuel; Facility construction & maintenance = 3 and company owned vehicle usage =1 |
| Biosolids (Landfill) | $CH_4$ | Waste disposal = 1 if landfill owner or 3 if outsourced |
| Biosolids (Incinerated) | $CH_4$, $N_2O$ | Fugitive emissions =1 |
| Biosolids (Fertilizer/Soil Amendment) | $CH_4$; $N_2O$ | Waste disposal as product = 3 |
| Biosolids (Composting) | $CH_4$, $N_2O$ | Waste disposal = 1 if on site or 3 if outsourced |
| Biosolids (Dewatering) | $CH_4$ | Fugitive emissions = 1 |
| Biosolids (Anaerobic Digestion) | $CH_4$ | Fugitive emissions = 1 |
| Biosolids (Digester Gas Combustion) | $CH_4$; $N_2O$ | Fugitive emissions = 1 |
| Biosolids (Combined Heat Power) | $CH_4$, $N_2O$ | Fugitive emissions = 1 |

[1] Depending upon fuel, $CH_4$ and $N_2O$ emissions may also occur which are then translated to $CO_{2e}$ values.

### *Scope 1*

Scope 1 GHGs, or direct emissions, in the water and wastewater industry primarily result from stationary and mobile combustion of fuel. Stationary fuel combustion sources at treatment facilities can include boilers, emergency generators and generators used for on-site heat and power production, and pumps that emit GHGs as a result of combustion processes. Mobile fuel combustion typically includes the utility transportation fleet.

For wastewater facilities, there are direct emissions of methane that can occur prior to biological treatment of the wastewater and during biosolids processing. Nitrous oxide emissions can occur during nitrification/denitrification processes within and following secondary treatment as well as during composting or land application of biosolids. Nitrous oxide emission can also occur during certain water treatment processes such as ozonation.

Emissions of other GHGs, such as HFCs from refrigeration leaks, SF6 from electrical power distributers or tracers in groundwater recharge, can occur at wastewater facilities, but these are largely considered to be de minimus. De minimus is defined differently around the world, but is typically <1% of the total facility emissions.

The IPCC and ICLEI/LGOP methodologies consider emissions of methane and nitrous oxide throughout the pathway of wastewater processing alternatives in a simplistic, high level manner and exclude $CO_2$ emissions because they are of biogenic origin. Sources of methane emissions are calculated on the basis of organic carbon content (activity level) and the extent to which this organic carbon generates methane (emission factor) through anaerobic processes. Sources of nitrous oxide emissions are calculated on the basis of protein content (activity level) and the extent to which this protein generates nitrous oxide (emission factor) through treatment processes or after discharge to the environment. While the protocol discusses use of different tier level input data to achieve increasing levels of specificity in the estimated emission, the simplistic calculations do not consider the underlying process models needed to accurately estimate facility level emissions. For this reason, the National Association of Clean Water Agencies (NACWA) commented unfavorably on the USEPA Draft Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2005 (USEPA 2007) that was largely derived from the IPCC methodology. The wastewater industry felt that the EPA methodology overestimated the methane and nitrous oxide emissions from the wastewater industry (NACWA 2008). California wastewater agencies formed the California Wastewater Climate Change Group (CWCCG) in anticipation of future regulatory requirements and in recognition of the need for more accurate GHG emission accounting protocols for the wastewater community.

### *Scope 2*

Scope 2 emissions, also referred to as indirect emissions, result from purchase of electricity to power pumps, blowers, motors, and other treatment process power needs. Scope 2 emissions also include imported steam, district heating or cooling, and combined heat and power (CHP) from a cogeneration plant.

For drinking water facilities, the majority of the GHG emissions are currently from purchased power utilized for pumping (Elliott et *al.* 2003), for systems that are not gravity fed. Deployment of advanced technologies, such as reverse osmosis and ultraviolet disinfection, could play a significant role in generating GHG emissions in the future. The power associated with these systems is primarily supplied as purchased electricity (Scope 2). Some utilities opt for use of on-site power generation from fuel (Scope 1) as a standby option for system reliability or for "peak shaving" (Reiling et *al.* 2009). Purchased electricity and on-site power generation result in $CO_2$, $CH_4$ and $N_2O$ emissions that are dependent upon the specific mix of fuels utilized to generate power.

### *Scope 3*

Scope 3 emissions include contractor or employee owned vehicles, product use, outsourced activities, and waste disposal occurring outside of an entity's jurisdiction. Additional sources of emissions may be included along the cradle-to-grave life cycle of all products or assets which enter and exit the facility's boundaries. Scope 3 emissions specific to water and wastewater treatment facilities that are typically included are those which arise from $CO_2e$ release that occurs during production and distribution of chemicals and other supplies used during treatment (life-cycle carbon) as well as $CO_2e$ emissions that occur during construction, maintenance, and demolition of facilities (embedded carbon). The UKWIR has developed a framework for consistent estimation of embodied carbon in construction, and operational carbon emissions in 'whole life carbon' accounting (UKWIR 2009). The guidelines suggest that whole life carbon accounting should follow the same principles as cost accounting and, as far as possible, use the same asset input data. The guidelines include methods for estimating embodied carbon and also emission values for common construction items.

## GHG EMISSIONS REPORTING: GASES

There are six common GHGs used in reporting around the world, these are: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$). The severity with which each causes the greenhouse gas effect differs, and considerable study has gone into what is called the “global warming potential” (GWP) of each gas. Carbon dioxide has a GWP of one, and the others have much higher values as shown in Table 3.4 below.

Typically, reporting GHGs to a regulatory or voluntary body must include all six gases reported individually by scope. In addition, the carbon dioxide equivalent ($CO_2e$) can be calculated for all gases by using the GWP of each gas as a multiplier. The following equation provides and example of how this is done, where each GHG gas is additive to the formula.

$CO_2e$ tonnes/yr = [$N_2O$ tonnes/yr x 310] ........................................................ (Equation 2)

**Table 3.4**
**Global Warming Potential (GWP) Estimates of GHG**

| GHG Gas | GWP |
|---|---|
| Carbon dioxide | 1 |
| Methane | 24 |
| Nitrous Oxide | 310 |
| Sulfur Hexafluoride* | 22200-23900 |
| Hydrofluorocarbons* | 120-14800 |
| Perfluorocarbons* | 5700-12200 |

*Actual value is compound specific.

## GHG EMISSIONS IN THE URBAN WATER CYCLE: METHODOLOGIES AND RESEARCH

This section discusses in detail the reporting of GHG emissions by scope throughout the Urban Water Cycle (UWC), as well as the status of current research into specific emissions from the different points in the UWC. Table 3.5 summarizes the applicability of reporting across the levels and scopes within the UWC.

## Table 3.5
## Levels of GHG emission standards and reporting as they apply to the urban water cycle

| Urban Water Cycle | | Combustion - $CO_2$ (Scope 1 ) | Combustion - $CH_4$ & $N_2O$ (Scope 1) | Power Use - $CO_2$, $CH_4$ & $N_2O$ (Scope 2) | Process $CH_4$ (Scope 1) | Process $N_2O$ (Scope 1) |
|---|---|---|---|---|---|---|
| **Sources** | | Facilities that combust fossil fuels or flare gas. | Facilities that combust sludges or fossil fuels or flare gas. | Facilities that utilize power, heat or steam. | Facilities that have anoxic or anaerobic zones or treatment processes. Much of this is from fugitive, unintentional emissions. | |
| **Processes** | | Water or Wastewater Treatment Plants with self-generation of power or steam. Utility-owned vehicle fleet. | | Pumping, Treatment, Biosolids Drying/Dewatering | Sewer/storm collection, head works, activated sludge basins, biosolids management, composting & landfilling | |
| **Level 1** | Global Accounting<br>Global Voluntary | Protocol is applicable to any point in the UWC. | | | | |
| | United Nations | IPCC methodology for combustion. | | N/A | Methodology for wastewater treatment, landfills. | |
| **Level 2** | National Government Environmental or Other Regulatory Agency | Combustion methodology covered by all regulators or voluntary GHG reporting bodies. | | No reporting of Scope 2 at this level. | Methodologies generally exist for landfills, which are usually regulated. Methodologies generally exist for wastewater treatment, but this sector is often unregulated. | |
| | Regional Voluntary Registries or Standards | | | Methodologies provided | | |
| | Region- or Sector-Specific Government Agency | | | Methodologies provided if applicable. | | |
| **Level 3** | Industry Association Standards and Research Papers | N/A | Research efforts to understand and model bottom-up data. | N/A | Significant research throughout the UWC. Specific discussions in report section below. | |
| | Facility-Specific | Monitoring protocol if combustion exceeds the regulator's thresholds. | | Activity-data from the facility-level | Research is drawing on data collected by some facilities at this level. | |

## $CO_2$, $CH_4$ & $N_2O$ Emissions - Scope 1 - Combustion

Scope 1 emissions from combustion can arise from the following sources: incineration of sludges or biogas, combustion of landfill gas, combustion of fossil fuels on-site to provide power, and combustion of mobile fuel for fleets owned by the facility. The specific GHGs which must be accounted for from each of these sources is shown in Table 3.4, and described below.

### *Sludge, Biogas & Landfill Gas*

The incineration, or combustion, of biological materials such as sludes, biogases and landfill gases produces three GHGs: $CO_2$, $N_2O$ and $CH_4$. $CO_2$ and $N_2O$ occur as the products of combustion, whereas $CH_4$ may occur as a pass through gas due to inefficiencies in the combusiton of biogas or landfill gas. Since the $CO_2$ emissions from these sources are biogenic, they are considered to be 'short cycle' gases because in principle they will be naturally reabsorbed by replacement biogenic materials which utlize $CO_2$ as they grow. For this reason most regulators and voluntary reporting bodies do not require the reporting of this biogenic CO2. However, the $CH_4$ and $N_2O$ emissions from these sources are considered to be anthropogenic and reportable sources of GHGs. The only $CO_2$ emission considered to be non-biogenic arises from the wastewater process practice of adding methanol as a carbon source for denitrification during the activated sludge process or with denitrifying filters. Biogenic $CO_2$ emissions are presently considered to be carbon-neutral, but are sometimes requested to be reported as separate biogenic emissions in a category separate from Scope 1 fossil fuel combustion emissions.

### *$N_2O$ from Combustion of Sludge*

$N_2O$ emissions have been documented from sludge incineration (Suzuki et *al.* 2003; Svoboda et *al.* 2006). Literature analysis performed in development of Biosolids Emissions Assessment Model (BEAM) (Canadian Council of Ministers of the Environment 2009) noted a wide disparity in the range of $N_2O$ emissions per dry tonne of biosolids (1,520-6,400 vs 800-1,500). The lower values (Svoboda et *al.* 2006) are published by the IPCC (IPCC 2006), but the higher emission values are utilized in BEAM due to their reliance upon multiple rather than single observation points. In the Suzuki study, $N_2O$ and freeboard temperature were monitored continuously at 6 facilities between 7-14 days. The $N_2O$ emissions were inversely related to freeboard temperature and the following relationship was proposed to estimate the $N_2O$ emissions factor of a given incinerator from its long-term average freeboard temperature:

$$\eta = 161.3 - 0.140T_f \qquad \text{(Equation 3)}$$

where,

$\eta$ = % of total N that is volatilized as $N_2O$; and

$T_f$ = average highest freeboard temperatures from the fluidized bed facilities.

### *Fossil Fuels*

Only utilities which combust their own fossil fuel for on-site power production will need to include these emissions as part of their scope 1 reporting. All of the emissions which come from purchased power, in other words power provided by the local electic utility, count as scope 2 emissions. If a utility has back up diesel generators, which is common, and those generators are *only* turned on for testing and maintenance then the utility typically does not need to include those emissions in their regulatory reporting.

To report these scope 1 emissions from fossil fuels, the utility will need to track the actual amount and type of fossil fuel combusted on a BTU, Joule or equivalent basis. The utility should then utilize the look up tables provided by the relavent environmental reporting agency to which they wish to or must comply. Those tables will typically provide lookup factors on a tons of $CO_2$ per mmBTU basis for each fuel type. Simple multiplication of the annual fuel use times the the lookup factor for each GHG gas (see Equation 1) will result in the total GHGs that are scope 1 from this category. These factors will also be given for $N_2O$ and $CH_4$, which are typically minor compared to the $CO_2$. Typically, the regulator will require the report to include line items for each GHG, and may also require a line item for calculating the $CO_2$ equivalents. Since these reporting requirements, and sometimes the lookup factors, may vary from reporting entity to reporting entity it is important to verify the requirements and document the process clearly. Typically, the lookup factors will be constant by fuel type from one region of the world to the next. This is because the quality of fossil fuels is relatively uniform and predictable.

For gas combustion processes there is a combustion efficiency factor to consider. Particularly for flaring, a small percentage of the methane ($CH_4$) gas may pass through the combustion process unconverted to $CO_2$. The efficiency of the combustion process is typically a factor of equipment age, equipment type, and use. Most regulatory agencies have specific guidance on the equations to use for this purpose, and this guidance should be speicifically referred to. Precisely for this reason, power plants or industrial facilities with large stationary combustion units may be required to employ continuous emission monitoring systems (CEMS) that detect GHGs and will report to the environmental regulator on this basis, rather than using fuel consumption data.

### *Mobile Fleet Fossil Fuels*

Vehicle fleets are mobile combustion sources of fossil fuel emissions that are estimated based on vehicle fuel use and corresponding emission factor. When fuel usage data are lacking, an estimate can be made from the fuel economy of each vehicle and the annual mileage or from total fuel dollars spent together with average annual fuel prices for the region if unit costs are missing from receipts.

$CH_4$ and $N_2O$ emissions occur from fuel combusted onsite to provide power to treatment facilities and from mobile fleets. These emissions are largely estimated from fuel look-up tables as previously described for Scope 1 $CO_2$ emissions. Harmonization issues arise in a global context from differences in the default emission factors per fuel type or discrepancies in incompletely reported volumetric units (e.g.,1 *metric* tonne = 0.98 *imperial UK* ton = 1.10 *US* ton).

## $CO_2$ Emissions – Scope 2 – Power, Heat & Steam Use

Scope 2 $CO_2$ emissions are performed in a similar manner to Scope 1 $CO_2$ emissions with electricity use substituted for fuel use activity level and electricity emission factors substituted for fuel emission factors. When unverified utility-specific emissions factors are obtained directly from an applicable utility company, they must include all of the power transmitted by the utility and not just the power directly consumed by the receiving water utility. Green power and renewable energy certificate purchases should not be deducted from Scope 2 emissions because doing so would constitute double counting as the renewable fraction is already accounted for in the eGRID factor (eGRID 2010). In the case of Combined Heat & Power (CHP) purchases, the "share" attributable to electricity and heat must be discerned by using a ratio based on the heat and/or electricity relative to the CHP plant's total output. Electric vehicles are included as Scope 2 emissions utilizing the electricity consumed and applying the appropriate emission factor.

## $CH_4$ Emissions – Scope 1 – Process

Septic systems and improperly managed aerobic treatment systems are additional sources of $CH_4$ emissions that are excluded from this discussion section. This omission is because septic systems are not under the jurisdiction of wastewater treatment facilities and improperly managed aerobic treatment facilities will not occur in urban regions where the majority of the world's population resides due to existing regulatory requirements.

Wastewater treatment processes can also directly produce $CH_4$ emissions when anaerobic conditions occur. These can occur, intentionally or unintentionally, during wastewater collection and treatment and during storage, landfilling or combustion of biosolids. There are three discrete locations that are possible emission sources of $CH_4$ in urban settings: (i) sewer collection systems and influent head works; (ii) anaerobic/anoxic activated sludge tanks; and (iii) biosolids processing and handling. A fourth source of $CH_4$ emissions from anaerobic wastewater treatment processes that are open to the atmosphere such as lagoons and complete anaerobic activated sludge processes are not typically utilized in urban regions. Unlike $CO_2$ emissions from organic matter which are considered to be of biogenic origin, $CH_4$ emissions from organic matter are classified as Scope 1 emissions because they would not have been produced if the biomass had decomposed naturally. Some portion of $CH_4$ emissions from biosolids handling and disposal can be considered Scope 3 emissions from a wastewater facility if handled by an independent third party. Accurately measuring methane emissions at sewage treatment facilities is difficult because most emissions come from fugitive losses or from large area sources.

### *Sewer Collection Systems and Influent Head Works*

Wastewater collection systems are a source of $CH_4$ emissions at points where the anaerobic underground conveyance infrastructure comes in contact with the atmosphere. While the 2006 IPCC guidelines consider wastewater in underground sewers to be an insignificant source of $CH_4$, it has been reported to occur (Guisasola et *al.* 2008) and is being further investigated by the wastewater industry. The potential for $CH_4$ emissions at sanitary sewage lift stations, force mains, and treatment facility head works is not well understood as many variables related to weather, hydraulics, sewer strength, pumping cycles and facility design condtions can impact the extent of emissions. This is further complicated by modeling uncertainties in the formation of $CH_4$ versus sulfide in the anaerobic environment of force mains due to competition for electron donors by the microbes responsible for the formation of these gases and the impact of oxygen in gravity sewers. Research, described below, is ongoing to collect CH4 emission data in order to better understand the range of observed values and to assist with calibration of force main CH4 generation models.

An ongoing 5-year WERF study, is seeking to better understand $CH_4$ emissions through gas phase measurements on 64 sanitary sewage lift stations and two treatment facility head works within DeKalb County, Georgia (WERF 2010; Brown and Caldwell 2010). Sampling during an initial phase of testing was performed once during cold weather and once during warm weather. Initial results from the instantaneous $CH_4$ monitoring phase confirm $CH_4$ emissions at all of the lift stations and at the head works of the treatment plants. Additional study will help in discerning how the instantaneous $CH_4$ readings relate to the range of emissions that occur at each location in relation to sewer strength and hydraulic retention time, temperature, pumping cycle influence on flow and ventilation rate, lift station dimensional design, and headwork inlet conditions. The two treatment facility headworks studied in the WERF Project #UN2R08 have open forebays at their influent lift stations and the raw sewage arrives at both facilities through gravity sewers. At one facility, combined flow goes through a parshall flume and influent screens which is likely to strip the methane prior to entering a partially covered influent wet well. In the second facility, combined flow splits and cascades into open wet wells. Additional study is needed to better assess municipal sector methane emissions from treatment facility forebay design configurations.

The WERF study is providing calibration data for the $CH_4$ generation models being developed by University of Queensland researchers to predict methane formation in force main sewers (Guisasola et *al.* 2009). The sewer model development derives from an extension of the hydrogen sulfide dynamic model presented in Sharma et *al.* (2008) extended to account for competition between methanogenic activity, sulfate-reducing bacteria, and fermentative bacteria for electron donors. Several assumptions are inherent in the modeling process. These include use of the steady state temperature factors from the steady state Wastewater Anerobic/Anaerobic Transformations in Sewers (WATS) model (Hvitved-Jacobsen et *al.* 2000), Monod kinetics with higher values of saturation constants for biofilm-catalyzed processes, and stoichiometry/kinetic assumptions amongst the interactive bacterial reactions as described in Guisasola et *al.*, 2009.

Modeling uncertainties relate to incomplete understanding of competitive mechanisms of methanogenesis and sulfidogenesis, although mg COD/mg S ratio and mass transfer limitations of the sulfate needed as electron acceptor for sulfidogenesis through biofilms are key parameters. The percentage acetate utilization by sulfate-reducing bacteria is also dependent upon the wastewater composition due to its influence on the sewer biofilm developed. The model simulations indicate that methane formation in force main sewers positively correlates with the hydraulic residence time and the biofilm surface area to volume ratio. Methanogens appear to be more competitive than sulfate-reducing bacteria under the sewer biofilm conditions investigated and methane production in sewers may contribute toward GHG emissions from wastewater systems which include force mains. Further study is needed to incorporate other field conditions as well as biological methane degradation and methane stripping from gravity sewers. It is also important that the analytical methodology employed in these studies is able to account for dispersed methane and pumping cycle effects on introduction of outside air, as both of these effects will result in underestimation of actual emissions (GWRC 2011).

Several existing models for estimating volatile organic carbon (VOC) and hazardous air pollutant (HAP) emissions from wastewater collection systems and treatment plants include WATER9, TOXCHEM+, and INTERCEPTOR. WATER9 is a computer-based VOC and hazardous air pollutant (HAP) simulation model developed and used by the USEPA to assess emissions from publically owned treatment works (POTWs), one of the source categories initially identified for a Maximum Achievable Control Technology (MACT) standard as specified in Section 112(c) of the Clean Air Act Amendments (CAAA) of 1990. None of these models have been adapted to address methane emissions, probably due to concerns about the predictive capabilities of their underlying algorithms, and difficulties in establishing model component setup and execution that is representative of the system being modeled (e.g. gravity sewers). Also, while there are similarities in the foundational mass transfer algorithms employed by the three models, there are significant differences in the handling of algorithm gas-phase mass transfer components (Quigley et *al.* 2006).

### *Activated Sludge Basins*

Considerably lower emissions of $CH_4$ are expected from activated sludge basins which are considered to primarily be a direct source of $N_2O$ emissions. Nonetheless, facility studies in France and the Netherlands for $N_2O$ emissions from wastewater treatment facilities have also included $CH_4$ in order to generate field data in an area where little previously existed (GWRC 2011). In France, four facilities were continuously sampled from the anaerobic, anoxic, and aerobic zones in the off-gas collected from these process basins utilizing a suspended (floating) gas hood. Emissions were obtained from the concentrations measured in the exit air from the sampling system (mg $CH_4/m^3$ air) multiplied by the air flow applied to the sampling system ($m^3/h$) and then divided by the influent COD concentration (mg COD/L) times the influent flow (L/h). In the Netherlands, three facilities were evaluated utilizing grab samples at various locations within the aqueous process train (after inlet/coarse screen, primary settling, selector, anaerobic tank, carousels). Emissions were obtained from the gaseous methane analytically purged from the aqueous grab sample (mg $CH_4/m^3$ air) multiplied by the off gas flow at the facility obtained using a pitot tube ($m^3/h$) and then divided by the influent COD concentration (mg COD/L) times the influent flow (L/h). The results from the Netherlands showed higher $CH_4$ emissions from the aeration tank than from the anaerobic tank and the emissions are suspected of being residual $CH_4$ from the sewers that was not completely stripped at the inlet works. The overall treatment facility emission factors for $CH_4$ ranged from <0.04-0.1% of the influent COD for the French facilities and 0.5-4.8% of the influent COD for the Netherlands facilities (GWRC 2011).

### *Biosolids*

Management of biosolids consists of storage, thickening, liquid stabilization, dewatering, thermal drying, stabilization, and end use or disposal. The chemicals and energy utilized in the processing, transport, and end use of biosolids that contribute toward GHG emissions are considered elsewhere in this discussion (i.e. chemicals are Scope 3 emissions, energy from purchased electricity are Scope 2 emissions or Scope 1 fuel emissions). This subsection is specifically focused on Scope 1 fugitive methane emissions during biosolids processing.

***Storage and Gravity Thickening.*** Methane can be emitted during storage of liquid wastewater solids prior to processing or during gravity thickening. Storage in lagoons will emit the largest amounts of methane, but lagoons are rarely employed in urban settings. Methane emissions from tank storage or gravity thickening can be eliminated if they are kept minimally aerobic by addition of effluent or other aerated water.

***Liquid Stabilization.*** While there are various forms of liquid stabilization (e.g., anaerobic digestion, aerobic digestion, autothermal thermophilic aerobic digestion, lime) only anaerobic digesters or anaerobic conditions within aerobic digesters have the potential for fugitive methane emissions. During anaerobic digestion, biosolids are broken down in the absence of oxygen to create $CH_4$, which is then combusted to produce heat or power that can be used to offset Scope 1 fuel usage or Scope 2 electricity purchases. Any inefficiencies in the process result in fugitive $CH_4$ emissions. When the volume of digester gas (biogas) and its fraction of $CH_4$ are measured, site-specific emissions can be calculated for an assumed $CH_4$ destruction efficiency. When these measurements are not available, estimates must be made from the population served and assumed values for the cubic feet of digester gas produced per person per day and the fraction of $CH_4$ in the biogas. Aerobic digestion systems with potential anaerobic zones are autothermal thermophilic aerobic digestion (ATAD) systems. These systems are much less frequently utilized because they do not provide energy credits. Furthermore, because an ATAD system will produce odorous off-gases, it is generally installed with a scrubber or biofilter that will likely reduce any $CH_4$ emissions.

The amount of methane produced during a typical mesophilic anaerobic digestion process can be estimated from assumptions about the percentage of volatile material within the sewage sludge dry solids (typically 70-80%) and the percentage of these volatile solids converted to methane and carbon dioxide (typically 30-60%). The methane content of the produced biogas is approximately 50%. A typical methane production rate of 143 kg per tonne of dry solids (tds) fed to the digester was reported in the UK. The fraction of methane released as fugitive emissions is an indeterminate variable that has been reported in the UK in the range of 5-10% with the lower emission rate representative of newer anaerobic digesters with fixed roofs without annular spaces (Hobson 1999). A study of anaerobic digester facilities in New York City reported an average digester methane leakage rate of 1% (New York Power Authority, 2005). The default efficiency for $CH_4$ destruction upon combustion is assumed to be 99% in BEAM (Canadian Council of Ministers of the Environment 2009).

***Composting and Landfilling.*** Oxygen limiting conditions during composting can contribute fugitive emissions of methane. There are default factors for emission of methane based on the organic carbon content in the compost pile. BEAM utilizes a default emission factor of 2.5% of the organic carbon in the pile, derived from a literature review on fugitive gas emissions from composting (Brown et *al.* 2008). Compost pile condition criteria are also proposed for determining whether the default emission should be utilized. Criteria for elimination of the default emission include use of water to keep the compost moist, sufficiently low initial moisture content of the pile, or employment of a finished layer of compost or a biofilter. BEAM considers fugitive methane emissions from composting to be negligible if the total solids content is >55%, as this will promote an aerobic environment or if process air is treated in a biofilter.

Fugitive methane emissions from landfilled biosolids will be reduced if the landfill has a gas collection system, the landfill is covered with mulch or compost which supports methanotropic bacteria that can oxidize any methane formed, the landfill is in the warmer climate needed to support the methanotrophic bacteria, and if the disposed biosolids have undergone prior stabilization. BEAM utilizes a protocol derived from the Clean Development Mechanism (CDM) of the Kyoto Protocol to calculate potential landfill $CH_4$ emissions based on default factors for percentage solids, total carbon, the carbon fraction degradable under anaerobic conditions, and a decay rate constant.

## $N_2O$ Emissions – Scope 1

### *Activated Sludge Basin Emission Modeling*

Tools for estimating direct emissions of $N_2O$ during activated sludge treatment are under development. Recent research in the United States has shown $N_2O$-N emissions from biological treatment can range from 0.01-1.8% of the influent TKN (WERF 2010). Similar ranges were observed for measurements collected in Australia, France, and Netherlands, with the exception of one very high value of 11.2% observed during one of three sampling rounds performed at a Modified Ludzack-Ettinger facility in Australia and two very low values of <0.01% observed at two facilities in France (GWRC 2011). Factors that likely contribute toward the observed variations include process configuration, operating parameters, seasonality, and nitrogen load variations from changes in influent flow rates. A wide range in estimated emission factors of 0.28-140 $N_2O$/PE/yr (WERF, 2010) supports the belief that it might not be possible to accurately estimate emission factors from measured $N_2O$ concentrations due to the difficulty in obtaining continuous flux data (L. Fillmore, personal communication). Instead, dynamic activated sludge modeling tools are being extensively explored (J. Porro, personal communication).

Tools for estimating $N_2O$ emissions need to expand on the activated sludge models developed to provide a common platform for simulating biological treatment processes. In 1982, a Task Group formed by IWA resulted in the 1987 publication of Activated Sludge Model No. 1 (ASM1) which incorporated a single sludge system carrying out carbon oxidation, nitrification and denitrification. Although biological phosphorus removal was practiced when ASM1 was published, a lack of complete theoretical understanding of the process did not allow inclusion of this process in ASM1. As the understanding of the basic phenomena of biological phosphorus removal increased from the mid-1980s to mid-1990s, the Activated Sludge Model No. 2 (ASM2) was published in 1995 to incorporate biological phosphorus removal. Then, as the role of denitrification in biological phosphorus removal was well understood, ASM2 was revised to incorporate denitrifying phosphorus accumulating organisms (PAOs), and the model was published in 1999 as ASM2d. The Activated Sludge Model No. 3 (ASM3), which is the latest version of the model, incorporates the concept of storage-mediated growth of heterotrophic organisms, assuming that all readily biodegradable substrate is first taken up and stored internally, and then used for growth. The ASMN model of Hiatt and Grady (2008) utilizing two-step nitrification and four-step denitrification of nitrate to nitrogen gas is frequently utilized as a base for $N_2O$ emissions, but requires adjustments to electron transfer processes. Furthermore, as for all existing models, it still requires calibration and is lacking full-scale validation.

Measured $N_2O$ emissions were found to be consistently higher from aerobic zones than anoxic zones (WERF 2010), but these results need to be substantiated throughdynamic process modeling. Several different pathways for formation of $N_2O$ exist within an activated sludge process with dominant pathways dependent upon reactor configuration conditions and associated microbial and water quality conditions. $N_2O$ can be generated during ammonia oxidation, heterotrophic denitrification, nitrifier dentirification, chemical dentrification, and methane oxidation. Several $N_2O$ models exist for each pathway due to different assumptions in the transformation mechanisms. The International Water Association (IWA) Task Group is evaluating state of the art models and modeling for the various $N_2O$ pathways with the ultimate goal of developing a unified model. At present, there is no proposed emission factor for $N_2O$ that can be utilized to accurately predict direct $N_2O$ emissions from treatment facilities. Some generalities are emerging from the research as to conditions that cause greater release of $N_2O$ such as effluent TKN values >5 mg/L. However, the reality is that results vary so greatly in the relationship between the input and output sides of the emissions equation that many in the industry feel that a standard emissions factor approach may be extremely challenging for $N_2O$ emissions.

### *Biosolids*

This subsection is specifically focused on Scope 1 fugitive $N_2O$ emissions during wastewater biosolids processing.

***Gravity Thickening.*** Gravity thickening might generate $N_2O$ emissions and additional study is needed to better discern the impact of upstream treatment on potential emissions.

***Liquid Stabilization.*** ATAD systems tend to operate with microaerobic conditions that create the opportunity for $N_2O$ production. While biofiltration is usually employed for gaseous odor control, high levels of ammonia in the incoming gas might result in $N_2O$ emissions.

***Composting and Landfilling.*** Oxygen limiting conditions during composting can contribute fugitive emissions of $N_2O$. There is a default factor for emission of $N_2O$ based on the total nitrogen content in the compost pile. BEAM (Canadian Council of Ministers of the Environment 2009) utilizes a default emission factor of 1.5% of the total N in the pile, derived from a literature review on fugitive gas emissions from composting (Brown et *al.* 2008). Compost pile condition criteria are also proposed for determining whether the default emission should be utilized. Criteria for elimination of the default emission include use of water to keep the compost moist, sufficiently low initial moisture content of the pile, a high C:N ratio of the pile in excess of 30:1, and a high pile temperature of 55°C. It is not known whether employment of a finished layer of compost or a biofilter will curtail any existing $N_2O$ emissions.

Fugitive $N_2O$ emissions from landfilled biosolids will be reduced if the landfill has a gas collection system and if the disposed biosolids have undergone prior nitrogen removal. BEAM utilizes the same compost $N_2O$ default emission factor (1.5% of total N in the biosolids) for landfills since the Clean Development Mechanism (CDM) of the Kyoto Protocol and the literature do not provide any factors for $N_2O$ emission from landfills.

***Land Application as Fertilizer.*** The IPCC provides direct and indirect factors for $N_2O$ emissions from municipal wastewater biosolids applied as fertilizer. Direct emission of volatilized N is assumed as 1% of the total N added and then converted from $N_2$ to $N_2O$ through multiplication by the molar ratio (44/28). Indirect emissions are calculated from the following equation:

$$\text{Fon} = \text{Application rate (Kg N applied)} \times \text{FracGASM } 0.2 \times \text{EF4 } 0.01 \qquad \text{(Equation 4)}$$

where,

Fon = indirect emissions of $N_2O$ from fertilizer
FracGASM = fraction of added N that will volatilize
EF4 = conversion factor for fraction of N that volatilizes that will convert to $N_2O$.

Additional factors likely to increase $N_2O$ emissions include higher annual rainfall, soils with higher clay content and little loam or sandy texture, and avoidance of tillage practice. Review of biosolids processing impact on $N_2O$ emissions for an imperfectly drained clay loam in Scotland demonstrated no difference in emissions for pelletized biosolids, composted biosolids, and digested liquid biosolids. The respective emissions in kg N ha-1 were 10.0 ± 0.67 for the composted biosolids, 8.0 ± 1.91 for the dried pellets, and 10.3 ± 2.12 for the digested liquid biosolids (Canadian Council of Ministers of the Environment 2009).

In all cases of biosolids application, a GHG accounting credit usually results if the biosolids use displaces application of synthetic fertilizer.

## Additional GHG Emissions

### *Scope 1 - HFCs*

HFCs originate from refrigerant use, which typically occurs in HVAC systems and kitchen refrigeration. Equations for these calculations are provided by most voluntary reporting bodies, the IPCC and if applicable the National Regulator. However, for facilities in the UWC these emissions are typically de minimus. Either the regulator or the voluntary reporting body may require that the determination of de minimus be made.

### *Scope 1 $CO_2$ – Process*

Considerable amounts of $CO_2$ are produced throughout the UWC, particularly in the wastewater treatment process. This process-based $CO_2$ has its origin in the biological material carried in the water, and is therefore considered biogenic in nature. From a pure accounting perspective, this $CO_2$ is a GHG. However, no regulator requires reporting of these emissions because they are considered ‘short-cycle’. This means that because the carbon comes from a grown biological material it will rapidly be reabsorbed, or sequestered, through the growth of the biological material which replaces the original source of the carbon. In other words, that particular amount of $CO_2$ is on a short-cycle through the atmosphere. As such, it is not considered to be part of the global warming problem.

Calculation of this carbon is certainly possible, however, and has been conducted by wastewater treatment plants. Reporting of this source of carbon may be done voluntarily by a utility to some reporting entities; however, they require this as a separate line item.

Some regulators, such as the US EPA, have considered requiring reporting of biogenic emissions. However, no concrete action to do so has taken place yet. It is very probable that if such action were to take place, wastewater treatment plants would become one of the major sources and fall within the regulation.

## A Summary of GHG Accounting in the Water Sector

Though well established standards are in place for GHG accounting across any sector, the water sector proves particularily challenging when it comes to the specific equations to be used. For the elements of the urban water cycle that involve non-biological and non-chemical processes, the accounting is simplified significantly and is well proven. This includes for example, emissions due to energy consumption. However, for the specific processes within the water treatment cycle – particularily for wastewater – these equations become very challenging and the results difficult to fit to a single equation even with variable emissions factors. This is largely because the underlying chemical and biological processes are complex with significant variables as conditions vary both diurnally, seasonally and geographically. Considerable additional research is needed in this area; however, it may be that for certain processes only actual emissions sampling will be able to predict the level of emissions which occur for that facility.

# CHAPTER 4

# ENERGY USAGE AND MONITORING PRINCIPLES FOR WATER UTILITIES

In the United States, wastewater plants and drinking water systems spend about $4 billion per year on energy to treat water and these operating costs can be as high as one-third of a municipality's total energy bill (Energy Star, accessed March, 2011). Electricity constitutes between 25 and 40 percent of a typical wastewater treatment plant's (WWTP's) operating budget (NYSERDA, 2000). At a facility level, the factors impacting energy use include:

- Type of equipment in place for a given process, and the efficiency of that equipment as well as the variability of that efficiency over the different load and use profiles for that facility;
- Deterioration in efficiency that may have occurred either as the facility aged or as equipment was improperly replaced or repaired over multiple operation and maintenance iterations;
- The ambient operating conditions that impact process performance, such as temperature and other environmental conditions that impact process performance, or whether the system is pumped or gravity fed; and
- The operating protocols and parameters for the system, for example pump system optimization, can reduce energy requirements significantly.

The energy requirement per volume of water is referred to as "energy intensity" or "embedded energy" of water when the total amount of energy required for the use of a given amount of water in a specific location is calculated on a whole-system basis (Wilkinson 2000). These values are typically reported as kilowatt hour per million gallon (kWh/MG) since a large majority of water providers receive the majority of their operating energy from electricity (Carlson and Walburger 2007). The range of energy intensities reported for water cycle segments ranged from 0-14,000 kWh/MG for water supply and conveyance, 100-16,000 kWh/MG for water treatment, and 250-1,200 kWh/MG for water distribution. This translates to energy intensities of municipal water supplies on a whole system basis ranging from 350-31,200 kWh/MG. The higher embedded energy values result from poorer quality or less accessible water sources, water system leakages, pump inefficiencies, and large spatial and topographical characteristics of the conveyance and distribution systems (Griffiths-Sattenspiel 2009).

Many utilities implement energy saving strategies that can range from equipment modification or replacement to continuous real-time monitoring of energy usage through the system after engaging in energy baseline monitoring studies. Reductions in non revenue water represents another opportunity for energy savings for urban water management (both water and wastewater).

There are a number of sources of information on best practices for measuring, reducing, and monitoring energy use at water and wastewater facilities. A comprehensive guide is provided in the WEF Manual of Practice No. 32, and an outline of the principles contained in MOP32 is presented in the following sub-section. Details on technical and managerial approaches toward achieving an energy efficient facility have been provided by the Alliance to Save Energy, an organization that has helped over 40 water utilities around the world (Barry 2007). An energy management guidebook for U.S. wastewater and water utilities is available from the USEPA that provides detailed steps for assessing current energy baseline status, benchmarking efficiency information, establishing an energy policy, and establishing energy objectives and targets (U.S. EPA 2008). The European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) BT Joint Working Group on Energy Management recommended a need for common methods of calculation of energy consumption, energy efficiencies, and energy savings as well as million gallons per day (MGD) of a common measurement and verification protocol and a methdology for energy use indicators (CEN/CLC 2005). The CEN/CENELEC Joint Working Groups are now developing standards in relation to benchmarking of energy use, energy audits and energy efficiency and saving calculations amongst other aspects of energy management systems and efficiency services. Standard EN 16001:2009 provides organizations and companies with a single framework for establishing systems and processes necessary to improve energy efficiency.

## ENERGY USE IN POTABLE WATER FACILITIES

### Facility Level Energy Baseline Studies

A fifteen year old study published by the Electric Power Research Institute (EPRI 1996) estimated a total energy requirement of 1,400 - 1,500 kWh/MG of water production for “typical” surface water facilities ranging in size from 1-100 MGD consisting of flocculation/sedimentation with filtration and chlorination. In all cases, ~85% of the required energy was used for treated water pumping, ~8% was utilized for raw water pumping, and the remaining ~7% was used for treatment processes. A requirement of 1,800 kWh/MG of produced water was estimated for utilities utilizing groundwater on the assumption of an average lift requirement of 150 feet from the groundwater table to the level storage tank, a distribution system booster pump with a discharge pressure of 125 psi, and a wire-to-water efficiency of 78% for production rates ranging from 1-20 MGD.

A more recent study performed for the Energy Center of Wisconsin (Elliott et *al.* 2003) published interquartile ranges (middle 50 percent of utilities in the state) of energy requirements of water production (treatment, conveyance, and distribution) of 1,160-2,780 kWh/MG for all drinking water facility sizes and a median value for the 271 largest utilities of 1,500 kWh/MG. Energy usage increased by 120-550 kWh/MG pumped for ozone disinfection and 0-700 kWh/MG pumped for membrane filtration at surface water treatment facilities. Groundwater facilities were observed to use approximately 1.3% more energy per gallon of water produced than surface water utilities. Electricity consumption at Massachusetts water treatment and distribution facilities was estimated at 1,500 kWh/MG (U.S. EPA 2008). In the state of New York, the energy consumption at drinking water facilities ranges from 600-1,080 kWh/MG (NYSERDA, 2008).

Beyond the United States, a Global Water Research Coalition (GWRC) water and energy strategy workshop compiled energy data from GWRC members and found average energy use by water utilities in different countries to be within a comparable range in spite of differences in treatment options. Total energy usage ranged from 378-3,823 kWh/MG, with typical values of 1,800 kWh/MG reported (GWRC 2008).

## Resource Management Strategies

Utilities in regions lacking adequate water supplies must augment their water portfolio with marginal water supplies of poorer quality or longer distances from the required point of use. These marginal supplies have greater embedded energy (Griffiths-Sattenspiel 2009). For example, in arid communities such as Southern California in the United States, water transport from the Sacramento-San Joaquin Delta over the 2000 feet Tehachapi Mountains requires 9,200 kWh/MG (Wolff et *al.* 2004).

West Basin Municipal Water District (WBMWD), a Southern California water supplier trying to reduce energy usage through modification of its water portfolio, analyzed the embedded energy of available energy sources. Of the four water supplies available to WBMWD, recycled water is among the least energy-intensive supply options available (1,503-3,928 kWh/MG), followed by groundwater that is naturally recharged and recharged with recycled water (1,074-4,802 kWh/MG). Imported water (7,806 kWh/MG, assuming a 50:50 usage of State Water Project and Colorado River Aqueduct) and ocean desalination (11,313 kWh/MG) are the most energy intensive water supply options in California (Wilkinson 2007). Another example for Portland Water Bureau, Oregon demonstrates how the energy intensity of their marginal groundwater source is approximately 6.5 times higher than their primary surface water source (3,675 kWh/MG vs. 570 kWh/MG) (Griffiths-Sattenspiel 2009), primarily due to pumping.

## Measuring and Managing Energy Use at Potable Water Facilities

Major factors impacting energy usage at water facilities include aging infrastructure, particularly for pumps, motors, and controls which might not benefit from use of variable frequency drive (VFD)s and premium efficiency motors (PEM), as well as permit requirements that necessitate use of higher energy treatment systems (e.g., ozonation, membrane filtration, and ultraviolet disinfection). For groundwater systems, well recharge, well maintenance, and well draw-down come into play (PG&E 2006). Distribution system Water Network Energy Efficiency (WNEE) can be estimated from the ratio of the power required to meet the minimum level of service pressure to the total (cumulative) actual power used. Computation of the minimum service pressure power at each junction node with a positive demand can be calculated as below.

$$P_{min} = \rho g q_T H_{min} \qquad \text{(Equation 5)}$$

Where,

$\rho$ is the water density ($kg/m^3$),ta
g is the acceleration of gravity ($m/s^2$),
qT is the total system demand (unit), and
$H_{min}$ is the minimum level of service pressure (unit).

Case study values of WNEE within eight zones of a water utility serving a large European city ranged from 31-59% (Boulos and Bros 2010). A Wisconsin Energy Best Practice Guidebook provides the following checklist of items to consider for energy savings at a water facility: (1) automate to monitor and control; (2) integrate system demand and power demand; (3) use computer-aided design and operation tools to demonstrate impacts of improvements; (4)

implement a system leak detection and repair program; (5) minimize or eliminate pump discharge throttling; (6) manage well production and draw-down; (7) sequence well operation; (8) promote water conservation; (9) implement outdoor irrigation reduction program; and (10) manage high volume users (SAIC 2006). There is also an energy management guidebook for water and wastewater utilities from the USEPA and NYSERDA, as well as a WaterRF report on best practices and case studies in North America for energy efficiency in drinking water treatment (Leiby and Burke 2011).

## ENERGY USE IN WASTEWATER FACILITIES

### Facility Level Energy Baseline Studies

An energy utilization range of 670-2,950 kWh/MG was determined for U.S. wastewater treatment facilities consisting of trickling filter, activated sludge, advanced treatment with nitrification or advanced treatment without nitrification processes at facilities ranging in size from 1-100 mgd (WEF 2009). A Massachusetts survey reported 1,750 kWh/MG of energy usage for wastewater treatment (not including collection) (U.S. EPA 2008). Energy usage values of 1,500-3400 kWh/MG reported by members of GWRC (i.e. Netherlands, Singapore, France, Germany, and Australia) were of similar range (GWRC 2008). The average energy use of 3,954 kWh/MG that was reported for activated sludge wastewater facility systems surveyed in Wisconsin were skewed higher due to the large number of small (<1 mgd) facilities participating. The average energy usage for the large (>5 mgd) facilities in Wisconsin was 2,288 kWh/MG (PG&E 2006). In the state of New York, the energy consumption at wastewater facilities ranges from 1,100-4,620 kWh/MG (NYSERDA, 2008).

Aeration typically requires over half of the electricity consumed in a typical wastewater treatment facility if energy recovery from anaerobic biogas production is not practiced and chlorination rather than UV is utilized for disinfection. There is an additional 15% of total energy usage for anaerobic digestion and another 15% for wastewater pumping (Crawford et *al*. 2010).

Benchmarking of energy usage within the secondary treatment process of ten facilities in California demonstrated an energy usage range of 508-2428 kWh/MG (27-60% of total plant energy consumption) and demonstrated the impracticality of developing single value energy baseline criteria for the various wastewater treatment processes (PG&E 2003). Benchmarking of energy usage at seven facilities in California with UV disinfection demonstrated an energy usage range of 117-557 kWh/MG for facilities meeting a 200 CFU/100ml fecal coliform discharge limit and one facility utilizing 1,001 kWh/MG to meet a 2.3 CFU/100ml fecal coliform discharge limit. The use of medium pressure lamps also required two to four times the energy used by the low pressure lamp systems to meet the same 200 CFU/100ml discharge limit (PG&E 2003).

### Measuring and Monitoring Energy Use at Wastewater Facilities

Factors relevant to energy usage include wastewater characteristics (i.e., quality and quantity). Mechanical characteristics such as pumps, blowers and ventilators; and treatment process and technology. (NEWRI, 2011).

Opportunities for energy efficiency within wastewater treatment facilities include use of fine bubble diffusers, dissolved oxygen control of aeration, high efficiency blowers, variable frequency drives (VFD) on pumps and blowers, premium efficiency motors (PEM), and reduction of the head against which pumps and blowers operate (PG&E 2003). A survey of facilities in Wisconsin demonstrated energy saving opportunities regardless of size, savings in the range of 20-40%, and the greatest opportunity for energy savings occurring within the aeration systems (SAIC 2006). A Wisconsin Energy Best Practice Guidebook provides the following checklist of items to consider for energy savings at a wastewater facility: (1) use variable frequency drive applications; (2) reduce fresh water consumption; (3) optimize flow with controls; (4) plan and design for operational flexibility; (5) stage treatment capacity upgrades; (6) manage for seasonal peaks; (7) design and operate for flexible sequencing of basins; (8) recover excess heat from wastewater; (9) cover basins for heat retention; (10) optimize aeration system; (11) use fine-bubble aeration; (12) asseses aerobic digestion options; (13) evaluate biosolids processing options; (14) evaluate biosolids mixing operations in aerobics; (15) require variable blower air flow rate in aerobics; (16) install dissolved oxygen control for aerobic process; (17) optimize biosolids mixing options for anaerobic process; (18) optimize ultraviolet disinfection options; and (19) optimize final effluent recycling (SAIC 2006). There is also an EPA report summarizing conventional and innovative and emerging energy conservation measures (ECMs) for wastewater facilities (U.S. EPA 2010) as well as a WERF report on best practices and case studies in North America for energy efficiency in wastewater treatment (Crawford et *al.* 2010). The energy efficiency in municipal wastewater treatment plants has also been published by NYSERDA ( NYSERDA, 2012).

An American Council for an Energy Efficient Economy (ACEEE) study showed that of the approximately 88,000 motors (>50 hp) operating in the water and wastewater industry, 24 percent have variable load and are mostly utilized in aeration equipment, of which approximately half employ VFD control (PG&E 2003). Numerous references are available on practical design considerations for installation of VFDs and PEMs (Europump and Hydraulic Institute 2004).

In order to assess pump and pumping system efficiency, flow rate, pump pressure and power, and usage parameters must be monitored through snapshot or real-time monitoring. Oftentimes, due to the impracticality of direct measurements, proxy methods such as pump head curves or electric power and motor performance curves are used to estimate flow rate, while differential pressure can be estimated from valve position together with valve characteristic curves and flow rates. Motor or variable frequency drive input power can be directly measured with a power meter. When flow measurements are not available, pump efficiency can be calculated by using the thermodynamic method which assesses temperature and pressure losses across the pump and motor. Two proprietary technologies, Robertson technology (Robertson 2010) and Advanced Energy Monitoring Systems (AEMS) provide equipment with sufficiently stable and accurate temperature probes to allow implementation of the thermodynamic method for pump efficiency monitoring.

## BEST PRACTICE AND GUIDELINES FOR ENERGY ASSESSMENTS AT WATER AND WASTEWATER FACILITIES

As mentioned above there is a significant body of work focused on the reduction and management of energy use at water and wastewater utilities. This section presents a consolidated ‘best practice’ approach to managing energy at a water utility, including a set of steps and a specific list of activities which should be conducted. Energy assessments typically include the analysis of the following areas at any given facility (Capehart et al, 2008):

- Building envelope
- HVAC system
- Electrical supply system
- Lighting
- Boiler and steam systems (or hot water if domestic)
- Motors
- Special purpose process equipment – in this case water and wastewater treatment
- Water and sewer systems – in this case service water

Energy managers in the water sector typically follow an order of analysis in their energy use assessments, as follows (WEF MOP32):

- Energy Audit – Conduct and energy audit to find opportunities in the near- and long-term for capital projects, operations and maintenance improvements, and standard operating procedures that result in energy savings.
- Full Energy Plan – Develop and implement an Energy Master Plan, which includes a full spectrum of activities to manage energy use, cost and security over the long term.
- Monitoring and Verification – Monitor and verify to assure project performance and identify further opportunities.
- Continuous Improvement – Continuous improvement in energy efficiency is typically accomplished by engaging staff throughout the facility to use guidelines and established standard operating procedures through the use of guideline or standard operating procedures in place with staff throughout the facility

A typical facility level, or system wide, energy assessment for a water utility addresses the following fundamental questions:

  - How can the use of energy be decreased or avoided?

*For example:* State-of-the-art controls enable delivery of aeration airflow quantities only when needed and only to the extent needed in order to meet effluent requirements. This in turn decreases aeration blower output requirements, which reduces the power costs.

  - How can existing equipment be optimized for energy efficiency?

*For example:* Replacement of pump drives or motors with high efficiency alternatives when they approach the end of their useful life. In addition, correct tuning of the boilers' combustion air intake reduces stack losses

  - Are there ways to recover energy that is currently lost?

*For example:* Capture waste heat available in liquid or gaseous flows or kinetic energy, and reuse them in other parts of the facility.

  - Can the operation of existing equipment be deferred to off-peak power cost hours?

*For example:* Backwashing filters or pumping sludge to storage tanks (where utilized) in the evening instead of during high peak hours during the day.

EPA Victoria's Carbon Management and Principals is a well established guide on how to assess and address carbon and energy responses ([www.epa.vic.gov.au/business-and-industry/lower-your-inpact/carbon-management-at-work](www.epa.vic.gov.au/business-and-industry/lower-your-inpact/carbon-management-at-work)) For any facility, the energy use assessment typically begins with analysis of the largest energy users, and works down the list from there. A standard breakdown of energy use at a typical wastewater treatment facility is shown in Figure 4.1 based upon data in WEF MOP 32. A more detailed discussion of energy minimization strategies within each usage category is discussed below.

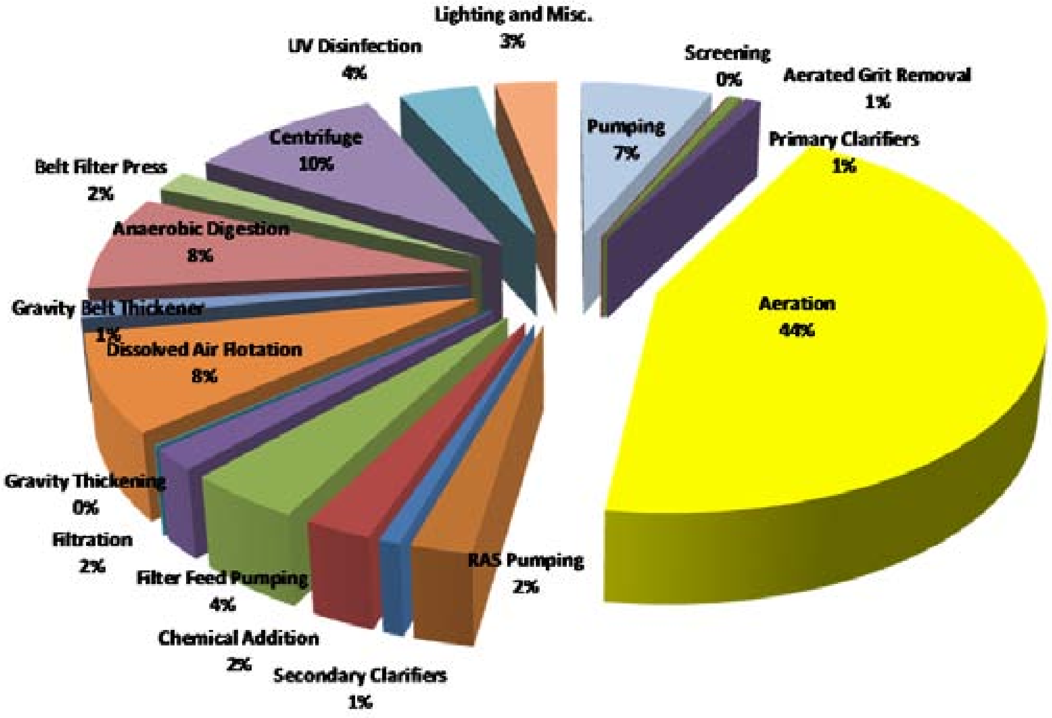


**Figure 4.1 Typical WWTP energy breakdown helps prioritize potential focus areas**

***Wastewater treatment process.*** Wastewater treatment processes must be analyzed holistically due to the interactions between the different treatment stages/components. For example, increasing the effectiveness of primary settling generally results in lower oxygen requirements downstream and produces a thicker sludge with a higher heating value. However, the organics removed in the enhanced primary process may limit the ability of the activated sludge to meet biological nutrient removal requirements, therefore requiring a careful balance. To support this holistic analysis, facilities often use dynamic process mathematical models such as BioWin® or GSPX, or analysis of other existing process models, to evaluate process energy reduction opportunities.

***Aeration***. The activated sludge aeration typically accounts for the large percentage of a facility's power consumption and it is therefore highly beneficial to thoroughly evaluate the system from the air inlet, through the blowers and discharge through the diffusers in order to integrate a robust control system as a means of reducing this energy consumption.

A key consideration in any aeration project is to make sure the system is efficient over its operating range, and not just at the design point. This procedure is used to select the best net present value blower system option, including consideration of blower and diffuser type. Evaluation of a facility's current activated sludge aeration systems is essential in order to reduce energy use and costs.

***Pumping***. The overall pump efficiency (wire-to-water) must be calculated for water and wastewater process pumps, using both electricity usage and flow data. For pumps that are equipped with pressure gauges and flow meters, a determination is made as to whether the unit is still operating on the pump curve. Deviations may indicate potential losses in the motor, drive, or pump. If the specific pump curve is not available, performance can be compared with a best practice, calculated with Department of Energy's (DOE's) pump system assessment tool (PSAT).

***Motors and Drives***. Motors are major contributors to power consumption, typically those greater than 10 hp and operated continuously, should be evaluated to determine whether a facility may evaluate whether replacement by a premium motor and/or installation of a VFD would be feasible and lead to relevant electricity savings. In the instance where other types of variable speed drives are used or required (e.g., eddy current couplings, adjustable pulley drives, etc.) strong consideration should be given to replacing those with VFDs. It generally doesn't pay to replace standard motors with premium efficiency motors unless the motor is near the end of its useful life and must be replaced anyway.

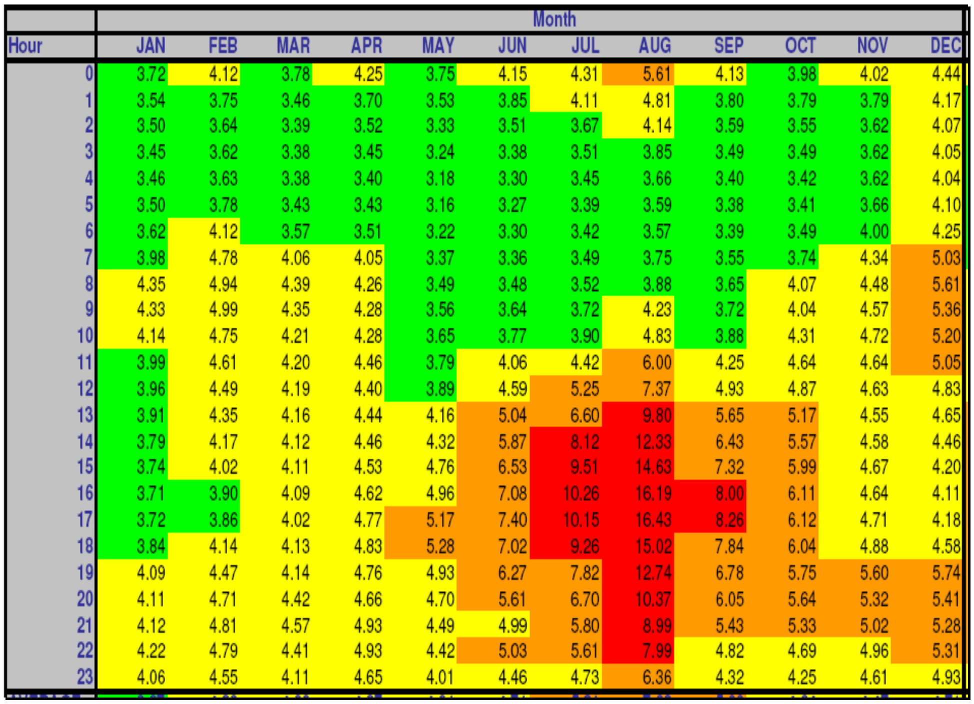
***Power distribution systems***. The analysis of the power distribution system is mainly focused on the efficiency of the transformers and the power factor. In this type of analysis facilities will often look for options to improve the power factor through the installation of capacitor banks. However, it must be noted that power factor improvement does not result in a net gain (or reduction) in kWh demand. Rather it results in a more stable, synchronized load on the equipment, and the reduction in reactive power can have a direct positive impact on the billed electrical rates.

***Buildings, HVAC, and Lighting***. The evaluation of HVAC improvements such as set point adjustments and possible waste heat recovery options for space heating is a standard aspect of any energy use assessment. Lighting often offers low-cost energy savings opportunities, and as such an inventory is typically developed and includes the type of fixtures, number installed, measured amount of foot-candles (compared with common luminance guidelines for the space type) and the available controls. This inventory is then used to identify potential lighting projects and control improvements. Building envelope improvements that can be cost-effectively implemented, e.g. roof insulation, replacement of windows and doors, weatherization, ventilation controls, etc., are another viable set of energy reduction measures.

***Energy Balance Development***. The development of an energy balance establishes a baseline of energy use, clarifying the exact impact of each energy reduction option identified at a facility. This can be done based on the invoices for the purchased primary energy carriers (electricity and natural gas) for the facility in a representative base year. If data is available at the equipment level, a baseline can be developed specific to the processes and operations at the facility. Using a combination of installed capacities, operating hours, load factors, or other operational data, energy consumption can be estimated.

***Billing and Rate Schedule Analysis***. Another general best practice is for a water utility to periodically review their power billing and the rate schedules. Generally speaking, the local power utility will have a representative responsible for relations with their large energy users, such as water utilities. This person can be contacted for any information about the billing and rate structure analysis. These types of reviews are generally conducted by the finance and accounting division of a water utility.

***Demand Management.*** Many utilities are subject to variable energy charges based on the times of day with the highest overall system demands. If the utility can shift the use of certain equipment to a lower cost time of day, there is an opportunity to save money. Figure 4.2 provides an example table of monthly and time-of-day changes in electrical unit rates. This type of tool is invaluable to fine tune operating strategy recommendations and minimize energy usage during periods with relatively high unit rates.



|  | Month |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
| 0 | 3.72 | 4.12 | 3.78 | 4.25 | 3.75 | 4.15 | 4.31 | 5.61 | 4.13 | 3.98 | 4.02 | 4.44 |
| 1 | 3.54 | 3.75 | 3.46 | 3.70 | 3.53 | 3.85 | 4.11 | 4.81 | 3.80 | 3.79 | 3.79 | 4.17 |
| 2 | 3.50 | 3.64 | 3.39 | 3.52 | 3.33 | 3.51 | 3.67 | 4.14 | 3.59 | 3.55 | 3.62 | 4.07 |
| 3 | 3.45 | 3.62 | 3.38 | 3.45 | 3.24 | 3.38 | 3.51 | 3.85 | 3.49 | 3.49 | 3.62 | 4.05 |
| 4 | 3.46 | 3.63 | 3.38 | 3.40 | 3.18 | 3.30 | 3.45 | 3.66 | 3.40 | 3.42 | 3.62 | 4.04 |
| 5 | 3.50 | 3.78 | 3.43 | 3.43 | 3.16 | 3.27 | 3.39 | 3.59 | 3.38 | 3.41 | 3.66 | 4.10 |
| 6 | 3.62 | 4.12 | 3.57 | 3.51 | 3.22 | 3.30 | 3.42 | 3.57 | 3.39 | 3.49 | 4.00 | 4.25 |
| 7 | 3.98 | 4.78 | 4.06 | 4.05 | 3.37 | 3.36 | 3.49 | 3.75 | 3.55 | 3.74 | 4.34 | 5.03 |
| 8 | 4.35 | 4.94 | 4.39 | 4.26 | 3.49 | 3.48 | 3.52 | 3.88 | 3.65 | 4.07 | 4.48 | 5.61 |
| 9 | 4.33 | 4.99 | 4.35 | 4.28 | 3.56 | 3.64 | 3.72 | 4.23 | 3.72 | 4.04 | 4.57 | 5.36 |
| 10 | 4.14 | 4.75 | 4.21 | 4.28 | 3.65 | 3.77 | 3.90 | 4.83 | 3.88 | 4.31 | 4.72 | 5.20 |
| 11 | 3.99 | 4.61 | 4.20 | 4.46 | 3.79 | 4.06 | 4.42 | 6.00 | 4.25 | 4.64 | 4.64 | 5.05 |
| 12 | 3.96 | 4.49 | 4.19 | 4.40 | 3.89 | 4.59 | 5.25 | 7.37 | 4.93 | 4.87 | 4.63 | 4.83 |
| 13 | 3.91 | 4.35 | 4.16 | 4.44 | 4.16 | 5.04 | 6.60 | 9.80 | 5.65 | 5.17 | 4.55 | 4.65 |
| 14 | 3.79 | 4.17 | 4.12 | 4.46 | 4.32 | 5.87 | 8.12 | 12.33 | 6.43 | 5.57 | 4.58 | 4.46 |
| 15 | 3.74 | 4.02 | 4.11 | 4.53 | 4.76 | 6.53 | 9.51 | 14.63 | 7.32 | 5.99 | 4.67 | 4.20 |
| 16 | 3.71 | 3.90 | 4.09 | 4.62 | 4.96 | 7.08 | 10.26 | 16.19 | 8.00 | 6.11 | 4.64 | 4.11 |
| 17 | 3.72 | 3.86 | 4.02 | 4.77 | 5.17 | 7.40 | 10.15 | 16.43 | 8.26 | 6.12 | 4.71 | 4.18 |
| 18 | 3.84 | 4.14 | 4.13 | 4.83 | 5.28 | 7.02 | 9.26 | 15.02 | 7.84 | 6.04 | 4.88 | 4.58 |
| 19 | 4.09 | 4.47 | 4.14 | 4.76 | 4.93 | 6.27 | 7.82 | 12.74 | 6.78 | 5.75 | 5.60 | 5.74 |
| 20 | 4.11 | 4.71 | 4.42 | 4.66 | 4.70 | 5.61 | 6.70 | 10.37 | 6.05 | 5.64 | 5.32 | 5.41 |
| 21 | 4.12 | 4.81 | 4.57 | 4.93 | 4.49 | 4.99 | 5.80 | 8.99 | 5.43 | 5.33 | 5.02 | 5.28 |
| 22 | 4.22 | 4.79 | 4.41 | 4.93 | 4.42 | 5.03 | 5.61 | 7.99 | 4.82 | 4.69 | 4.96 | 5.31 |
| 23 | 4.06 | 4.55 | 4.11 | 4.65 | 4.01 | 4.46 | 4.73 | 6.36 | 4.32 | 4.25 | 4.61 | 4.93 |

**Figure 4.2 Typical time-of-day electricity rates**

The energy cost schedule, in combination with the 24 hour and seven day energy profiles, shows opportunities for cost savings. To capitalize on these opportunities requires that part of the load be shifted to a period with a lower unit rate.

***Managing Demand Charges***. In addition to the time-of-use factor, demand management can have the added benefit of reducing the demand portion of a water utility's power bill. Power utilities must build their systems to provide the maximum amount of power or 'peak load' that could be demanded at any instant in time, measured in total kW of demand. As such, the user of that power will see a separate demand charge on their power bill based on the maximum amount of instantaneous power demand incurred, usually within any 15 minute period of time. This demand charge can be significant, and is in addition to the total energy charge based on the kWh of energy use. Thus it is beneficial for a water utility to keep their total instantaneous maximum demand as low as possible.

***Peak Shaving Using Standby Generators***. The economic feasibility of using standby generators to shave peak loads is another means of reducing energy costs. This is generally cost-effective if the cost for running the backup generators is lower than the financial benefits from peak load reduction. In addition, since the generators generally have to be regularly operated to ensure they will perform when needed, using them for peak shaving will be a partial substitute for that operating requirement, thereby reducing the cost of fuel and production of exhaust gases.

# CHAPTER 5
# TOOLS FOR ENERGY AND GHG EMISSIONS ESTIMATIONS

This chapter discusses the underlying process model algorithms that support GHG emission estimations and the importance of the modeling approach utilized to the accuracy in the GHG emissions accountancy. A designation of the output accuracy was previously presented in Table 3.1 as three levels of reporting, with each subsequent level representing a greater degree of specificity in the estimated GHG emission outputs. The models discussed in this section primarily deal with methods for refining estimates of activity level output as a function of treatment facility design and operational parameters for Scope 1 direct emissions. There is also discussion about available tools for enhanced estimation of energy usage and linkage to real time emission factors for Scope 2 indirect emissions and availability of tools for life cycle assessment of Scope 3 emission factors.

## PROCESS MODELS FOR DIFFERENT GHG EMISSION SOURCES

### Wastewater Treatment Modeling

Modeling for wastewater is currently occurring at three distinct stages:

- Stage 1 empirical modeling is suitable for the type of inventory reporting required in IPCC, 2006; LGOP, 2010; and NGER, 2011. The methodologies at this stage of modeling are equivalent to the methodologies provided within Level 1 or Level 2 of the high-level accounting standards previously presented in Table 3.1;
- Stage 2 encompasses comprehensive steady-state process models for wastewater and biosolids treatment. This approach is taken in the CHEApet tool for wastewater treatment and the BEAM tool for biosolids processing. The methodologies being developed at this stage of modeling are equivalent to the industry-specific methodologies provided within Level 3 of the high-level accounting standards previously presented in Table 3.1, and;
- Stage 3 is comprised of mechanistic process models such as IWA ASM models extended with appropriate sub-models to provide $CO_2$, $N_2O$, and $CH_4$ mass balance equations within a dynamic simulator. The methodologies being developed at this stage of modeling are equivalent to the facility specific methodologies provided within Level 3 of the high-level accounting standards previously presented in Table 3.1.

Each stage of modeling may also vary regarding the inclusion of Scope 3 emissions resulting from life cycle assessment of utilized chemicals, off-site transportation needs, or process embedded or full-life cycle carbon accounting. Stage 2 models provide a means of optimizing overall facility design to achieve treated water quality requirements with minimal energy usage and GHG emissions. Stage 3 models provide the capability of assessing emissions in real time as a function of operational parameters. Table 5.1 provides an overall summary of existing tools along with their application area, modeling stage, covered processes, and underlying models and outputs.

## Wastewater Treatment Process Direct GHG Emissions

IWA activated sludge models provide a common platform and standard nomenclature for further process simulation software development of $N_2O$ emissions. The simulation programs that are most commonly utilized for wastewater process modeling include BioWin and GPS-X. BioWin is a Windows-based simulator for the design of wastewater treatment processes. It utilizes an integrated kinetic model and mass balance approach that incorporates a general Activated Sludge/Anaerobic Digestion (ASDM) model which has fifty state variables and sixty process expressions (EnviroSim 2012). BioWin also provides users with an option to model using IWA's ASM models. GPS-X utilizes their own internal Mantis model, but it can also simulate wastewater treatment using IWA's ASM models. The GPS-X model is being modified to account for $N_2O$ gas in addition to $CO_2$ and $CH_4$ as both emissions and offsets that allow a carbon footprint model to be implemented within a dynamic process simulator (Goel et *al.* 2012).

Gas-phase modeling is available in BioWin for six gases: hydrogen, carbon dioxide, ammonia, methane, nitrogen and oxygen and it is conducted using a gas-liquid mass transfer model. The current version of BioWin (as of February 2011) cannot predict $N_2O$ emissions during wastewater treatment; however, Envirosim (developer of BioWin) expects the next version to have that capability. The proposed correlation function (logistic switching function) discussed in Chapter 3 can be used to determine the proportion of ammonia directed toward different nitrogen products, and was incorporated into the existing BioWin model and tested by its authors against actual observations at a pilot plant at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG). After calibration of the correlation function, the model accurately predicted $N_2O$ emissions from the pilot plant, details of which are discussed elsewhere (Houweling et *al.* 2011). Envirosim expects to incorporate this switching function into the next version of BioWin to allow users to predict $N_2O$ emissions during wastewater treatment modeling.

Work on benchmark simulation models (BSMs) has focused on validating the implementation of underlying models such as ASM1 (Henze et *al.* 1987), the secondary clarification model (Takács et *al.* 1991), and ADMI (Batstone et *al.* 2002) to produce similar outputs from the various commercial simulation packages (WEST, STOAT, Simba, GPS-X, BioWin) and open code platforms (Matlab/Simulink, Fortran) (Copp et *al.* 2008). The Aquifas+ simulator has expanded the IWA-ASM2d single step nitrification and denitrifcation model to include the intermediate steps responsible for the production of $N_2O$, NO, and $NO_2$ and expanded the 21 suspended growth processes to more than 74 processes. It is being applied at several plants to understand the impact of operational changes such as DO levels, mean cell residence times, and aerobic zone partitioning on $NO_2$ emissions. It will be useful to compare the predictive capabilities of such simulators with empirical field data being actively collected at participating wastewater treatment facilities for nitrogen greenhouse gases.

## Table 5.1
## Models and associated protocol/tools for wastewater process GHG emissions

| Model and Stage of Specificity | Associated Protocol/Tool | Application Sources | Description |
|---|---|---|---|
| Wastewater plant empirical data (Stage 1) | LGOP<br>IPCC<br>NGERS<br>UKWIR Workbook | Biotreatment, sludge digestion, sludge reuse, chemical usage, power consumption, biogas usage | Compiled literature of emission factor estimates for use in emission factor – activity level calculations. |
| Wastewater plant static model (Stage 2) | Bridle model | Biotreatment, sludge digestion, sludge reuse, chemical usage, power consumption, biogas usage | Stoichiometric equations described in Snip, 2010. Calculates $CO_2$ of biotreatment, biogas and chemicals, $N_2O$ of biotreatment, $CH_4$ of biogas, calculates aeration power and converts this plus additional power use to $CO_2$ emissions, calculates power generation credits from sludge. |
| Wastewater plant static simulator (Stage 2) | CHEApet | Influent pumping, 1°, 2°, filtration, UV disinfection, effluent pumping, sludge pumping, sludge thickening, sludge stabilization, sludge dewatering, side stream treatment | Steady-state simulation model, IWA ASMN model (Hiatt and Grady 2008), IWA ADM1 model (Batstone et *al.* 2002) integrated with mass/calorific balance, electrical consumption, thermal consumption/capture to provide carbon footprint. |
| Wastewater plant dynamic simulator (pending next revision) (Stage 3) | Biowin<br>GPS-X<br>WEST<br>STOAT<br>Simba<br>Auifas | Same processes as CHEApet minus UV disinfection | Biokinetic dynamic process models derived from IWA ASMN2d, ADM1 models. Needs extension of state variables to include $N_2O$. Aquifas has modified IWA ASM2d biokinetic model that includes four step nitrification and denitrification processes (Sen and Lodhi 2010). |
| Wastewater plant dynamic simulator coupled with rising main sewer benchmark simulator (in progress) (Stage 3) | IWA Task Group GHG Subgroup | Same processes as CHEApet plus collection system; minus UV disinfection | BSM2 modeling platform with ASMN two-step nitrification model, ASM1, ADM1, and model of Guisasola et *al.* (2009) for methane in mains |
| Biosolids Processing (Stage 2) | Biosolids Emissions Assessment Model (BEAM) | Storage, conditioning & thickening, aerobic & anaerobic digestion, dewatering, drying, alkaline stabilization, composting, landfilling, combustion, land application, transportation | Extension of IPCC guidelines utilizing data from published literature and Kyoto Protocol Clean Development Mechanism protocols (UNFCCC/CCNUCC 2008). Inclusion of fugitive emission estimates together with Scope 1, 2, and 3 processing requirements enable assessment of solids handling alternatives with lowest GHG emissions. |

## Water and Wastewater GHG Emissions from Energy Usage

The majority of GHG emissions from water and wastewater treatment processes are attributable to energy usage, with over 80% of this energy being utilized for pumping in systems that are not gravity fed (EPRI 2002). Energy usage is also very high in wastewater treatment facilities and associated with process requirements as well as pumping/motors and other factors. Therefore, the greatest impact on GHG reduction for the water sector and important reductions in the wastewater sector will occur from utilization of energy benchmarking and efficiency tools described in Table 5.2 and 5.3. Benchmarking tools for the US water and wastewater sector include EPA's Energy Star and Water Research Foundation and NYSERDA's energy benchmarking models (Carlson and Walburger 2007).

The Water Research Foundation water utility energy use model relates energy consumption to total flow, total pumping horsepower, distribution main length, distribution elevation change, raw pumping horsepower, and the amount of purchased flow. The model allows a utility to compare it's energy use to an industry-wide distribution, obtain a metric score for it's energy utilization performance, and utilize it's ranking to support facility capital investments that result in an improved metric score and reduction in energy consumption. The wastewater treatment plant model relates energy consumption to average influent flow, influent BOD, effluent BOD, the ratio of average influent flow to design influent flow, the use of trickle filtration, and nutrient removal. An international effort by the Global Water Research Coalition to collect and share best practices in energy efficiency from North America, Europe, Asia, Australia, and South Africa resulted in publication of *Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies* (2010, UK Water Industry Research Limited). It identifies leading practices and technologies that will help deliver energy efficiency through optimization of existing assets and operations. A companion document funded by the WaterRF and NYSERDA, *Energy Efficiency Best Practices for North American Drinking Water Utilities* (Leiby and Burke 2011) includes detailed information on selection, operation, and maintenance of pumps, motors, and variable frequency drives in order to optimize energy efficiency that includes reference to pumping efficiency tools such as DOE's Pumping System Assessment Tool (PSAT) (DOE 2011). Another companion document published by WERF for wastewater utilities is *Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches* (Crawford and Sandino 2010).

Accuracy in reporting GHG emissions from energy usage is directly dependent upon the accuracy of the data available for energy utilization. In addition, the accuracy of the associated GHG emission factors per unit energy consumed is critical. The least accurate energy usage estimates are derived from electric utility monthly billing summaries; if attribution to different processes is desired this data then has to be apportioned to specific application areas as approximate usage percentages. The most detailed and accurate estimates are achieved when real-time electricity data is collected from a network of primary and secondary electric meters. This more detailed data can also be utilized as a means of monitoring and managing peak demand power, power factor, and power usage (Leiby and Burke 2011; NYSERDA 2006). While not particularly useful for carbon accounting, these latter data points are critical for managing energy costs at the facility level. Linkage of real-time energy use data with the real-time emission factors of the supplying power utility can then provide real-time GHG emission data. Several energy management tools are also available on the market to track and optimize real-time energy usage. These include Derceto Aquadapt, Innovyze IW Live, and Optima. However, this level of energy monitoring and GHG correlation is rarely used in the water sector.

**Table 5.2**
**Tools for energy benchmarking**

| Name of Tool | Application | Description |
|---|---|---|
| EPA Energy Star | Water and wastewater | Ordinary least-squares regression across a filtered survey data set with EUI (source energy use per gallon of treatment per day) as the dependent variable. |
| Water Research Foundation Energy Benchmarking | Water and wastewater | Provided survey data analysis to the EPA Energy Star benchmarking tool for wastewater facilities and contributed toward testing of the final model in coordination with NYSERDA and EPA. |
| NYSERDA | Water and wastewater | New York State energy use survey data aggregated by facility size for water and wastewater facilities. |
| DOE PSAT | Pumps | Assesses efficiency of pumping system operations using achievable pump performance data from Hydraulic Institute standards and motor performance data to calculate potential energy savings. |
| DOE MotorMaster Version +4.0 & Version MotorMaster+ International | Motors | Motor selection management tool based on motor efficiency standards. Internal version includes50 Hz metric" or IEC motors, multiple language capability, multiple currency calculations, and regional minimum full-load efficiency standards and country-specific motor repair and installation cost defaults. |
| Water to Air Model | Water Supply Portfolio | Emission-activity factor Excel spreadsheet calculations for input portfolio of energy mix alternatives and default or actual energy use for each supply portfolio option |

**Table 5.3**
**Tools for energy management**

| Name of Tool | Application | Description |
|---|---|---|
| Derceto Aquadapt | Water pumping and storage scheduling interface with SCADA and telemetry systems | Uses live data collection from SCADA to predict future water consumption and optimize energy time of use; peak demand reduction; pump efficiency; reduction in water travel distance; source optimization. |
| Innovyze IW Live for InfoWater | Water distribution system control through hydraulic modeling in the control room inclusive of energy reduction schemes | Real-time water supply hydraulic modeling |
| Optima™ Energy Management | Whole agency within United Kingdom | Energy consumption automatic monitoring and targeting |

## Water and Wastewater GHG Emissions from Scope 3 Sources

Reporting of GHG emissions does not always include assessment of Scope 3 sources. These sources can sometimes be difficult to accurately assess due to insufficient regional or industry specific databases of appropriate emissions factors for facility construction or manufacturing of utility supplies. Table 5.4 provides an overview of protocols for estimating embodied and whole life carbon and life cycle assessment tools typically utilized for Scope 3 emission assessments.

**Table 5.4**
**Tools for life cycle carbon assessment**

| Name of Tool | Application | Description |
|---|---|---|
| UKWIR Embodied & Whole Life Carbon | Whole agency within United Kingdom | Guidelines for independent tool development. Specific to GHG accounting, not applicable for the other environmental accounting aspects of full life cycle assessments. |
| Water-Energy Sustainability Tool (WEST)<br>(Level 1) | Water supply, treatment, and distribution life cycle impacts of source alternatives | Hybrid of process-based LCA to assess environmental effects of system construction and operation to obtain process-specific results. Economic input-output analysis-based LCA to determine effects of material acquisition, transformation and production. |
| SimaPro | Products and systems | Life cycle analysis of products and systems using parameters and Monte Carlo simulations that can be integrated with the Ecoinvent database for GHG emission assessment, product eco-design, environmental impact assessment, environmental reporting, and determination of key performance indicators |
| GaBi | Products and systems | Life cycle costing, greenhouse gas accounting, energy benchmarking and efficiency, life cycle engineering, and life cycle sustainability assessment. |

Additional details about the energy usage and carbon emission tools associated with the water and/or wastewater industry previously presented in Tables 5.1 through 5.4 are provided below.

## DISCUSSION OF SPECIFIC WASTEWATER PROCESS TOOLS

### CHEApet

The Carbon Heat Energy Analysis Plant Evaluation Tool (CHEApet) funded by the WERF is a static predictive modeling tool for quantifying and managing energy consumption and greenhouse gas estimation associated with wastewater treatment processes. The objective of this tool is to create a baseline scenario or inventory of a utility's existing carbon footprint against which different scenarios can be compared. CHEApet is designed to predict the thermal, electric, and carbon footprint performance of treatment scenarios at the individual unit process level as well as for an entire plant process train. The tool covers both liquid and solids treatment processes and heating and lighting requirements of associated building facilities.

The combination of user provided facility data with the tool's mass balance algorithms allows the modules within CHEApet to simulate plant performance for the following four categories:

- Calorific energy (i.e., energy recovery potential of organic waste)
- Electric energy (i.e., power consumption of the plant)
- Thermal energy (i.e., potential for heat recovery)
- Recovered biogas energy (i.e., gas recovered from anaerobic digestion)

### *Model Body*

Details of the CHEApet process components are presented by Johnson et *al.* (2010). The sources of the model components are presented below in Table 5.5.

**Table 5.5**
**Process components and sources of basic equations in CHEApet tool**

| Unit Process | Model Source | References |
|---|---|---|
| Primary clarification | General mass balance | N/A |
| Secondary treatment-activated sludge | Activated Sludge Model for Nitrogen (ASMN) | Hiatt and Grady (2008) |
| Secondary treatment-aeration | Aeration | N/A |
| Tertiary treatment-filtration | Granular media filtration | Johnson et *al.* (2010) |
| Solids thickening | Solids removal | Johnson et *al.* (2010) |
| Aerobic digestion | Uses a refined stoichiometric model for aerobic biological processes | Daigger and Grady (1995) |
| Anaerobic digestion | Mesophilic anaerobic digestion follows International Water Association's ADM No.1 model | Batstone et *al.* (2002) |
| Dewatering | Solids dewatering | N/A |
| Sidestream treatment | Nitrogen removal alone | WEF 8 2009a |

### *Input Parameters*

The general input parameters of the tool include:

- Daily monitoring data (e.g., flows and concentrations)
- Design criteria/dimensions of the unit processes utilized (e.g., basin volume, solids retention time (SRT))
- Configuration of biological process

- Operational monitoring data (e.g., DO, pH)
- Electrical data (e.g., pump power)
- Miscellaneous input data (e.g., building size and electric usage, information on anaerobic digester co-generation, emission factors from the regional power generation)

### *Limitations*

The current version of the tool does not include the following items:

- Chemical phosphorus removal
- Biological phosphorus removal
- Phosphorus recovery by struvite
- Additional carbon sources
- Heat drying
- High efficiency air diffusers
- Defined blower technologies
- Global power production emissions factors

## UKWIR Carbon Tool

The UK Water Industry Research (UKWIR) has produced a spreadsheet based standardized approach for estimating greenhouse gas emissions from operations of water and wastewater industry facilities. The approach was developed in accordance with both United Kingdom Department of Environment Food and Rural Affairs ( Defra) Guidelines and Carbon Reporting Commitment (CRC) requirements. A Microsoft Access database holding metadata on required data conversion elements are included within the tool. The tool can also calculate year-to-year changes in the emissions. The latest version of the tool, which is a modified version of a previously developed UKWIR tool (UKWIR 2007) incorporates several changes which include:

- Revision of the conversion elements, including emission factors to the latest available values.
- Presentation of the outputs to comply with the latest (2009) version of the Defra Guidelines and the proposed CRC requirements, with each output in a clearly labeled column.
- Purchased green electricity generated from renewable energy is now calculated as a savings in emissions based upon whether the accounting has been done according to the CRC or Defra guidelines.
- Creation of a separate input for on-site generated renewable electricity and the ability to account for the use, export and import of electricity and heat from natural gas CHP.
- Requirement to split grid electricity accounting according to metered data

### *Input Parameters*

The tool has been categorized into the following independent input sheets:

- Drinking
- Sewage
- Sludge
- Administration
- Transport
- Electricity Details

A 'Sludge Guide' sheet is included as a guidance tool and a 'Conversion Components' worksheet is included to make emission factors and conversion factors transparent to the users. The 'Outputs' sheet displays the $CO_2$ emissions using separate columns for CRC and Defra Guideline outputs. The output cells are color coded depending on whether the outputs are direct emissions, indirect emissions or whether they can be either direct or indirect emissions according to circumstances. In addition, a total is provided and a summary of the errors in major GHG source estimates, as relative standard deviations (RSDs) is also presented in the tool.

### *Limitations*

The following emissions are excluded from the UKWIR carbon accounting tool:

- $N_2O$ emissions from effluent downstream of a wastewater treatment plant because of the uncertainty of the mechanism by which emissions of $N_2O$ are simulated in a river.
- Minor gases from transport, grid electricity and on-site fuel use because they were not included in the Defra Guidelines.
- Travel of staff to and from work because a water/wastewater company has no control over employee's choice of commute.

## UKWIR Embodied Carbon and Whole Life Cycle Carbon Accounting

The UKWIR has developed a framework for consistent estimation of embodied carbon in construction, and operational carbon emissions in 'whole life carbon' accounting (UKWIR, 2009). The guidelines suggest that whole life carbon accounting should follow the same principles as cost accounting and, as far as possible, use the same asset input data. The embodied carbon estimation for construction aims to use the same structure and input data as for construction cost estimation. The guidelines include methods for estimating embodied carbon and also emission values for common construction items. Another important part of the guidelines is the discussion on whole life cycle carbon accounting (e.g., pricing, discounting, and design life). The guidelines do not include any carbon tools, but suggest that the water utilities utilize these guidelines to develop their own carbon tools and estimating curves focussed on their own critical asset types and cost estimating frameworks. It is important to note that this methodology is for use in whole of life carbon accounting, not for full life cycle environmental assessments. The former is limited to the environmental impact and cost of the single pollutant carbon; while the latter, LCA, is for all environmental impacts of any given project. Later in this chapter there is a discussion of LCA tools for the water sector.

## Wastewater Process Dynamic Simulators

Commercially available wastewater process dynamic simulators allow the users to model various wastewater treatment processes including:

- A range of activated sludge treatment processes such as suspended growth reactors, sequencing batch reactors (SBR), media reactors for integrated fixed film activated sludge (IFFAS) and moving bed biological reactor (MBBR) systems, and variable volume reactors.
- Various process configurations for chemical and biological nutrient removal
- Anaerobic and aerobic digesters
- Various settling tank modules
- Fine screens, holding tanks, equalization tanks and dewatering units
- Membrane filtration for the membrane bioreactor (MBR) process

Wastewater process dynamic simulators allow the user to conduct steady state and dynamic simulation of various process configurations once the process flow diagram is established and necessary input is provided.

### *Model Body*

An example flow diagram for a process model in Envirosim's BioWin is shown in Figure 5.1. Using the main simulator window, the user can monitor key parameters for each unit process including oxygen uptake rate, oxygen transfer rate, off-gas flow-rates, mechanical mixing power per unit volume, etc. Properties, rates and mass balance for individual treatment element/unit process can also be monitored and edited.

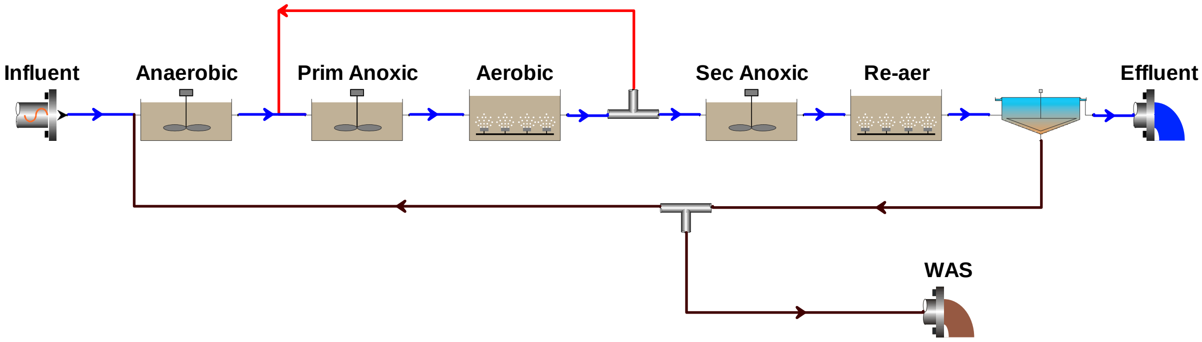


**Figure 5.1 Process flow diagram used in BioWin**

Although BioWin and the other wastewater process dynamic simulators are not presently configured for calculating a carbon footprint, they can be utilized for establishing certain design parameters that impact energy utilization requirements or calculating greenhouse gas emissions from reactor processes, such as:

- Mass rates for exit gases (methane, nitrogen and hydrogen) from individual bioreactor basins including aeration, anoxic and anaerobic secondary treatment processes as well as aerobic and anaerobic digesters.

- Air-flow requirements to maintain a dissolved oxygen (DO) set point in the bioreactor basins, which can then be utilized to calculate power consumption for biological process aeration.
- Optimize process aeration requirements, mechanical mixing requirements, recirculation pumping and other key design parameters to achieve a targeted effluent water quality with minimum energy consumption.

### *Input Parameters*

- Influent and temporal variability in flow-rate
- Concentrations and temporal variability of key constituents present in influent wastewater (COD/BOD, nitrogen and phosphorus species, alkalinity, pH, etc.)
- Process tank volumes and dimensions
- Operational, water quality, and element specific process monitoring parameters for aeration process such as mechanical mixing power input, diffused aeration parameters for coarse and fine bubble aeration
- Flows, including recirculation, between bioreactors, clarifiers or membrane filtration treatment train unit processes
- Flow-rates and doses for chemicals added to enhance biological treatment for nutrient removal (e.g. external carbon sources, volatile fatty acids) and chemical treatment for phosphorus removal (metals)
- Settling model parameters for clarifiers (number of layers, top feed layer, number of feed layers)
- Parameters for membrane filtration utilized in the MBR process (area, depth of the membrane tank, number of membrane cassettes and packing density, membrane specifications such as displaced volume/cassette and membrane surface area per cassette, percent retention for colloidal and solids retention, operation and flow-splits)
- SRT, temperature and location for sludge wasting.

## SUMMARY WASTEWATER GHG ESTIMATION TOOLS

A summary of key characteristics of the tools discussed here is presented in Table 5.6. It was clear from this review that most of the tools were developed for wastewater applications and not for drinking water applications. Since the major source of GHG emissions from drinking water facilities is due to energy consumption, some of the energy management and estimation tools discussed in a subsequent section of this review may prove beneficial to carbon footprinting for water treatment facilities.

**Table 5.6**
**Comparative evaluation of process GHG emission tools**

| Criteria | CHEApet | UKWIR Carbon Tool | UKWIR Embodied Carbon Tool | Dynamic Process Simulators |
|---|---|---|---|---|
| Commercial Product | Yes | No | No | Yes |
| Carbon reporting program affiliation | No | Yes | No | No |
| Access to underlying equations | No | No | Yes | No |
| Carbon Footprint Output | Yes | Yes | Yes | No |
| Metric format requirements or restrictions | No | Yes | No | No |
| Sectors where the tool is marketed | Wastewater | Water & Wastewater | Water & Wastewater | Wastewater |
| Typical application of tool output | Stand-alone | Stand-alone | Limited | Limited |
| Geographic regions of use | Global | UK | UK | Global |

## ENERGY MANAGEMENT AND EVALUATION TOOLS

There are a variety of energy assessment and benchmarking tools available that target various geographical regions, technologies, and objectives (Connolly et *al.* 2010). This review is restricted to energy tools that have a direct application to the water/wastewater industry.

### Water and Wastewater Process Related Energy Tools

Each of the energy tools reviewed in this section includes information available from the tool developer and/or published literature.

#### *EPA Energy Star*

EPA's ENERGY STAR program consists of energy efficiency tools and resources to assist the user in saving energy related costs and minimizing greenhouse gas emissions. Water and wastewater utilities can track energy use, energy costs, and associated carbon emissions by using the program's bench-marking tool called Portfolio Manager. This interactive energy management tool aids in tracking and assessing energy and water consumption for an entire portfolio in a secure online environment. Utilizing this tool, wastewater treatment plant managers are able to benchmark the energy usage of their plants against peer facilities using the EPA energy performance rating system. The principal components of the Portfolio Manager are listed below and more detailed descriptions, inclusive of tool offerings, are presented on EPA's Energy Star website (Energy Star, accessed March, 2011), these include:

- Energy and water consumption management strategies for buildings
- Energy performance benchmarking for buildings
- Carbon foot printing
- Prioritization of investment strategies
- Verification and progress tracking of improvement projects
- EPA brand recognition

It should be noted that the Energy Star Portfolio Manager is currently being upgraded. The upgraded version is expected to have the following features:

- Easier to use (completely new user interface, user friendly data entry, and enhanced data sharing features)
- Streamlined system database (faster processing, easier to update in the future)
- Modern approach to automated benchmarking (New Representational State Transfer (REST)-based web services, granular and synchronous services)

The underlying principles and ranking procedure will not be impacted. The upgraded version of the Energy Star Portfolio Manager is expected to be released in 2013.

***DOE PSAT***

A survey by Carlson et *al.* (2007) showed that approximately 99% of the electricity use at groundwater drinking water plants and 91% of the electricity use at surface water drinking water plants is associated with pumping. Therefore, an evaluation of energy saving opportunities in pumping system design and operation should be one of the most important elements of reducing greenhouse gas emissions from water facilities. The U.S. Department of Energy (DOE) has developed a software tool to assess the efficiency of pumping system operations that is referred to as the Pumping System Assessment Tool (PSAT) (DOE 2011). This software tool combines pump performance data from the Hydraulic Institute standards with motor performance data from the DOE MotorMaster+ database to calculate the maximum attainable energy efficiency for the pumping system under evaluation. Comparison of this value with existing operating energy usage then provides an assessment of the energy and associated cost savings potential.

The input parameters for the model are (DOE 2011):

- Pump style
- Units
- Number of stages
- Pump and motor speed(s)
- Motor nameplate ratings
- Operating duty (fraction of time the equipment runs at the specified condition)
- Energy cost rates
- Flow rate
- Pump head (calculated from user-supplied pressure and line dimensional data)
- Electric power or current and voltage

Based on this input, PSAT provides the following output (DOE 2011):

- Estimated pump and motor efficiencies and shaft powers for both existing and "optimal" equipment
- Annual energy use and energy costs for existing and optimal equipment
- Potential annual energy savings
- Optimization rating

### *WaterRF Energy Benchmarking*

Carlson et al. (2007) developed an energy bench-marking model for the Water Research Foundation to create a metric that would allow comparison of utility energy use among peers. A survey was mailed to 2,725 wastewater treatment plants and 1,723 water utilitiies. The survey was to create a representative data set of energy use and utility characteristics . The final filtered analysis data sets representated 266 wastewater treatment plants and 125 water utilities. The approach was to apply and evaluate a multi-parameter benchmark score method similar to the EPA's ENERGY STAR rating system for buildings. This database was used as the foundation for the Energy Star tool created for wastewater plants.

In this method, all utility energy use was converted to source energy by accounting for generation and transmission energy use. The wastewater treatment model applies a logarithmic transformation of energy consumption based on the following parameters: average influent flow, influent BOD, effluent BOD, the ratio of average influent flow to design influent flow, the use of trickle filtration and nutrient removal. Other important parameters that had significant impact on energy usage are: on-site electricity generation, sludge incineration/sludge land application, and pure oxygen. Carlson et *al.* (2007) also developed an empirical multi-parameter energy model for bench-marking energy usage of water utilities. This model also applies a logarithmic transformation statistical analysis method that relates energy consumption to operating characteristics such as total flow, total pumping horsepower, distribution main length, distribution elevation change, raw pumping horsepower, and the amount of purchased flow. This model allows users to determine the impacts of each parameter on the overall energy use.

The rating utilized in this bench-marking tool is useful for utilities to track energy performance, identify facilities for potential efficiency upgrades, and evaluate the success of energy efficiency projects. One of the limitations of this tool is that it does not specify how to improve energy efficiency, but rather provides a relative assessment of energy performance (Carlson et *al.* 2007).

### *Water to Air Model*

The Water to Air Model, developed by the Pacific Institute under a grant from the California Energy Commission Public Interest Energy Research (PIER), can be utilized to quantify the energy and air quality impacts of water management decisions (Wolff et *al.* 2004). In this model, energy and air pollution impacts can be assessed for various water sources and conveyance options. For example, seawater desalination, and inter-basin transfers can be weighed against other alternatives such as conservation, conjunctive use, or reclamation of wastewater. The models allow comparison of the energy use and air pollutant emissions of two water management scenarios that are created by the user. The output of the model presents estimated annual energy use and emissions for both scenarios, and the annual differences between the scenarios. The model allows the user to create eight different energy portfolios from mixes utilizing of different energy sources. The possible selection of energy portafolios includes:

- California Grid Mix
- Natural Gas Power Plant
- Oil Fired Power Plant
- Natural Gas Direct Drive

- Coal Fired Power Plant
- Hydro/Solar/Wind/Nuclear
- Diesel Direct Drive
- Biogas Generation
- Biogas Direct Drive

### *Aquadapt*

Aquadapt is a proprietary, real-time energy cost reduction software for water utilities, designed to optimize water production and distribution in real-time. Once an initial energy baseline is created, this software may reduce energy consumption in one or more of the following manners: scheduling pumps to be operated in off-peak periods, resulting in reduced peak demand charges, running pumps closer to the best efficiency points, choosing shortest path from source to destination, and choosing the lowest cost source of water. This real-time closed loop water network optimizing system has been successfully installed in various utilities in the US (Reynolds and Bunn 2010). This software uses the actual pump operating curves developed from flow and pressure measurements read from telemetry. Using data from the monthly energy bill, it selects the combination of pump settings which delivers the overall lowest operating cost and highest possible efficiency.

### *Optima™*

Optima™ is a proprietary energy management software providing an advanced solution for energy monitoring and targeting, bill validation, contract analysis, and budgeting. The Optima™ Carbon Footprint software is equipped to estimate energy consumption accurately and to prepare an annual report to comply with the CRC. The mandatory CRC scheme in the UK was discussed previously in the report, and focuses on improving energy efficiency and reduction in GHG emissions. A large number of water utilities in the UK are currently utilizing this software for time-efficient and effective energy management of their facilities.

### *IWLive*

IWLive, developed by Innovyze, makes the results of modeling by InfoWorks WS and InfoWater, instantly accessible to water distribution system operators. This tool is designed to regularly update warnings to draw the operator's attention to problems that may occur in the coming minutes, hours, or days. Based on the predicted severity of problems, the operation is able find necessary solutions to that problem. Beyond automatic prediction, this tool can also enable the control room operator to evaluate problem-solving approaches by simulating the closure of valves or a change in a pump's operating schedule. It allows operators to see a map of all water infrastructures including pipes, valves, pumps, reservoirs and other water assets. According to Innovyze (2012), some of the benefits of this tool are:

- Decision support software for water supply control room operator
- Model updates from telemetry data and simulates the current situation
- Incident and Response simulations to allow operators to determine best action
- Plan and manage day-to-day operations

## Summary of Energy Tools

A summary of the key characteristics of the tools discussed in this section is presented in Table 5.7. Most of the tools developed for energy evaluation and management can be applied to either water or wastewater facilities. It should be noted that each tool is specific for an intended use and the geographic location of its development. So in order to obtain a more perspicuous understanding of the energy management of a particular utility, more than one of the tools might need to be used.

## Table 5.7
## Summary of energy evaluation tools

| **Criteria** | **USEPA Energy STAR** | **USDOE PSAT** | **Energy Bench-Marking** | **Innovyze IW** | **Derceto Aquadapt** | **Water to Air** | **Encompass (nPower)** | **Optima$^{TM}$** |
|---|---|---|---|---|---|---|---|---|
| Commercial Product | No | No | No | Yes | Yes | No | Yes | Yes |
| Carbon footprint output | Yes | No | No | No | No | Yes | No | No |
| Carbon reporting program affiliation | No | No | No | No | No | No | No | No |
| Access to underlying equations | No | No | No | No | No | Yes | No | No |
| Metric format requirements or restrictions | No | No | Yes | No | No | No | No | No |
| Sectors where the tool is marketed | W/WW | W/WW | W/WW | W | W | W/WW | W/WW | W/WW |
| Typical application of tool output | Stand-alone* | Stand-alone | Stand-alone | Stand-alone | Stand-alone | Limited | Stand-alone | Stand-alone |
| Geographic regions of use | US | No boundary | No boundary | No boundary | No boundary | California, US | No boundary | No boundary |

*The water utility tool was never made available on the ENERGYSTAR website; the EPA believes it needs further testing. The wastewater tool was made available. It is a modified and user-friendly version of the WaterRF tool from the Carlson work. The best use of this tool is not as a stand-alone piece of information, but results should be compared with results from other similar wastewater utilities or annual results compared internally over-time.

## Life Cycle Assessment Tools

A life cycle assessment (LCA) is the process of evaluating the total environmental impact that a product or process exerts during its entire existence from production to eventual disposal. This process accounts for energy and resource inputs and air, land and water pollution outputs, (e.g., GHG emissions). This is a complex process primarily because it requires high volumes of data that are not always readily available. There are a number of tools available for environmental impact assessment. Menke et al. (1996) conducted a comparative evaluation of thirty-seven LCA tools that are capable of providing an objective, scientific and numerical basis for decision making. According to a survey among LCA practitioners, 58% of participants used GaBi Softwater developed by PE International, 31% of participants used SimaPro developed by PRe Consulting and 11% of respondents used a series of other tools (Cooper and Fava 2006). LCAs developed in industrial countries have been traditionally used to assess the environmental impacts of industrial products (Berger and Finkbeiner 2010). However, very little emphasis has been given to the application of LCA tools for impact assessment of different elements of municipal water and wastewater facilities. This review only focused on the LCA tools that have been used by water and wastewater utilities.

Life cycle assessment tools that consider embedded carbon from facility construction tend to be utilized in regions with related regulated requirements such as the UK. Sydney Water engaged in LCA because of a state law requiring that they conduct their operations in accordance with the principles of ecologically sustainable development (ESD) strategies. The majority of commercially available LCA tools are fairly generic and a high level of effort is usually needed to make them applicable to the water sector and their specific regional area of application. WEST is an example of a LCA tool that has recently been developed for utilization within the water sector.

The most commonly used LCA tools and the WEST tool recently developed for the water industry are described here:

### *SimaPro*

SimaPro is a software tool developed to conduct a life cycle analysis of products and systems using parameters and Monte Carlo simulations. This tool is integrated with the ecoinvent database which is the world’s leading database with up-to-date Life Cycle Inventory (LCI) data in the areas of agriculture, energy supply, transport, biofuels and biomaterials, bulk and speciality chemicals, construction materials, packaging materials, basic and precious metals, metals processing, ICT and electronics as well as waste treatment. It can be used for a variety of applications, such as:

- Carbon footprint calculations
- Product design and eco-design
- Environmental impact assessment of products or services
- Environmental reporting
- Determination of key performance indicators

Using SimaPro, emissions can be specified as air, water, and soil. In addition, solid waste and waste streams (gas, liquid and solids) can be linked in this tool. All inputs and outputs are associated with uncertainty data, specified as lognormal, normal triangular and even distributions. The impact assessment methods are defined as a series of tables for impact categories, normalization, and weighting. More than ten different impact assessment methods are included in this tool.

A comparison of the life cycle assessment of different wastewater treatment plant processes in Spain was conducted using SimaPro for conventional activated sludge (CAS), conventional activated sludge with tertiary filtration (CAS-TF), and a MBR in both external and submersed configurations (Ortiz et *al.* 2007). An example comparison output based on Eco-indicators 99 (EI 99) impact assessment method is presented Table 5.8. One of the study conclusions was that environmental impacts due to emissions were highest in the operational stage rather than construction and disposal phases.

**Table 5.8**
**Percent emission contributions at different phases estimated by SimaPro 5.1**

| **Process** | **Life cycle phase (% emission)** | | | |
|---|---|---|---|---|
| | **Assembly** | **Operational** | **Membranes** | **Disposal** |
| CAS | 42.7 | 57.2 | - | 0.14 |
| CAS-TF | 24.9 | 74 | 1.03 | 0.08 |
| External MBR | 26.1 | 69.7 | 3.5 | 0.089 |
| Submerged MBR | 30 | 65.7 | 4.2 | 0.11 |

### *GaBi*

GaBi is another leading software tool for performing life cycle assessments. The tool is also capable of estimating life cycle costing, greenhouse gas accounting, benchmarking and energy efficiency, life cycle engineering, and life cycle sustainability assessment of products and companies. This tool contains a comprehensive database that includes the European Commission's European Life Cycle Database database. This tool allows users to conduct scenario analysis, parameter variation, sensitivity analysis, and a fully user controlled Monte Carlo analysis. For example, Vince et *al.* (2008) performed an environmental assessment according to the ISO 14040 standardized LCA procedure with Gabi 4.2 software for a surface water treatment process consisting of demineralization, clarification (coagulation, flocculation), filtration, on sand filters, ozonation, filtration on granular activated carbon, pre-filtration on cartridge filters, ultra-filtration and finally chlorination. Global warming potential estimated for different processes can be found in Vince et *al.* (2008). This tool allows users to bench mark and compare the environmental impacts of different treatment and water distribution scenarios.

### *Water-Energy Sustainability Tool*

The Water-Energy Sustainability Tool (WEST) is an MS Excel-based tool developed to determine the life-cycle energy and environmental effects of water system infrastructure and operation (Stokes and Horvath 2006). This tool incorporates life-cycle assessment (LCA) quantifying cradle-to-grave material and energy inputs and environmental outputs (i.e., air emissions). Five different sources of water such as groundwater, reservoir, importation, desalination, and recycling can be analyzed. This tool provides the results of analysis according to different life-cycle phases (e.g, construction, operation, or maintenance), treatment plant process components (supply, treatment, or distribution), water source (e.g., groundwater, surface water, imported water, desalination, and reclaimed water), and carbon emission activity (e.g., material production, material delivery, equipment use, and energy consumption). The WWEST tool is developed to quantify life-cycle effects of wastewater systems including infrastructure and chemical manufacturing and energy production. Unlike WEST, it allows the user to evaluate a broader range of material inputs with greater flexibility when analyzing electricity and fuel production. This tool also allows users to calculate offsets for energy that may be generated through their treatment process. WWEST can analyze the impacts of transporting materials, emissions from construction and maintenance, and the effects of waste disposal. WEST and WWEST were developed at the University of California with funding from the California Energy Commission.

## Summary of LCA Tools

A comparative evaluation of the life cycle assessment tools is presented in Table 5.9. Although a significant amount of information is available on life cycle assessment tools, very little information is reported on the applicability of these tools for the water and wastewater industry. Most of examples on the applicability of these tools for water and wastewater processes are from European and Australian studies. The application of life cycle assessment is still not widely used by utilities in the US.

**Table 5.9**
**Comparison of life cycle assessment (LCA) tools**

| Criteria | SimaPro | Gabi | WEST | UKWIR |
|---|---|---|---|---|
| Commercial Product | Yes | Yes | No | No |
| Built-in Data-base | Yes | Yes | No | No |
| Country of Origin | Netherlands | Germany | USA | UK |
| Sectors where the tool is marketed | Any sector | Any sector | W/WW | W/WW |
| Carbon footprint output | Yes | Yes | No | No |
| Access to underlying equations | No | No | No | Yes |
| Typical application of tool output | Stand-alone | Stand-alone | Limited | Limited |
| Geographic regions of use | Global | Global | USA | UK |

## Applying the Levels of Accounting, Stages of Modeling and Tools to the UWC

Regardless of the region and portion of the UWC in question, the use of a prescriptive protocol with well documented methodologies and lookup factors is necessary to ensure the precision and representativeness of reported GHG emission values. This level of precision of reported data is a minimum requirement, even when such reporting is voluntary, because the ultimate goal of documenting GHG emissions is to present to the public or the regulator an accurate quantification of that utility's GHGs; to enable accurate national-level legislation, reporting, and cap and trade programs; to understand GHG mitigation projects which could be part of the capital improvement program; and to facilitate discussion on possible future shifts in regulatory policy. The utilization of facility-specific bottom up modeling improves the accuracy and completeness of the GHG emissions assessment.

At present, all levels of GHG emission estimation algorithms rely upon an assessment of the activity level causing the emissions that is then multiplied by an appropriate unit activity emission factor. A Level 1 protocol, while applicable to any urban water cycle, results in a high-level estimate of GHG emissions that might not cover all contributing sources and lacks specificity in the emission estimates. As an example, the IPCC utilizes over-simplified calculations for direct wastewater process emissions such as $N_2O$, and lacks consideration of potentially contributing sources such as $CH_4$ emissions from sewer systems. Modifications to the IPCC to ensure its regional specificity have resulted in Level 2 protocols such as ICLEI/LGOP and the UKWIR that have been driven by regional regulatory reporting requirements. Level 2 protocols achieve regional specificity primarily through reliance upon more regionally-specific emission factors rather than an enhancement in activity level assessments. The water/wastewater industry sector has been actively funding research to obtain better activity level assessments through data collection efforts that are integrated with more sophisticated process modeling efforts. Such research is critical to the establishment of Level 3 protocols that have facility-specific GHG emission estimation capabilities.

When the greatest level of specificity is desired in GHG accounting, either modeling or direct data measurement must be done. Modeling, as discussed in Chapter 5, can occur at three stages. Stage 1 empirical modeling typically assumes a single process performance characteristic for a particular portion of the urban water cycle, and lacks consideration of variations in process design and operation; whereas, in reality, the secondary processes employed can vary dramatically in performance. This, in turn can translate to a wide variation in direct process GHG emissions. Stage 2 and stage 3 modeling efforts are meant to capture the impact of plant design alternatives on GHG emission estimates. Stage 2 modeling utilizes process simulations that assume steady-state operating conditions and therefore only simulate "average" plant performance characteristics. Stage 3 utilizes dynamic modeling that can simulate the effects of real-time process changes. Certain wastewater processes are more difficult to maintain at steady-state, and are more accurately predicted with a dynamic Stage 3 model. These processes include nitrification/denitrification, and anaerobic digestion of biosolids for energy recovery. Empirical observation and model simulations research is still ongoing to determine the impact of process design and operating variations on the extent of $N_2O$ emissions from nitrification/denitrification processes, and the $CH_4$ emissions and energy balance for anaerobic digestion process variations. This knowledge then determines whether the $CO_2e$ impact of these emission ranges can be sufficiently handled using stage 1, 2, or 3 modeling efforts.

Two examples of Stage 2 modeling tools for wastewater facility GHG emissions are CHEApet (WERF 2011) and BEAM (CCME 2009). CHEApet (carbon, heat, energy assessment plant evaluation tool) is a steady-state whole plant simulator that utilizes solids, nitrogen, and COD mass balance equations that follow several widely accepted kinetic models and integrates them with calorific, thermal, and electrical modules to estimate overall plant energy usage, energy-associated GHG emissions, and direct $N_2O$ and $CH_4$ emissions from process models. CHEApet also allows the use of higher Level 1 protocol methodologies (e.g. LGOP) for estimating direct process emissions of $N_2O$ and is one of the only tools to allow a choice in specificity of GHG emission estimations for selected emission sources within the treatment facility. The estimation of emissions from biosolids is considerably weaker and relies extensively on the high Level 1 guidelines contained within the IPCC (IPCC 2006). A Level 2 estimation of biosolids handling is available in BEAM (CCME 2009). The algorithms utilized in

BEAM were obtained from an extensive literature review of biosolids practices and nine Canadian jurisdiction facilities. Integration of BEAM with CHEApet would present a fairly comprehensive Level 2 protocol for wastewater emissions. Still lacking is integration of $CH_4$ emission estimations from anaerobic portions in sewer conveyance and headworks.

Stage 3 modeling of wastewater facilities is being developed by commercial vendors of dynamic process simulators (e.g. BioWin, GPS-X, Aquifas). Incorporation of $N_2O$ within the Petersen matrix of these biological models and use of additional biological process model equations are being developed. Non-commercial development utilizing shareware such as MATLAB offers another avenue of simulator development. Stage 3 modeling of energy recovery via solids treatment alternatives is available with LCAMER (Life Cycle Assessment Manager for Energy Recovery (WERF 2006)). LCAMER applies systems level life cycle assessment modeling of solids treatment energy recovery technologies and evaluates the impact of these sludge treatment alternatives on overall plant operations. LCAMER does not cover all aspects involved with biosolids handling, processing, and disposal and in this respect it is less comprehensive than BEAM. LCAMER is more comprehensive than BEAM, however, in providing a systems level assessment of optimal energy recovery options with respect to life cycle cost. BEAM lacks adequate information on $N_2O$ emissions during sludge handling and LCAMER provides no information on $N_2O$ emissions in evaluating energy recovery alternatives.

# CHAPTER 6
# SURVEY RESULTS

## OBJECTIVES

The goal of this task was to identify water industry baseline performance metric needs through a broad global utility survey. The objectives of the task were to:

- identify GHG and energy tools currently being utilized,
- identify energy measurement, benchmarking or management methodologies, and
- understand emission accounting practices,
- identify the gaps between industry needs and actual tool capabilities.

Other points of interest included: assessing the severity of identified gaps between metric needs and tool capabilities, ease of tool utilization, extent of tool implementation by water industry facilities, transparency of tool approach and documentation support of tool methodologies, demonstrated ruggedness of output metrics relative to input variations, and ease of incorporating harmonization approaches.

## SURVEY METHODOLOGY

The questionnaire was distributed to 46 water and wastewater utilities around the world. These utilities were chosen within the WaterRF/GWRC core geographies with the aim of providing an accurate picture of the current "state of the industry" of GHG reporting across the globe.

The questionnaire consisted of the following:

- Initial questions in order to establish contact details and willingness to participate.
- Questions on the tools used for GHG emission reporting and energy management, their scope, inputs and outputs, method of data entry, frequency of reporting, and use in decision-making.
- Questions on GHG measurement and reporting, establishment of base year, baseline emissions for different treatment processes, process boundaries, process energy use, reporting requirements and categories of emissions reported.

The utility survey that was used is attached in Appendix B.

## RESULTS

### Facility Characteristics

Of the 46 water and wastewater utilities that were invited to participate, 22 utilities responded with a completed survey. The geographic distribution of survey respondents were: 9 from the United States (US), 6 from the United Kingdom (UK), 4 from Australia (AUS), 2 from New Zealand (NZ), and 1 from the Netherlands (NL). The list of participating utilities is shown in Table 6.1. There was no participating utility from Asia. The Water Research Commission in South Africa responded to the survey inquiry to say that due to the lack of regulatory requirements for reporting, their answers to the questions are not available.

**Table 6.1**
**List of participating utilities and their locations**

| Number | Utility Name | Location |
|---|---|---|
| **1** | Yorkshire Water | UK |
| **2** | Northumbrian Water | UK |
| **3** | Scottish Water | UK |
| **4** | Requested anonymity | UK |
| **5** | Southern Water | UK |
| **6** | United Utilities | UK |
| **7** | South East Water | AUS |
| **8** | Western Water | AUS |
| **9** | Melbourne Water | AUS |
| **10** | Water Corporation | AUS |
| **11** | Water Care | NZ |
| **12** | Palmerton North | NZ |
| **13** | Water Board Veluwe | NL |
| **14** | Coachella Valley WD | USA (California) |
| **15** | Requested anonymity | USA |
| **16** | District of Columbia Water | USA (Washington, DC) |
| **17** | Denver Water | USA (Colorado) |
| **18** | Los Angeles Bureau of Sanitation (LABOS) | USA (California) |
| **19** | Metropolitan Water District of Southern California | USA (California) |
| **20** | City of San Diego | USA (California) |
| **21** | Tarrant Regional WD | USA (Texas) |
| **22** | Requested anonymity | USA |

The function of each utility also varied, with some utilities only performing water treatment or wastewater treatment (seen in Figure 6.1). However, most utilities (over 75% or 16 of those surveyed) performed some combination of water, wastewater, or water reuse treatment.

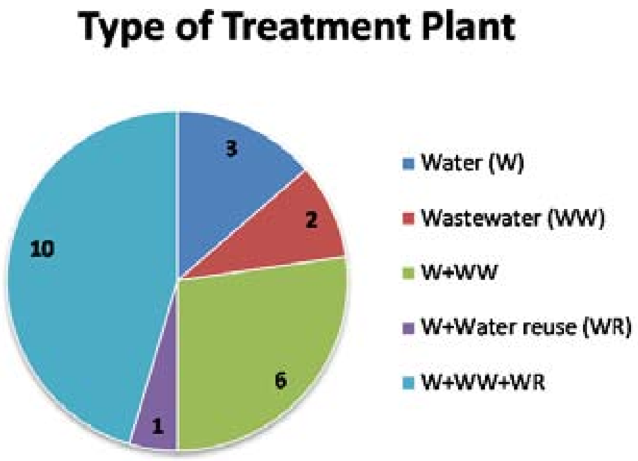
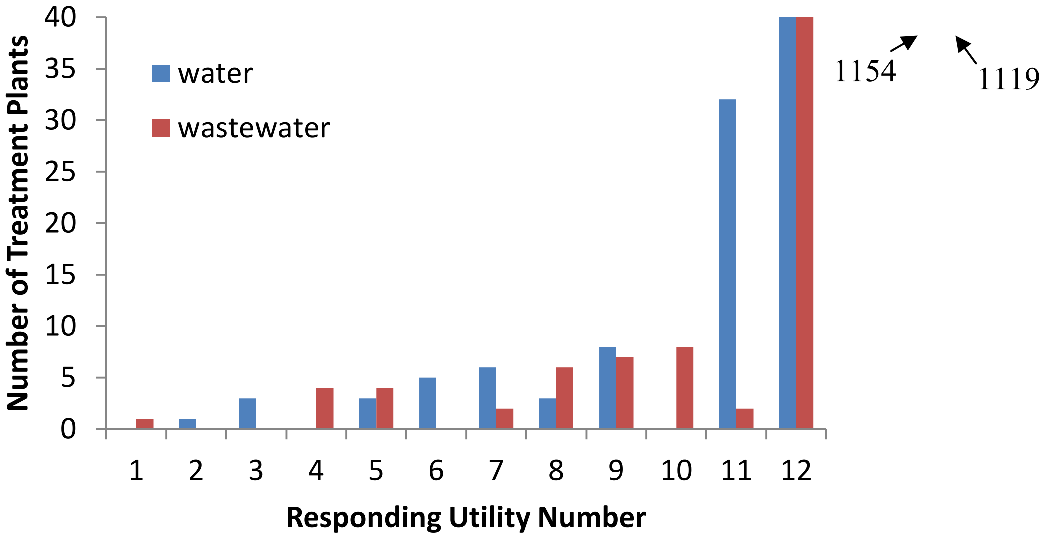


Figure 6.1 Breakdown of types of water treatment plants within utilities

In addition to differences in water treatment type, the size of the utilities that participated in the survey varied drastically. One served areas that required over 1,100 water and waste water treatment plants each, whereas others only operated one treatment plant. Although not all the participating utilities reported their plant number and plant specifications, the range of plants is shown in Figure 6.2.



* Only 55% of the responding utilities (12 utilities) provided this information

Figure 6.2 Number of water and wastewater treatment plants per utility.

Similarly, the total design flow per utility was highly dependent upon the number of water or wastewater treatment plants the utility had in their jurisdiction and therefore varied greatly. The ranges for both the water and wastewater treatment processes per responding utility is shown in Table 6.2.

**Table 6.2**
**Range of Total Design Flows and Total Average Flows per Water and Wastewater Treatment Plant of Reporting Utility**

| | Range of Design Flow (mgd) | Range of Average Flow (mgd) |
|---|---|---|
| Water | 14 – 94,810 | 4 – 2,796 |
| Wastewater | 33.5 – 39,700 | 18 – 2,904 |

* Only 55% of the responding utilities (12 utilities) provided this information

## Drivers for Reporting

Utilities from around the world reported different motivations for performing GHG emissions accounting. Some have regulations in place now that require GHG reporting, while others are anticipating regulatory changes in the near future and are trying to be early adopters in the industry. In the questionnaire, utilities were asked what their motivation was for reporting GHG emissions. These results are shown in Figure 6.3.

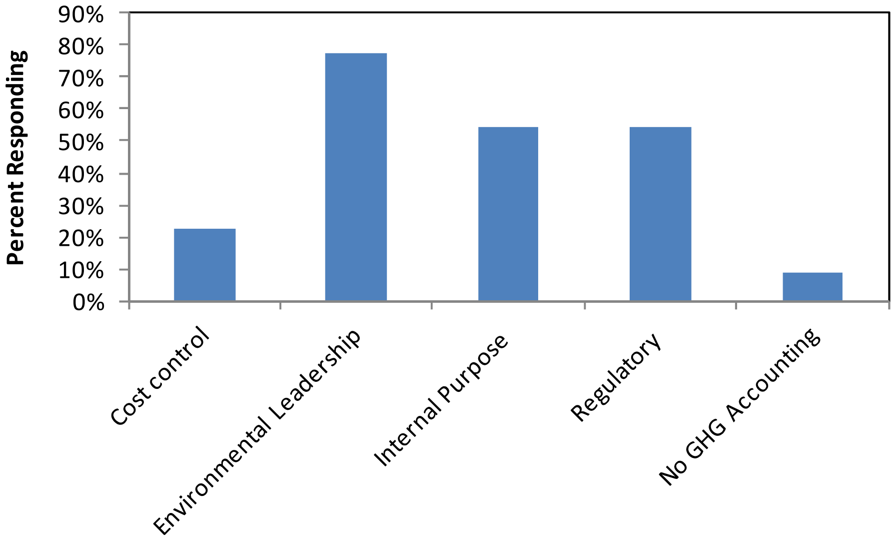


**Figure 6.3 Reported motivation of utilities to perform GHG emission accounting.**

Utilities were allowed to respond with multiple reasons for reporting GHGs. The majority of utilities cited "Environmental Leadership" as a motivating driver (77%), while "Internal Purpose" and "Regulations" were both also common reasons (55%). Cost control was only provided as a reason 23% of the time, perhaps because some of the respondents were required to report for regulatory purposes.

## Methods and Algorithms Used

### *Energy*

The majority of the utilities surveyed used energy bills in a bottom-up approach to estimate energy usage. However, three utilities in the US employed additional methods to estimate energy usage. Utilities for which billing data were unavailable obtained estimates from the Energy Information Administration and Online Meeting Data. For additional process and miscellaneous stationary combustion emissions, estimates used were based on interviews and published information. Utilities in the UK used the Optima™ Energy Management program to report energy usage of operations. Additionally, aside from one utility putting an electricity meter at the end of each treatment stage, none of the utilities have performed baseline carbon emissions calculations for individual stages of the treatment process.

Utilities should select an emissions "base year" in order to establish metrics for energy usage and carbon emissions reduction. Utilities generally recognized the importance of this step and all but six utilities, or 73% of the utilities surveyed, already had a previously established base year. However, only two utilities reported having a system in place to recalculate their base year.

### *GHG Emissions*

The specific GHGs chosen for estimation varied per utility. All the utilities in the UK estimate four main GHGs:

- Carbon dioxide ($CO_2$);
- Methane ($CH_4$);
- Nitrous oxide ($N_2O$); and
- Sulfur hexafluoride ($SF_6$).

In Australia, New Zealand, and the US, $CO_2$, $CH_4$, and $N_2O$ are routinely reported by 92% of the utilities who responded to this question (11 of 12 utilities). One third of those utilities also reported $SF_6$ emissions and two utilities in the US also report emissions from hydroflurocarbons (HFCs).

The following methodologies were reportedly used by the responding utilities to calculate GHG emissions:

- GHG protocols as interpreted by Defra/DECC;
- OFWAT reporting requirements;
- Carbon Trust Standard/Certified Emissions Measurement and Reduction Scheme (CEMARS);
- GHG protocol and WSAA Industry Guidelines;
- National Greenhouse and Energy Reporting Scheme (NGERS);

- EPA protocols;
- The Climate Registry General Reporting Protocol;
- CARB; and
- CCAR (now part of The Climate Registry) ICLEII/IPCC.

The methodologies used were very dependent upon the geography of the utility and corresponded with regulations in place, as shown in Table 6.3.

**Table 6.3**
**Methodologies Reported by Utilities per Region**

| Region | Methodology Reported |
|---|---|
| USA | The Climate Registry General Reporting Protocol<br>CARB<br>CCAR<br>EPA Protocol |
| UK | Defra/DECC<br>OFWAT<br>Carbon Trust Standard/CEMARS |
| Australia | GHG Protocol<br>WSAA Industry Guidelines<br>NGERS |
| New Zealand | ICLEI/IPCC |
| Netherlands | IPCC |

The most common methodology used in the USA was The Climate Registry's General Reporting Protocol. The Climate Registry Protocol is based on the WRI/WBSCD protocol, ISO 14064-1, CCAR, and the US EPA Climate Leaders regulations. CCAR has since merged with The Climate Registry protocol and are now one in the same, even though these survey results were reported before the merger. NGER is the regulatory protocol for Australia and is based on emissions and sources from the IPCC guidelines. Utilities in both New Zealand and the Netherlands did not report particular methodologies but did reference the IPCC. A key point is that the lack of regulatory reporting requirements in most regions other than the UK result in reliance upon high level methodologies, such as IPCC, with internally produced spreadsheets typically utilized to compile the information needed for voluntary reporting interfaces. This lack of reporting requirement and tool availability has led to a general reliance upon Level 1 methodologies.

## Tools Used

### *Energy*

As mentioned previously, the majority of the utilities surveyed use energy bills in a bottom-up approach to estimate energy usage instead of using a specific tool or directly measuring the energy consumption per process. This is primarily done because only 27% of the utilities (6 utilities) used tools that included an energy estimation feature. The tools that incorporate energy estimation include Encompass (by npower) and Optima$^{TM}$ Energy Management, both used by utilities in the UK. All of the utilities surveyed manually entered energy and emissions data into reporting forms and produced annual summary reports for energy and emissions. Energy and emissions data was entered manually and reports were summarized annually for all of the utilities surveyed.

### *GHG Emissions*

The following tools were reported to be in use by the responding utilities to calculate GHG emissions from the water and wastewater treatment processes:

- UKWIR Carbon Accounting Workbook;
- ICLEI Tool;
- Online System for Comprehensive Activity Reporting (OSCAR) for National Greenhouse and Energy Reporting Scheme (NGERS);
- Biosolids Emission Assessment Model (BEAM);
- Local Government Operations Protocol (LGOP);
- MWH Master GHG Inventory Tools;
- WaterRF 4090 Decision Support System Tool; and
- The Climate Registry Information System.

These tools were chosen based on regulations of the geographic area of interest, yet varied based on the granularity of data inputs that utilities voluntarily selected or were required to use. Where specific regulatory requirements were not present, utilities reported that internal tools were developed for ease of customization and flexibility for the future. Only 14% of the utilities (3 utilities) reported performing a comparative study in order to determine the best tool available. Table 6.4 presents the type of GHG emission tool used by the utilities per geographical region. Although emissions factors were retrieved from high level protocols, the actual tool used to calculate the final emissions was predominately an internally or third party developed spreadsheet.

**Table 6.4**
**Type of GHG Emissions Tool Used by Utilities per Region**

| Region | No. of Utilities Responding | Type of Tool Being Used | Sources of Emission Factors |
|---|---|---|---|
| **USA** | 9 | BEAM, MWH Master GHG Inventory Tools, WaterRF 4090 DSS Tool | eGRID and LGOP/ICLEI |
| **UK** | 6 | UKWIR | UKWIR, from IPCC |
| **Australia** | 4 | OSCAR | NGERs, NGA, developed own |
| **New Zealand** | 2 | ICLEI | IPCC, Ministry of Environment and Economic Development, Water Services Association of Australia |
| **Netherlands** | 1 | Climate Footprint Tool | Simapro database (EcoInvent) and literature |

BEAM was utilized by a wastewater treatment facility, while MWH Master GHG Inventory Tools and WaterRF 4090 DSS Tool were both used by water treatment facilities. As just 2 utilities performed wastewater treatment only and 3 utilities performed water treatment only, there are not enough data points to conclude the ease of reporting via a prevalence of tools for a certain treatment process. Emissions factors and tools from The Climate Registry were predominately used for the water treatment plants.

The UK exemplifies a harmonized regional GHG reporting framework since all utilities in the UK reported use of the same GHG emission tool. The consistent reporting scheme is reflective of the regulatory agency's requirement to ensure uniformity and consistency across utilities. Another advantage of the UKWIR tools is that the boundary conditions (scope wise) are well-defined and directly applicable for the water and wastewater industry.

The reporting interfaces employed by the utilities in the US, Australia, and New Zealand were either developed in-house by the utility or contracted to a third party. Correspondingly, utilities in these countries were more likely to respond that their tools were not specific to the water and wastewater industry. Especially in the US, the tools required further customization to include the relevant equations for use in the water and wastewater industry. The paramount reason there was no consistency in the tools used by these countries is that there is no regulatory requirement for a uniform national GHG reporting framework for the water sector as there is in the UK. Most GHG emission tools do not include the treatment processes unique to the water and wastewater industry, let alone to a specific utility, so customization is usually required anyway. As was described in Chapter 5, many of these tools are still under development and are not widely used and/or accepted. Also, GHG emission calculations remain complex for process emissions where it is difficult to quantify inputs and emission factors for specified boundary conditions. This makes developing a tool internally that can be modified on an as needed basis depending on the uniqueness of the operation, a difficult endeavor. Therefore, the lack of a regulatory driver within a country, creates a situation where the level of granularity utilities are voluntarily selecting is higher than utilities in other countries.

## Typical Ranges of GHG Emissions

Most of the utilities reported that their GHG tools only covered Scope 1 and Scope 2 emissions (73% of the utilities that answered the question). Generally, this is all that is required to report to the regulatory agencies since Scope 3 emissions are more removed, indirect emissions and more difficult to quantify. The utilities that responded to the survey with exact values of scope emissions are shown in Table 6.5.

## Table 6.5
## Percent distribution of emissions for each scope per utility. W = Water, WW = Wastewater, and WR = Water Reuse plants.

| Scope Type | Categories | Yorkshire | United Utilities | North-Umbrian | Melbourne | MWD† | LABOS | Ano-nymous* | Denver |
|---|---|---|---|---|---|---|---|---|---|
| | | W/WW | W/WW | W/WW/WR | W/WW/WR | W | WW | W/WW/WR | W/WR |
| **Percent Distribution** | | | | | | | | | |
| **Scope 1** | Onsite Fuel | - | 3% | 9% | | 0.23% | 25% | 90% | 7.4% |
| | Own Vehicle Transport | - | - | 3% | | 2.04% | 10% | <1% | 7.5% |
| | Direct Process | 15% | 15-20% | 6.6% | 45% | 0.04% | 50% | <1% | 0.3% |
| **Scope 1 Subtotal** | | 20% | 18-23% | 18.6% | 45% | 2.31% | ~92% | 90% | 15.2% |
| **Scope 2** | Grid Elec. Pump & Treatment | 70% | 70-75% | 78.7% | 55% | 97.3% | 11% | 10% | 71.6% |
| | Grid Elec. Ancillary | - | - | 1.2% | - | 1.8% | - | - | 13.2% |
| | Purchased heat or steam | - | - | - | - | 0.8% | 5% | - | - |
| **Scope 2 Subtotal** | | 65% | 70-75% | 79.9% | 55% | 99.9% | 16% | 10% | 84.8% |
| **Scope 3** | Chemicals | - | - | - | - | - | - | - | - |
| | Business travel | - | - | 0.4% | - | - | - | - | - |
| | Other | - | - | 1.2% | - | - | - | - | - |
| **Scope 3 Subtotal** | | 0% | 0% | 1.6% | 0% | 0% | 0% | 0% | 0% |

*Anonymous is also a power provider, hence the large Scope 1 emissions.
†These data do not add up to 100% and are currently being verified.

Reported emissions came primarily from the Scope 2 category, with the exception of the anonymous utility, which is a power provider and thus produces its own power onsite. For the utilities that do not produce or consume their own fuel onsite, the majority of GHG emissions are indirect and from purchased electricity required to run the pumps and processes rather than from the processes themselves (ranging from 65% to 97.3%). These findings are consistent with the literature review, which showed that between 91 – 99% of electricity costs are associated with pumping costs, depending on the source water (Carlson *et al*. 2007). Scope 3 emissions were not generally reported, but when they were they did not significantly contribute to total emissions.

## Level of GHG Emission Estimation

In order to use each tool, GHG emissions need to be either estimated or directly measured. However, most of the utilities avoided any direct measurement of GHGs for a variety of reasons. Most importantly, directly measuring GHG emissions is not required even in the countries with the most regulations, as most of the protocols and tools are still on a level 1. Direct measurement would incur additional costs and there is still no agreed upon method for direct measurement to create harmonization across the utilities. Most importantly, as was discussed in a previous section, electricity is still the major contributor to emissions. There is an increased interest in understanding direct $CH_4$ and $N_2O$ emissions because of their much greater global warming potentials than $CO_2$.

There were several utilities that did directly measure one or all of the GHGs emitted from their plants. Scottish Water (UK) directly measured methane from CHP as part of controlling ongoing biogas firing. United Utilities (UK) is directly measuring GHG emission as part of an ongoing research project in conjunction with the Suez Environment Group. In the US, LABOS is continuously monitoring digester gas flow rate and $CO_2$ composition for ongoing biogas firing, as well measuring $N_2O$ at two nitrification/denitrification treatment plants as part of a separate research project. Finally, DC water is directly measuring $CH_4$, $CO_2$, and $N_2O$ emissions as part of ongoing research. Most of the utilities involved in Level 2 or 3 reporting are doing so voluntarily and are engaging in research in order to further the knowledge base for future GHG reporting.

## Drivers for Harmonization

The key objective of performing this international survey of water and wastewater utilities was to understand how utility reporting of GHG emissions might be globally unified to a common framework that would allow comparison of reported emissions despite regional differences in GHG emissions regulations, methods and tools. The survey responses confirmed that regulations foster harmonization, but such harmonization tends to occur for higher level reporting and there is still a great deal of research needed before the necessary tools for regulatory reporting occurs from a bottom-up perspective rather than a top-down approach. The difficulty with the top-down accounting is in the lack of accuracy and precision inherent to these approaches which are based upon emission factor and activity level calculations. Such approaches have been shown to be inadequate for estimation of direct emissions such as $CH_4$ and $N_2O$ from wastewater conveyance and treatment. Newer tools (e.g., CHEApet) will be able to use process modeling to link emissions to specific process operations. Tools of this sort will not only enable bottom-up reporting, but should also serve as predictive tools for selecting optimization strategies at the utility level. One driver for harmonization would be for utilities to model their emissions through use of such predictive tools in order to take away the uncertainty involved with applying general emission factors. However, this research is ongoing and is yet to be available to the majority of utilities.

Additionally, with a great majority of utilities developing tools internally in the absence of any regulatory requirement, the proprietary nature of the tools makes it difficult to assess what commonalities exist. However, developing an international process framework specific to the water and wastewater industry and/or a tool to quantify the emissions from treatment processes would be very useful given that most utilities report that the tools they use are not industry specific.

### Anticipated Changes in Reporting

As reported earlier, the most common drivers for water utilities to report their GHG emissions are (in order) environmental leadership, internal purpose, and regulatory requirement (Figure 6.3). Globally, GHG reporting by water utilities at this point is mostly voluntary so a utility can exhibit leadership by preemptively reporting GHG emissions with the anticipation of future changes to reporting requirements. Table 6.6 outlines utility responses when questioned about what changes are anticipated regarding GHG emission reporting requirements in the near future.

**Table 6.6**
**Anticipated changes to GHG emission reporting requirements**

| Region | Anticipated Changes |
|---|---|
| **USA** | • No real indication of regulation, likely well into future (DC Water)<br>• California Cap-and-Trade program will start soon |
| **UK** | • Reporting for CRC is likely to change (Yorkshire)<br>• Mandatory reporting of operational emission by 2012 (UU) |
| **Australia** | • A price on carbon by July, 2012 (Melbourne Water)<br>• Victoria Climate Change Act was passed and provide EPA power to regulate GHG emission (South East Water and Melbourne Water) |
| **New Zealand** | • No change anticipated in near future; Water/wastewater emissions are not included in the Emission Trading Scheme |
| **Netherlands** | • No specific information when the regulations specific to the water sector will take place |

## Industry Needs

Several industry needs to better fulfill mandatory and voluntary GHG emissions reporting were identified over the course of reviewing the survey responses:

- Better harmonization between international regulations or preparation of position papers that clearly specify the key differences that will impact the precision and/or accuracy of reported emissions.
- Better oversight of carbon emissions tools, particularly those internally developed by water utilities within countries without mandated approaches specified in regulations.
- Better communication and transparency amongst water industry professionals about tool development, perhaps through an industry-sponsored committee dedicated to the harmonization of GHG reporting protocols and tools.
- Translation of developed tools that calculate emissions as a function of processes, such as CHEApet, BEAM, and/or BioWin into industry-specific design and operational guidance documents. Currently, the ability to identify improvements and specific losses for each treatment step is missing because carbon emissions are not calculated individually within each process. This information is being generated and when available in the near future, should be consolidated into some sort of best practices compendium.

# CHAPTER 7
# DECISION FRAMEWORK FOR GHG EMISSIONS ACCOUNTING AND REPORTING

Water utilities in many parts of the world are in a state of regulatory uncertainty for GHG reporting. Meanwhile, demand for more energy intensive treatment processes is increasing, driven not only by high intensity treatment needs but also by water scarcity. As discussed in the previous chapters, the GHG emission accounting of a water utility is largely driven by one or more of the following objectives:

- Environmental leadership – Water utilities around the world are charged as stewards of the local environment, and GHG accounting is a natural aspect of that stewardship.
- Regulatory reporting mandated by a governing entity.
- Understanding of potential regulatory risk exposure –A water utility anticipates that mandatory reporting might be required in the future, and wishes to understand the process, their potential emissions levels, and ways to reduce emissions.
- Public transparency and voluntary reporting – Many utilities may be driven by community needs or public responsibilities to report their emissions in a full and transparent manner. For these utilities, it is critical to choose their reporting standard and reporting entity according to the specifics of their goal. For example, a company wishing to achieve an actual certification might choose to use the ISO or ANSI standard. A water utility that wishes to accomplish a community profile for their activities should choose a reporting agency with which their communities familiar. An entity seeking global voluntary recognition might choose to report voluntarily to a global reporting entity such as the GRI.
- Contributes to other strategic goals – GHG accounting can be one way in which to identify opportunities and demonstrate actions toward utility strategic goals for energy reduction, renewable energy, sustainability, or cost control.

The quality of data, accuracy of emission factors, and selection of methods necessary for calculating GHG emissions are oftentimes influenced by the GHG accounting objectives, available resources, and employee skill sets of a particular utility. Although there have been sporadic efforts by individual utilities or research organizations around the world to understand salient features impacting the accuracy of carbon accounting, sufficient data has not been collected or analyzed to harmonize underlying methodologies from a global perspective. Until globally uniform methodologies are established, a water utility should follow the best possible framework that provides guidance in selecting protocols and methods. The framework provided in this chapter guides a water/wastewater/water reuse utility that is in a region with uncertain or no regulatory requirements through the process of determining which regulations may be most applicable to them, which standards to use, and whether to use voluntary standards or relevant research findings. This chapter presents a conceptual framework and demonstrates the application of that framework through three different case studies.

The framework that is presented in the Figures 7.1 through 7.4 represents how GHG accounting should be done in areas of regulatory uncertainty. It is important to note that the case studies do not follow the exact steps outlined in these figures, because each case study was conducted in isolation of the others and could not benefit from any single best practice document or work flow guidance. Rather, each of the case study utilities had to forge their own way in creating a methodology that they felt could work for them and lead to compliance in their situation of regulatory uncertainty.

In each case study the respective utilities are reporting, or considering reporting, to multiple regulatory or voluntary bodies. In most countries and regions around the world a utility will have a much higher degree of certainty, in that either they are required to report to a single regulatory entity or they are not. If a utility is reporting to a single regulatory agency then that agency’s guidance should be used exclusively.

### GHG Accounting Framework for Water Utilities

In this section of the report, a decision framework that will help a utility to conduct their GHG accounting according to best practices are presented. This section is addressed specifically to the decision making needs of utilities operating in the urban water treatment cycle. It should be noted that these flow charts are comprehensive enough to represent best practice for utilities in complex regulatory conditions, where they may have to report to more than one entity, or have assets which are not explicitly or adequately covered in the methodology of their reporting entity.

There are four fundamental steps in the process, as shown in Figure 7.1. A brief description of each step is presented below:

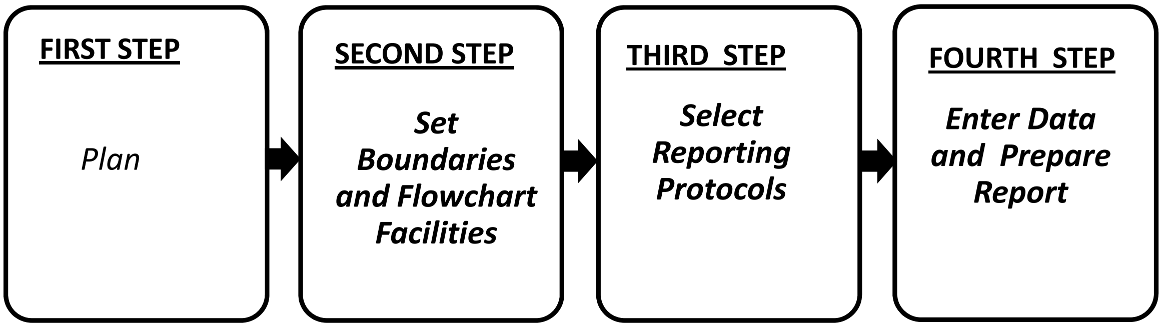


**Figure 7.1 High level flowchart for GHG emissions accounting and reporting**

### *First Step: Plan*

The first important step of GHG accounting is to plan. This includes clearly identifying the drivers to undertake GHG emissions accounting and reporting. For utilities that do not have a regulatory driver, the purpose of GHG accounting should be identified and clearly articulated through discussions between management and operations teams. The water utility will require coordinated interdisciplinary efforts between their power support unit, fleet team, power resources team, accounting unit, and planning team to conduct GHG accounting.

### *Second Step: Set Boundaries and Flowchart Facilities*

In this step, the utility begins the GHG accounting process by creating their own basic diagram, flow chart or other representation of all of the assets it owns that are likely to produce GHG emissions. The utility should utilize the WRI/WBCSD framework to identify organizational boundaries, and understand the different scopes of emissions that might be produced. This decision process is relatively straightforward, and shown in Figure 7.2 below.

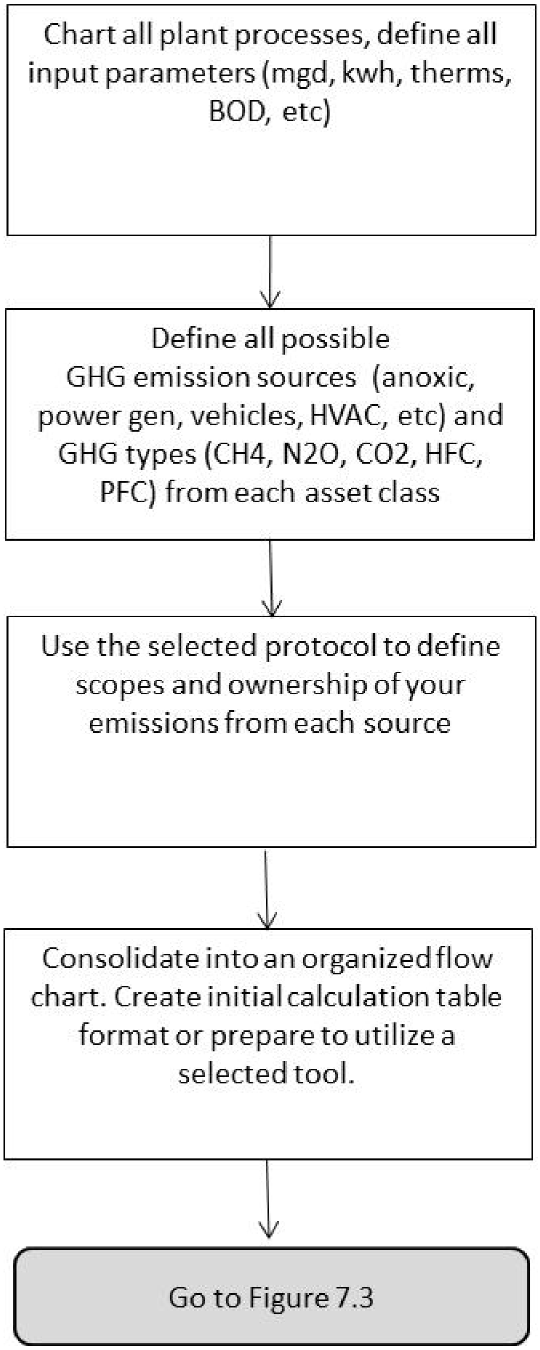


**Figure 7.2 Conceptual flowchart for setting boundaries and identifying assets**

### *Third Step: Select Reporting Protocol*

In this step, the utility should identify the entity to which they either are required to or which they desire to report. The reality for many facilities, though, is that either:

- Reporting is oftentimes performed to multiple entities. An example of this situation is in the US State of California where a utility might need to report at a National level to the US EPA, at a State level to the California Air Resources Board (CARB), and since neither of those reports covers all of the utility's emissions they may also wish to report their full GHG footprint to The Climate Registry (TCR).
- Some of the owned assets are not adequately covered in the methodology and protocols of their reporting entity. For example, utilities must dispose of their sludge, and in many cases this is not done in a landfill but is land applied. While the prevailing standards may cover the methodology for quantifying GHG emissions from water treatment processes, the methodology for quantifying GHG emissions from land application are not commonly covered and may require separate research.

As such, the flowchart shown in Figure 7.3 guides a utility through this decision making process.

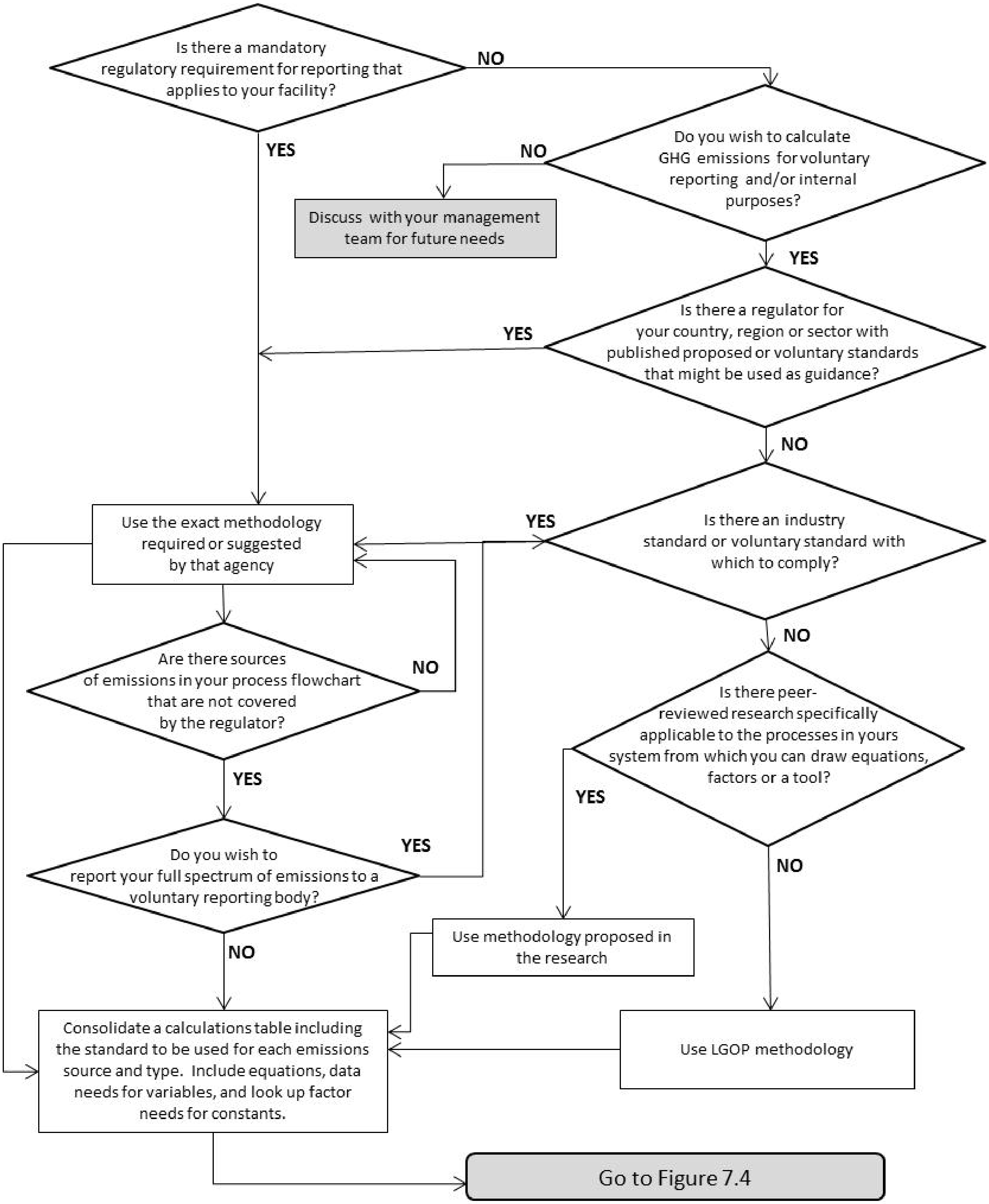
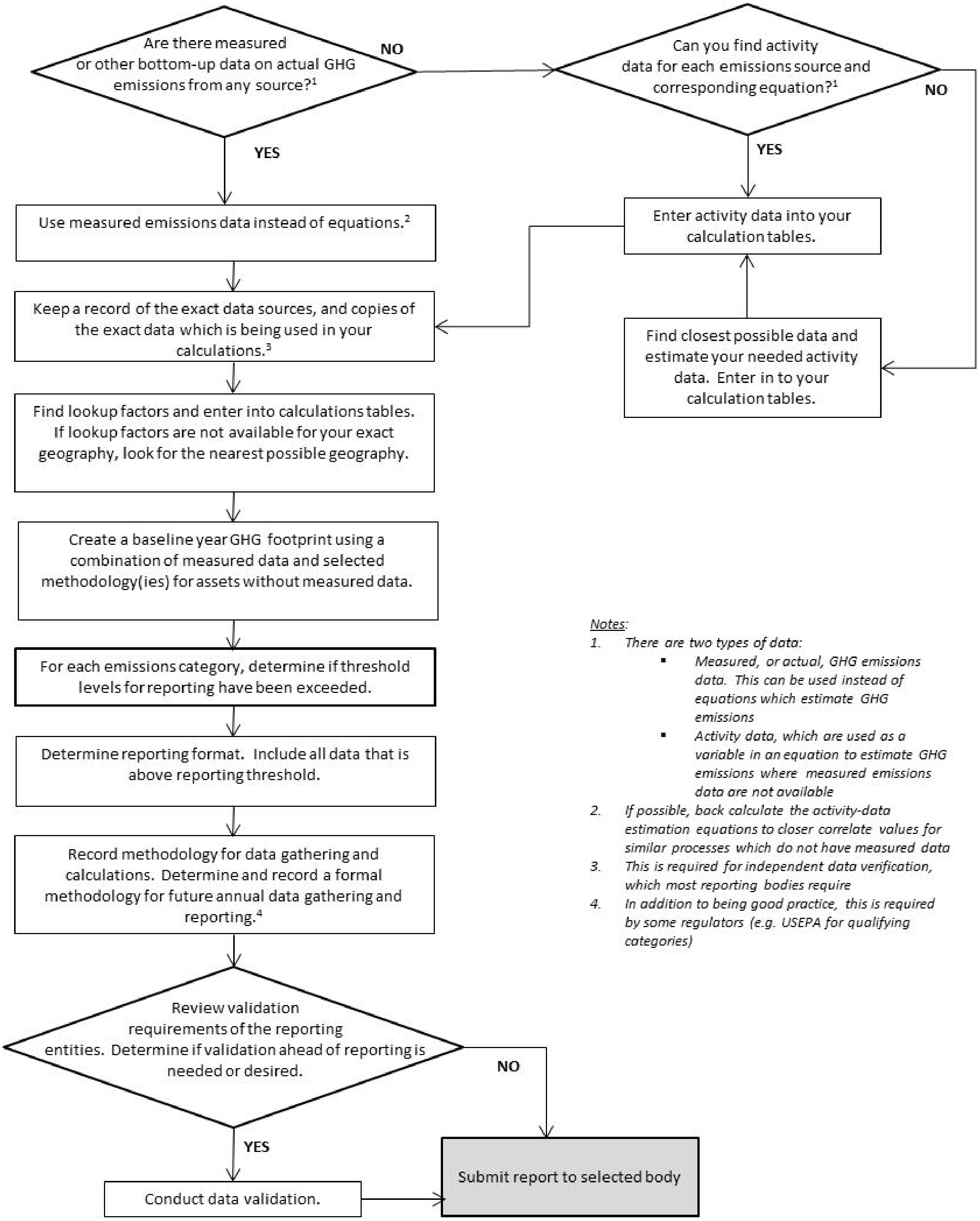


**Figure 7.3 Flowchart showing protocol selection process**

### *Fourth Step: Collect Data and Prepare Report*

In this step, as shown in Figure 7.4, the utility collects and records data, prepares their report, conducts a third-party audit, and finally submits the report to the desired reporting entity.



*Notes:*

1. *There are two types of data:*
    - *Measured, or actual, GHG emissions data. This can be used instead of equations which estimate GHG emissions*
    - *Activity data, which are used as a variable in an equation to estimate GHG emissions where measured emissions data are not available*
2. *If possible, back calculate the activity-data estimation equations to closer correlate values for similar processes which do not have measured data*
3. *This is required for independent data verification, which most reporting bodies require*
4. *In addition to being good practice, this is required by some regulators (e.g. USEPA for qualifying categories)*

**Figure 7.4 Flowchart showing data collection, analysis, and reporting decision processes**

## Case Studies Demonstrating the Application of the Framework

The application of the framework to water and wastewater utilities, was evaluated through three case studies that included a water utility, a wastewater utility and a water reuse utility. The project team worked with each utility's GHG accounting team and compared their calculations and reporting procedures with the framework developed in this study in order to validate it's usage for other utilities. A brief description of each case study is presented in this subsection.

### Case Study 1: Wastewater Case Study

The selected wastewater case study agency owns several wastewater treatment plants, several landfills, and is responsible for biosolids handling. The other facilities within the utility boundaries are office buildings, equipment buildings, and vehicle fleets. This utility is located in California, USA.

This case study is presented within the general framework shown in Figures 7.1 through 7.4 above. It is important to note that these figures represent a best practice framework for GHG accounting in areas of regulatory uncertainty. The below case study does not follow the exact steps outlined in these figures, because it presents the actual work done by a utility in isolation of any single best practice document or work flow guidance. However, the case study does present an example of how the steps outlined in the framework shown in Figures 7.1 to 7.4 can benefit a utility's GHG process.

**First Step: Plan.** The utility's GHG planning efforts revealed the following drivers:

- To assess compliance needs with pending Federal reporting requirements under the US EPA Mandatory Reporting Rule
- To assess compliance needs with the California Air Resources Board AB32
- To participate in Los Angeles's GHG emissions reduction goal of 35 percent below 1990 levels by the year 2030, which requires reporting of all municipal emissions to The Climate Registry
- To quantify biogenic $CO_2$, which is being required as a reportable quantity by CARB
- To participate in a study to monitor and measure the actual $N_2O$ emissions from two of their wastewater treatment plants
- To estimate the amount of GHG sequestered through land application of biosolids to obtain emission credits

**Second Step: Set Boundaries and Flowchart Facilities.** A table that includes the utility facilities that produce GHG's is shown in Table 7.1.

## Table 7.1
## Table of GHG producing facilities at LABOS

| GHG Generating Assets: | Waste Water Treatment Plants:<br>- Hyperion Treatment Plant<br>- Terminal Island Water Reclamation Plant<br>- Donald C. Tillman Water Reclamation Plant<br>- Los Angeles Glendale Water Reclamation | Landfills:<br>- Lopez Canyon<br>- Toyon Canyon<br>- Sheldon-Arleta Canyon<br>- Gaffey Canyon<br>- Bishops Canyon | Other GHG Generating Assets:<br>- Pumping Plants<br>- Biosolids Hauling<br>- Biosolids Land Application<br>- Biosolids Composting<br>- Waste Collection Fleet<br>- Chemical Deliveries<br>- Employee Commuting |
|---|---|---|---|
| Actual GHG Sources: | - Treatment processes<br>- $N_2O$ downstream discharge<br>- Fuel Combustion | - Fugitive emissions<br>- Landfill flares | - Power purchases across all facilities<br>- Hauling<br>- Land Application<br>- Composting<br>- Fleets<br>- Building HVAC & Refrigeration |
| GHG's Generated | - $CH_4$<br>- $N_2O$<br>- Anthropogenic $CO_2$<br>- Biogenic $CO_2$ | - $CH_4$<br>- Anthropogenic $CO_2$<br>- Biogenic $CO_2$ | - $CH_4$<br>- $N_2O$<br>- Anthropogenic $CO_2$<br>- Biogenic $CO_2$<br>- PFCs (likely *de minimis*)<br>- HFCs (likely *de minimis*) |

For each major facility it is useful to flowchart the GHG emissions. A conceptual schematic of a flowchart showing sources of GHG emissions from one of the larger WWTPs is shown in Figure 7.5. Note that in this case, the GHG accounting is complicated by the fact that the WWTP sells digester gas to a nearby power plant, and buys back steam.

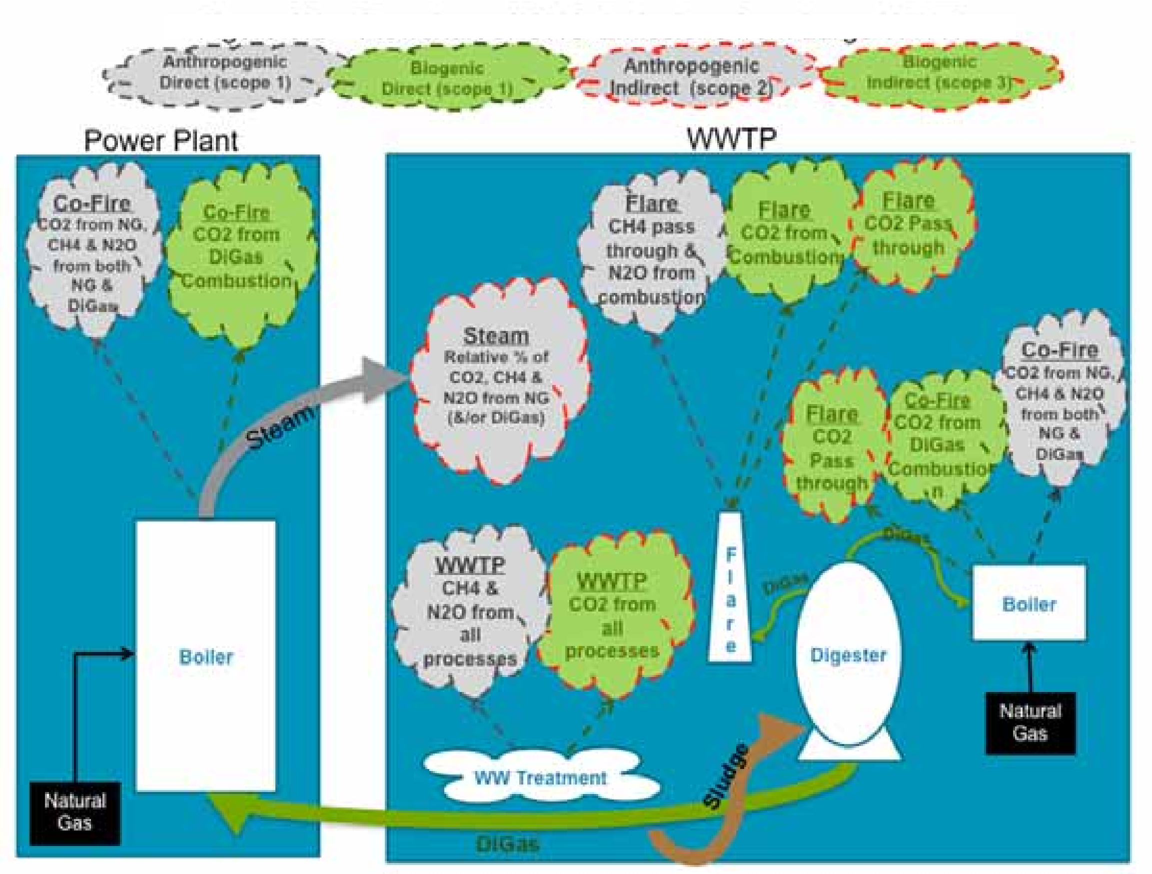


**Figure 7.5 Sources of GHG Emissions from Large WWTP**

**Third Step: Select Reporting Protocols.** The project team reviewed the logic utilized by this wastewater utility and compared it with the framework. The protocol selection procedure that was used by this utility is mapped to the conceptual framework as shown in Figure 7.6, suggesting that the framework would have been effective in identifying the appropriate protocol and methodologies for this particular utility. It should be noted that some of the decision pathways that were included in the framework were not applicable for this utility case study, and are not included in Figure 7.6.

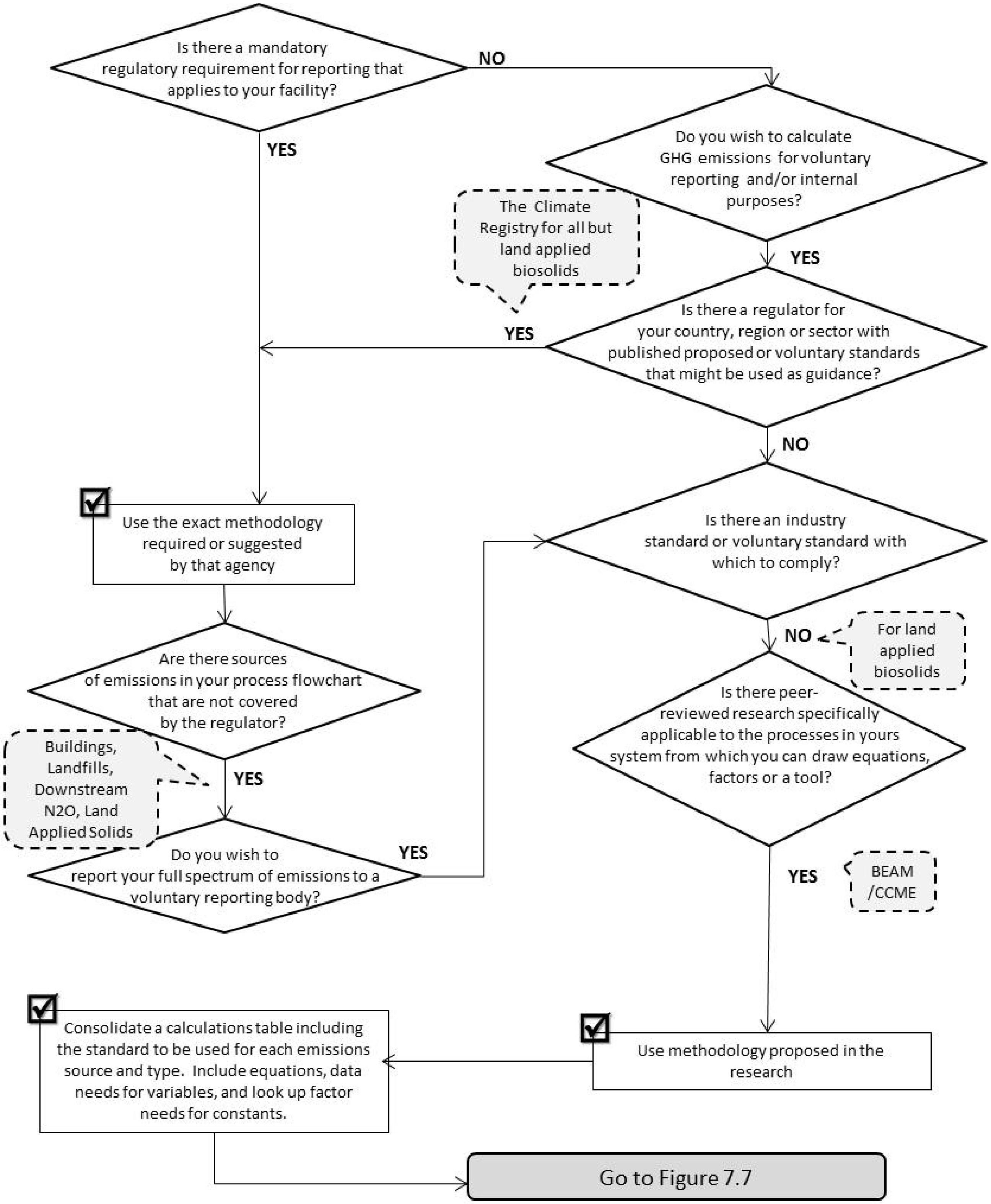


**Figure 7.6 Validation of the protocol selection Framework using a wastewater case study**

**Fourth Step: Collect Data and Prepare Report.** The project team compared the data collection and report preparation with the approach applied by this particular utility. The decision flow paths that were applicable to this utility are shown in Figure 7.7. This comparison illustrates that the framework developed in this study was effective in identifying appropriate methodologies. A summary of the GHG emissions estimated is presented in Table 7.2.

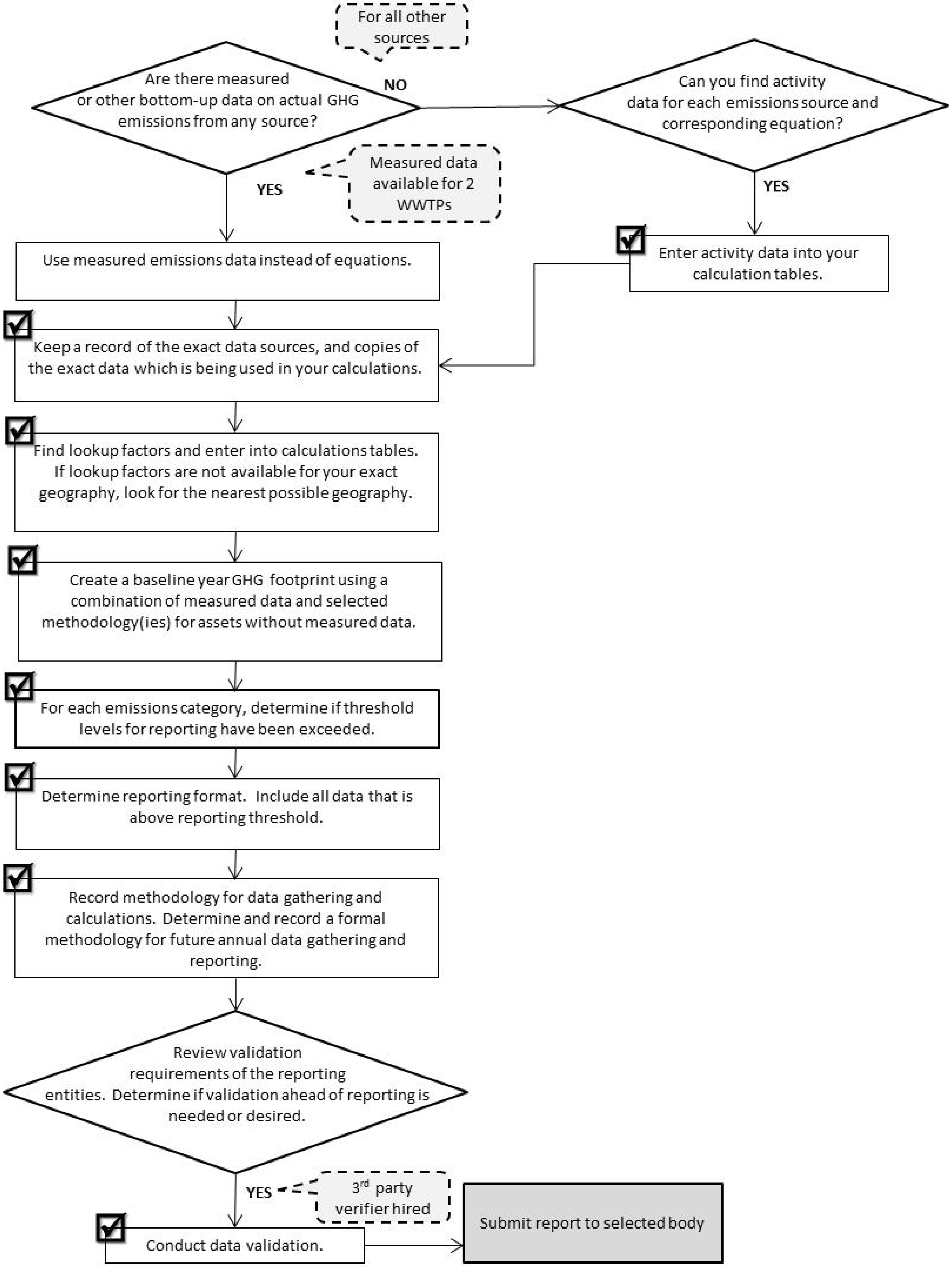


**Figure 7.7 Data collection and reporting flowchart utilized by the wastewater case study**

**Table 7.2**
**LA BOS GHG Emissions, 2009**

| **ANTHROPOGENIC GHG** | | |
|---|---|---|
| **Scope 1 ($N_2O$ and $CH_4$ emissions)** | | Percentage |
| Anthropogenic Process Emissions | 6,148 | 1% |
| Fuel Combustion for Power | 2,514 | 0% |
| Fuel Combustion for Vehicles | 56,377 | 8% |
| Landfill Flares & Fugitives | 149,617 | 21% |
| ***Scope 1 subtotal*** | **214,657** | 31% |
| **Scope 2** | | 0% |
| Purchased Electricity or Steam | 228,657 | 33% |
| ***Scope 2 subtotal*** | **228,657** | 33% |
| **Scope 3** | | 0% |
| Anthropogenic $N_2O$ (effluent in receiving water after discharge) | 43,182 | 6% |
| Vehicle Fleets for Chemical Deliveries & Employee Commuting | 7,020 | 1% |
| ***Scope 3 subtotal*** | **50,202** | 7% |
| **Total Anthropogenic Emissions** | **493,516** | 71% |
| **BIOGENIC** | | 0% |
| $CO_2$ from DiGas and Landfill flares | 215,882 | 31% |
| $CO_2$ from Biosolids Land Application and Composting | -9,855 | -1% |
| ***Biogenic subtotal*** | **206,028** | 29% |
| **Grand Total** | **699,543** | 100% |

In addition to the final GHG accounting numbers, the project team also looked at how numbers compared across the different levels of reporting and accounting. In this case, actual $N_2O$ emissions at two of their wastewater treatment plants were compared to the values that were calculated using the methodology suggested by the regulatory agencies applicable for this utility. This comparison is shown in Figure 7.8. The data illustrates that GHG accounting based on on-site measurement provides a more accurate estimation, but that in this specific case the equations yield a result that is well within the acceptable range.

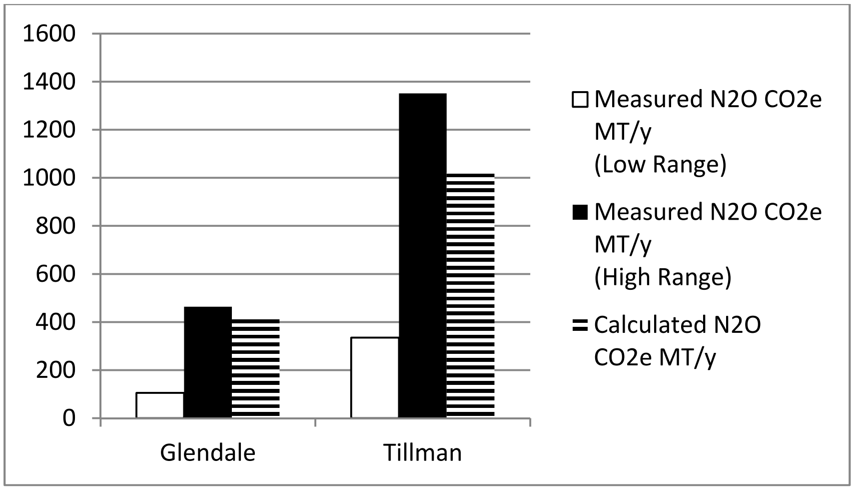


**Figure 7.8 Comparison of Measured vs. Calculated $N_2O$ at LABOS**

**Case Study 2: Water Utility Case Study**

This water utility is a regional water district that serves approximately 19 million people in six counties. This utility operates five drinking water treatment plants with a total design flow of 2,640 MGD. The total average flow in 2009 was 908 MGD.

This case study is presented within the general framework presented in the Figures 7.1 through 7.4 above. It is important to note that these figures represent a framework for GHG accounting in areas of regulatory uncertainty. The below case study does not follow the exact steps outlined in these figures, because it presents the actual work done by a utility in isolation of any single best practice document or work flow guidance. However, the case study does present an example of how the steps outlined in the framework shown in Figures 7.1 to 7.4 can benefit a utility's GHG process.

**First Step: Plan.** This water utility is currently not required to report their emissions to a national regulatory body (i.e., the US EPA) since the amount of direct emissions is lower than the regulatory limits (i.e., 25,000 metric tonnes). However, this utility followed other requirements imposed by the state-level/regional regulatory and/or voluntary reporting agencies.

The utility's planning for GHG accounting was driven by:

    - Requirement to comply with California Air Resources Board (CARB)
- Choice to voluntarily report to The Climate Registry (TCR), driven by a desire to provide a completely transparent and full GHG report according to an accepted standard.

**Second Step**: **Set Boundaries and Flowchart Facilities**. A conceptual illustration of the process flow schematics of the treatment plants are shown in Figure 7.9. This utility operates an aqueduct, various pumping plants, treatment plants, and an extensive distribution system that includes reservoirs, hydroelectric power plants, pressure control structures, and valve structures. This utility also operates a 230kV transmission line system as part of its aqueduct pumping operations. The GHG emissions for this facility were divided into several major areas as shown in Figure 7.10.

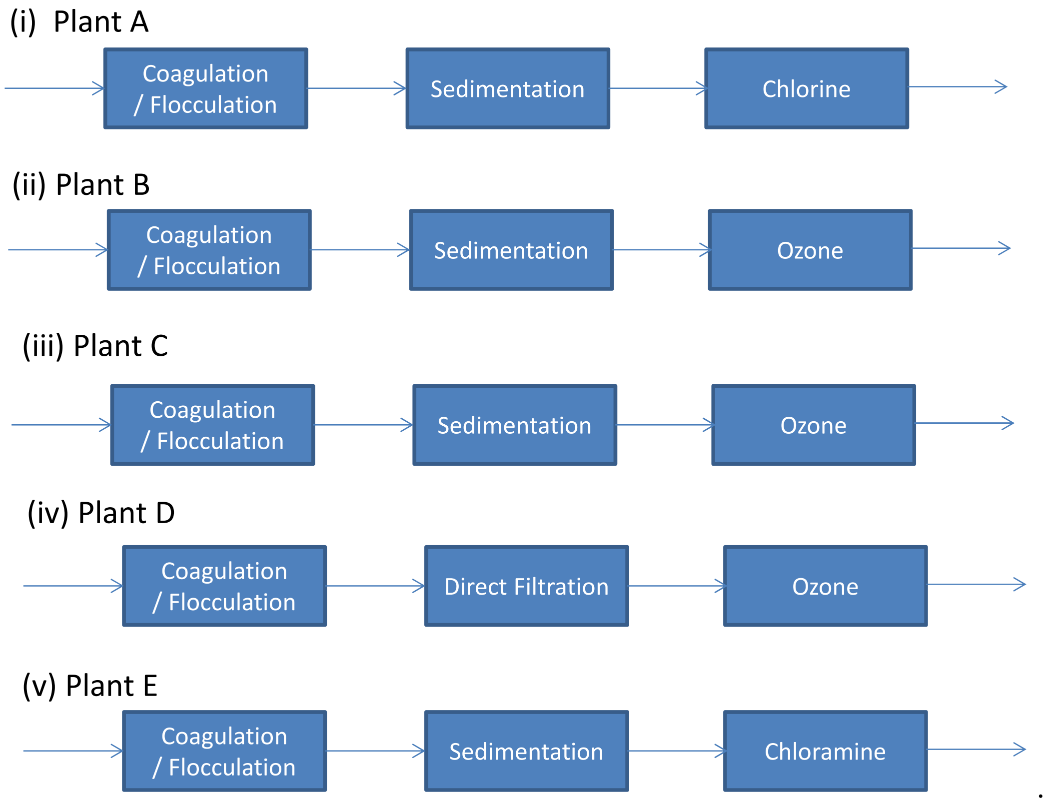


**Figure 7.9 Conceptual process flow diagrams of the treatment plants**

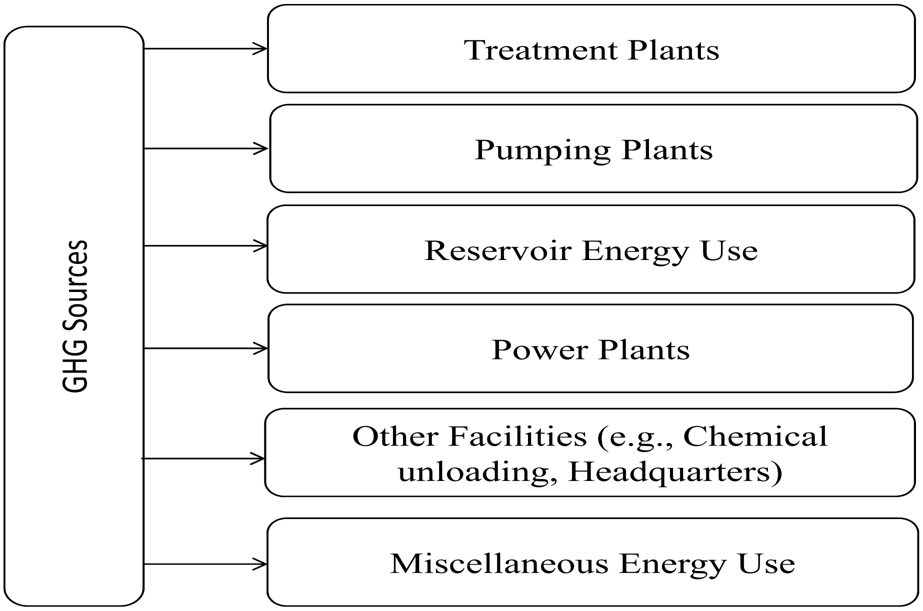


**Figure 7.10 Major sources of GHG emissions from this water utility**

**Third Step: Select Reporting Protocol**. The project team reviewed the logic utilized by this water utility and compared it with the framework. The protocol selection procedure that was used by this particular utility is mapped to the conceptual framework as shown in Figure 7.11, suggesting that the framework would have been effective in identifying appropriate protocol and methodologies for this particular utility. It should be noted that the utility did not use the framework but that it was applied retrospectively to determine its adequacy. Some of the decision pathways that are identified in the framework were not applicable for this utility case study and are not included in Figure 7.11.

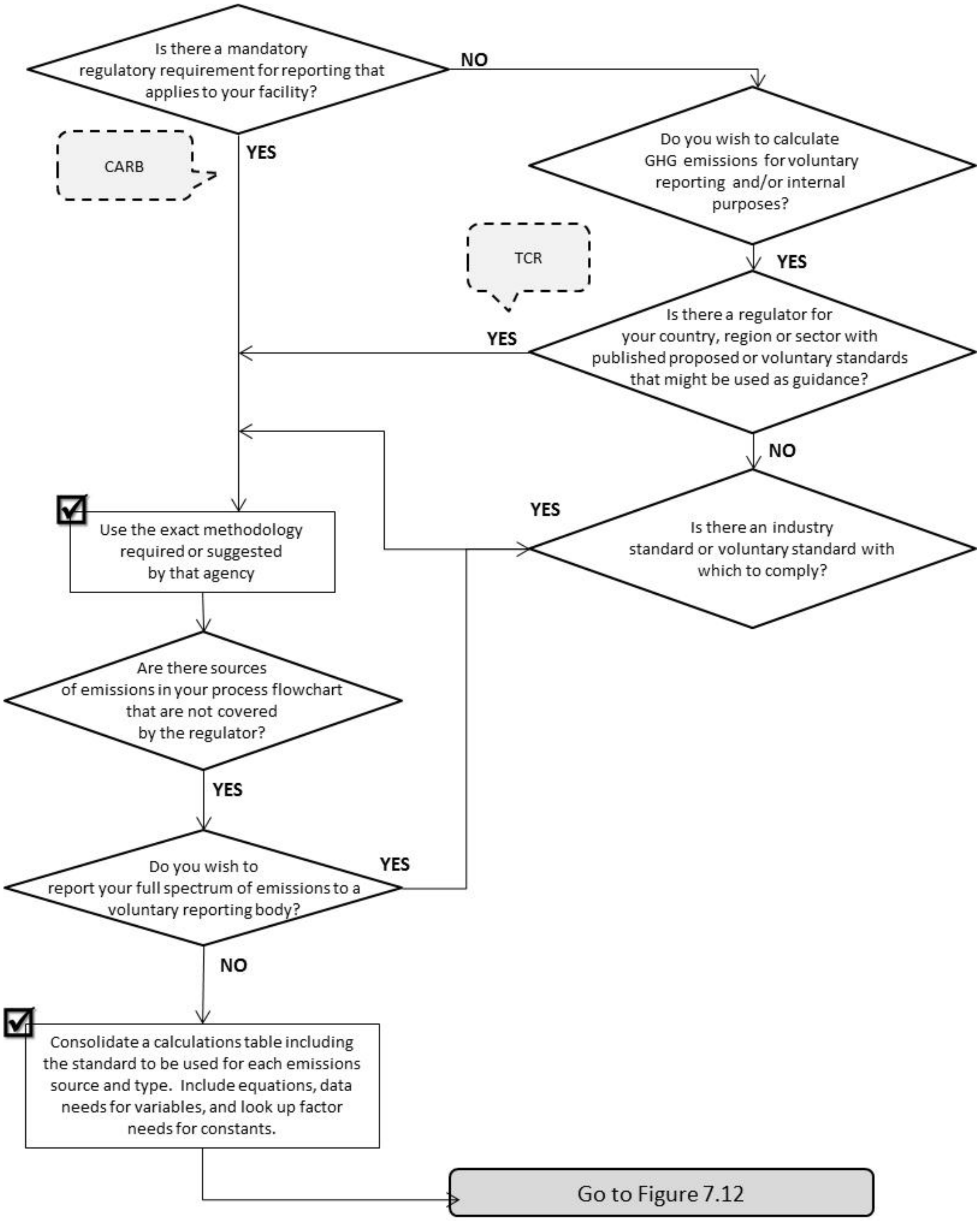


**Figure 7.11 Protocol selection framework validation using water case study**

**Fourth Step: Enter Data and Prepare GHG Report.** The project team compared the framework with the data collection and report preparation procedure utilized by this particular utility. The decision flow paths that were applicable to this utility are shown in Figure 7.12. This comparison illustrates that the framework developed in this study would have been effective in identifying appropriate methodologies. A brief summary of reported GHG emissions is presented below.

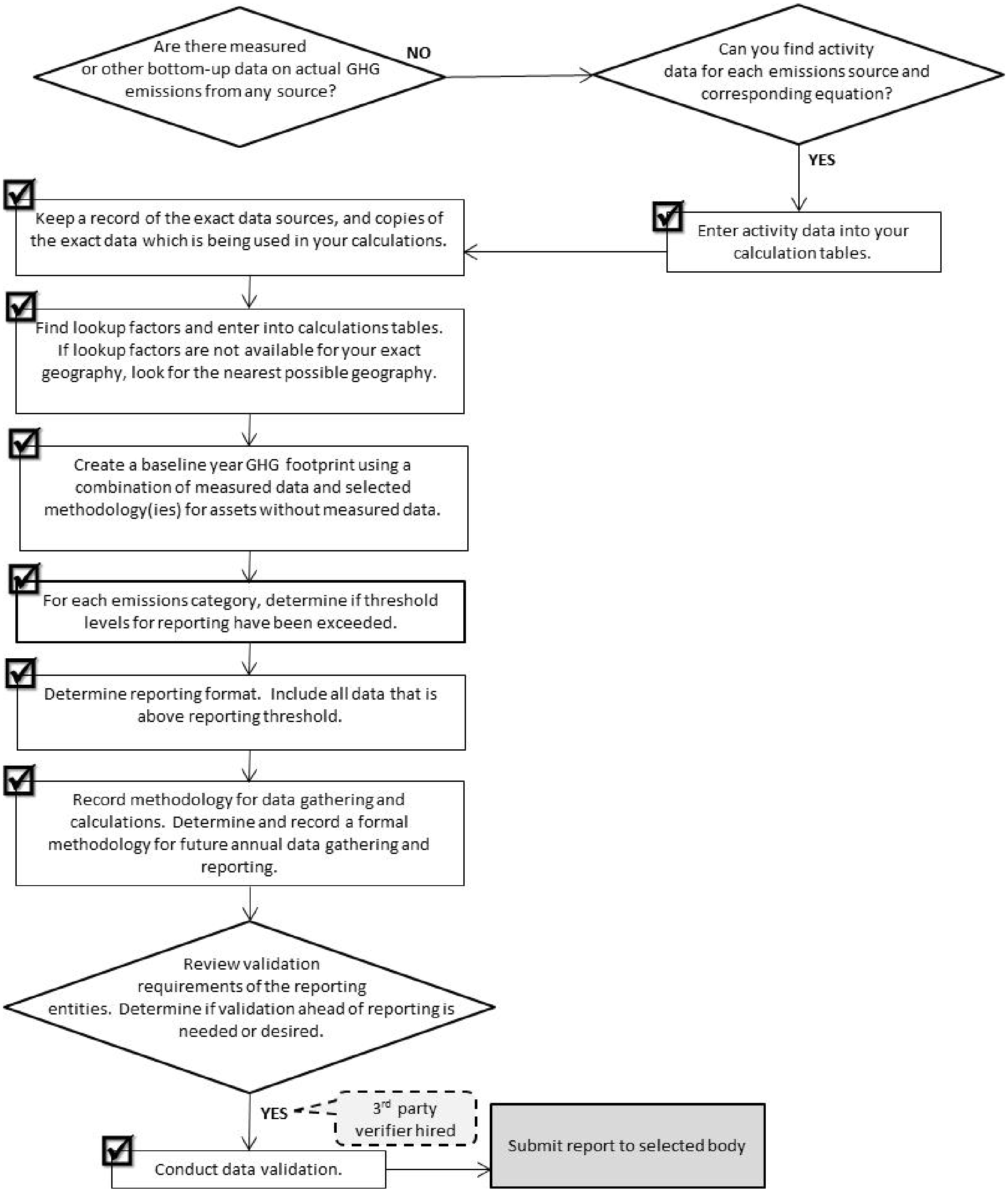


Figure 7.12 Data collection and reporting flowchart utilized by the water case study

Total GHG emissions for this water facility were 617,028 metric tonnes for the reporting year of 2010. Scope 1 and Scope 2 emissions from this facility were 9,046 and 607,983 metric tonnes, respectively. A relative distribution of GHG emissions based on the facility type or major sources is shown in Figure 7.13. This distribution illustrates that in 2010, the majority of the GHG emissions of this facility was due to water pumping.

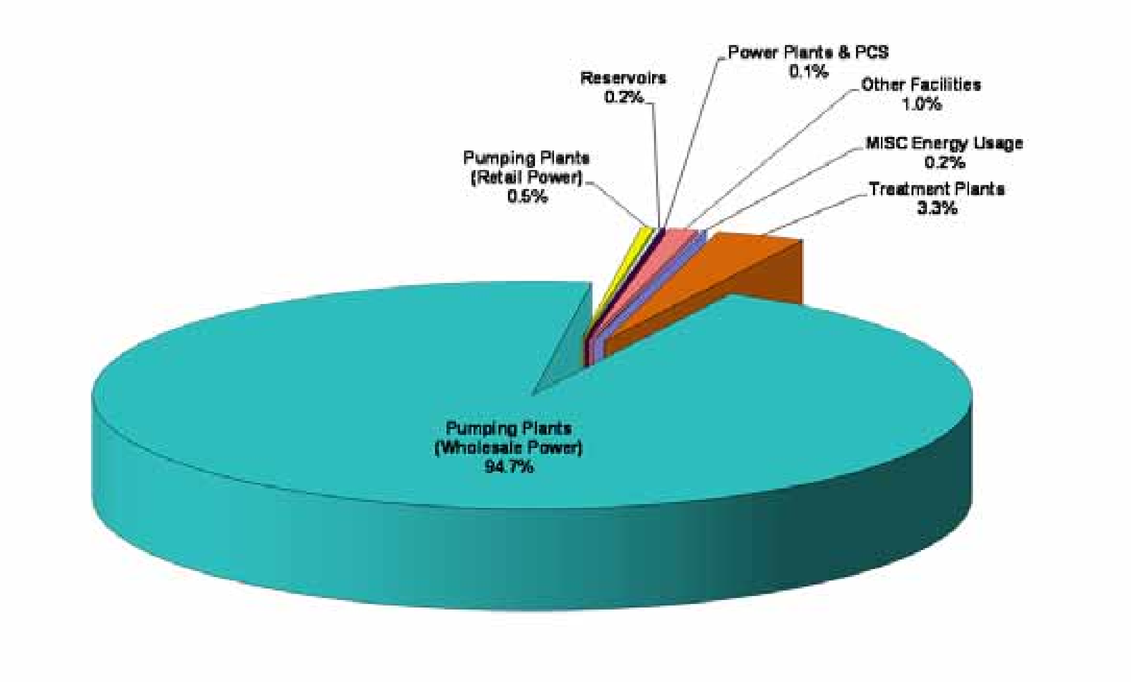


**Figure 7.13 Distribution of GHG emissions from the water utility for calendar year 2010**

The distribution of GHG emissions based on the fossil fuel consumption types, including electricity usage, natural gas consumption, propane consumption, diesel consumption, gasoline consumption, and SF6 and HFCs was also evaluated for the reporting year of 2010 and is shown in Figure 7.14a. The data show that electricity usage contributed ≥ 97% of the total GHG emissions of the facility as Scope 2 emissions. The distribution of electricity usage is shown in Figure 7.14b, indicating that pumping plants operated by wholesale electricity were the major electricity users of the facility. It should be noted that the GHG emissions from the water treatment plants were due to electricity usage alone. Although ozone technology was used in a number of treatment plants, nitrous oxide emissions were not reported because this utility does not generate ozone from liquid oxygen stored on site.

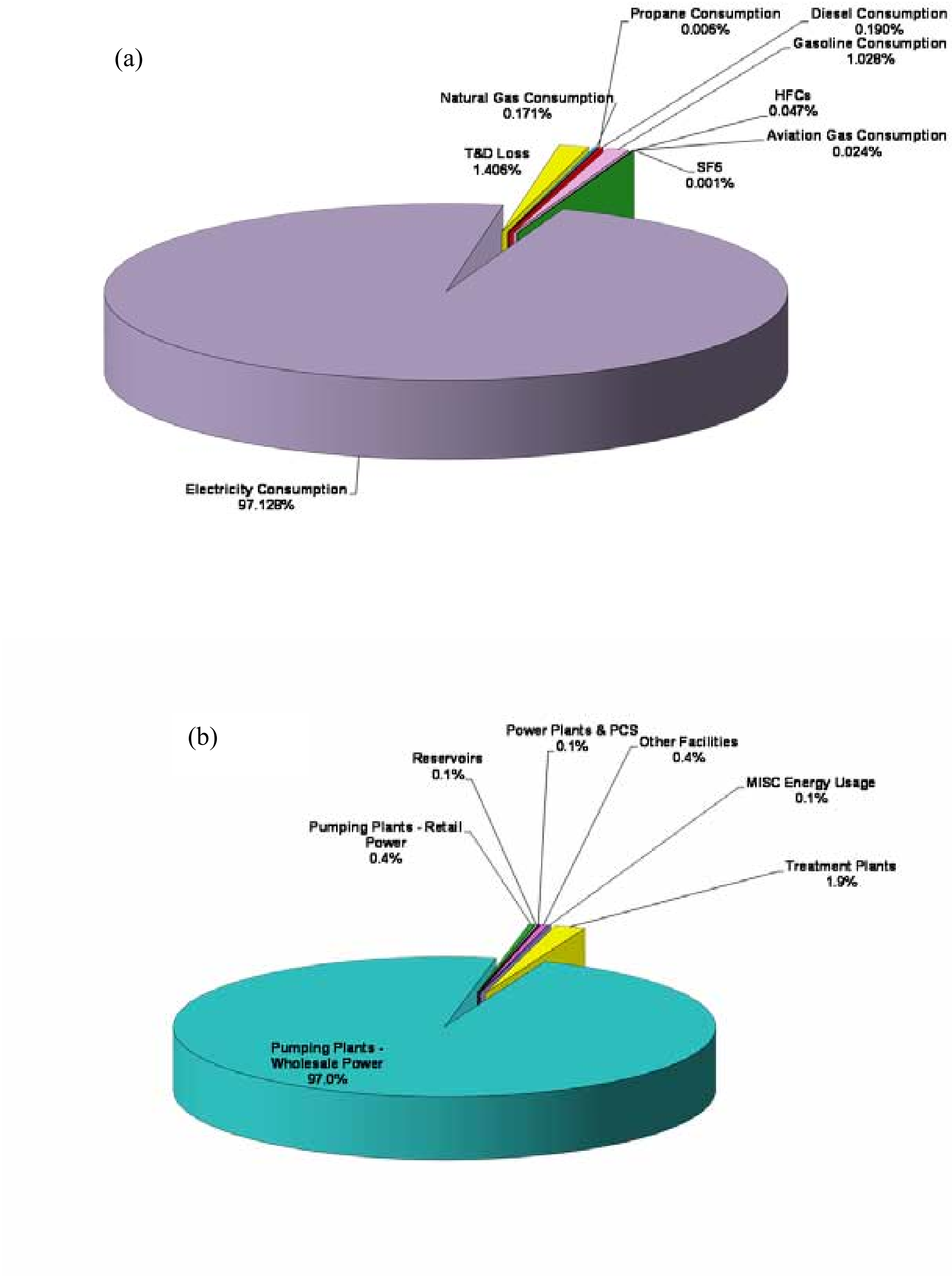


**Figure 7.14 GHG Emissions by sources (a) and electricity usage by the facility (b)**

As shown before, Scope 2 indirect GHG emissions from electricity usage were the primary source for this facility. This water utility utilizes energy from both wholesale and retail energy sources. The wholesale energy sources were used to meet this utility's internal power needs. Power is acquired from Hoover and Parker Power Plants, Southern California Edison, Los Angeles Department of Water and Power (LADWP), and others. One of the important factors impacting GHG emissions accounting accuracy was the selection of appropriate emission factors.

The TCR suggests that the following three classes of utility-developed emission factors can be used to calculate emissions from the use of purchased electricity: (i) electric delivery metrics reported and verified in accordance with the Registry's Electric Power Sector; (ii) emission factors reported and verified in accordance with the California Climate Action Registry's Power Utility Reporting Protocol (PUP), or (iii) emission factors developed by the electricity supplier that are publicly disclosed. In this case study, the emission factors used were those developed by the electricity suppliers that are publicly reported to the TCR. In some cases where these data were not available, the Emissions and Generation Resources Integrated Database (eGRID) was used. It should be noted that the eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States.

A comparison of the emission factors for different power suppliers as calculated by this water utility is shown in Figure 7.15, which clearly indicates that a representative emission factor is an important parameter to be considered for the GHG emissions estimation. It should be noted that according to the eGRID database for the Western Electricity Coordinating Council (WECC California), the emission factor is 0.683, which is higher than the emission factors determined by the electricity supplier that provided the emission data. These comparisons illustrate that in order to get a higher level of accuracy in GHG accounting, a site-specific and representative emission factors needs to be included in the calculations.

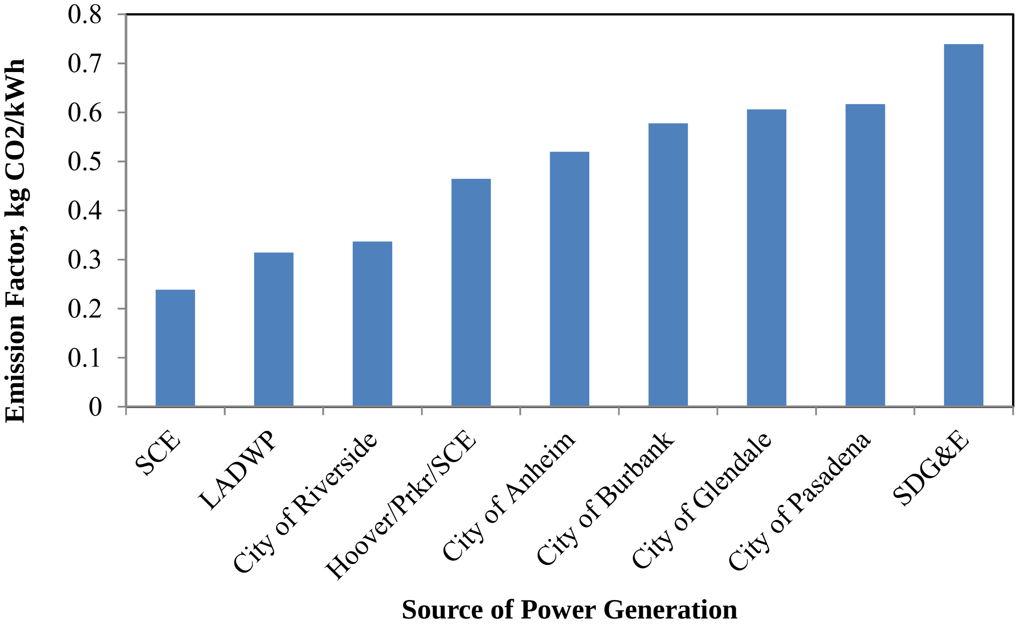


**Figure 7.15 Variation of emission factors depending on the source of power generation**

### *Case Study 3: Reuse Case Study*

This utility encompases a large service area that covers over 15 cities and unincorporated areas and serves a population of about 1 million approximately 196 MGD of imported potable water. It also serves about 28 MGD of recycled water to more than 200 customer sites within the service area for landscape irrigation, industrial applications, and seawater intrusion barrier applications. The proportion of reuse water demand for each application and its quantity in terms of number of customers and volume is shown in Figure 7.16.

This case study is presented within the general framework shown in Figures 7.1 through 7.4 above. It is important to note that these figures represent a framework for GHG accounting in areas of regulatory uncertainty. The below case study does not follow the exact steps outlined in these figures, because it presents the actual work done by a utility in isolation of any single best practice document or work flow guidance. However, the case study does present an example of how the steps outlined in the framework shown in Figures 7.1 to 7.4 can benefit a utility's GHG process.

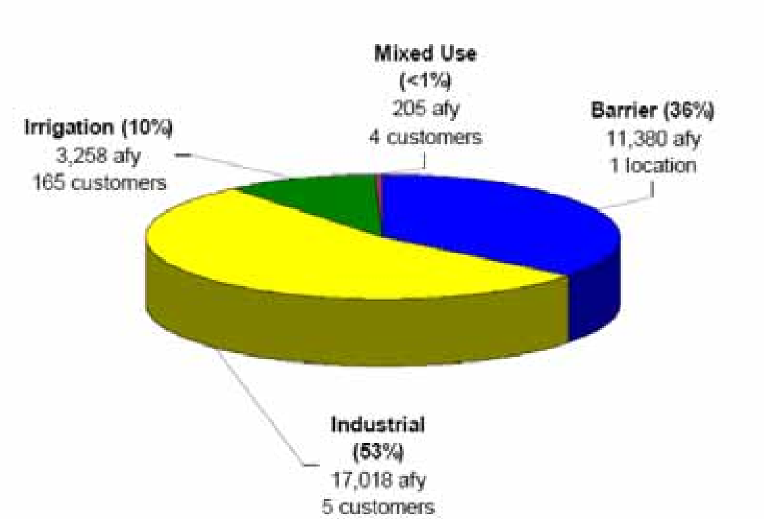


**Figure 7.16 Existing demand by user type**

Five different "designer" reuse waters are created at the different treatment plants, tailored to meet the customer's needs:

- Title 22 Water – Tertiary recycle water for industrial and landscape irrigation
- Barrier Water – Softened Reverse Osmosis [RO] water pretreated by microfiltration (MF) and disinfected through ultraviolet (UV) and advanced oxidation processes (AOP), and stabilized with lime for groundwater recharge.
- Industrial RO – Pure RO water for refinery low-pressure boiler feed.
- Industrial RO Ultra – Ultra-pure RO water for refinery high-pressure boiler feed water.
- Nitrified Water – for refineries.

The source water for all recycled waters is secondary effluent from a local wastewater treatment plant. After arriving from the local wastewater treatment plant, the recycled water is first treated to the requirements of the first four waters listed above at the main facility. Some of the Title 22 (1) water is then sent on to the remaining three treatment plants for tertiary treatment to become Industrial RO (3) and Nitrified Water (5). Since the main facility is the largest and includes treatment processes to produce the first four recycled waters, it is the focus plant of this case study. The overall treatment scheme for the plant is detailed in Figure 7.17.

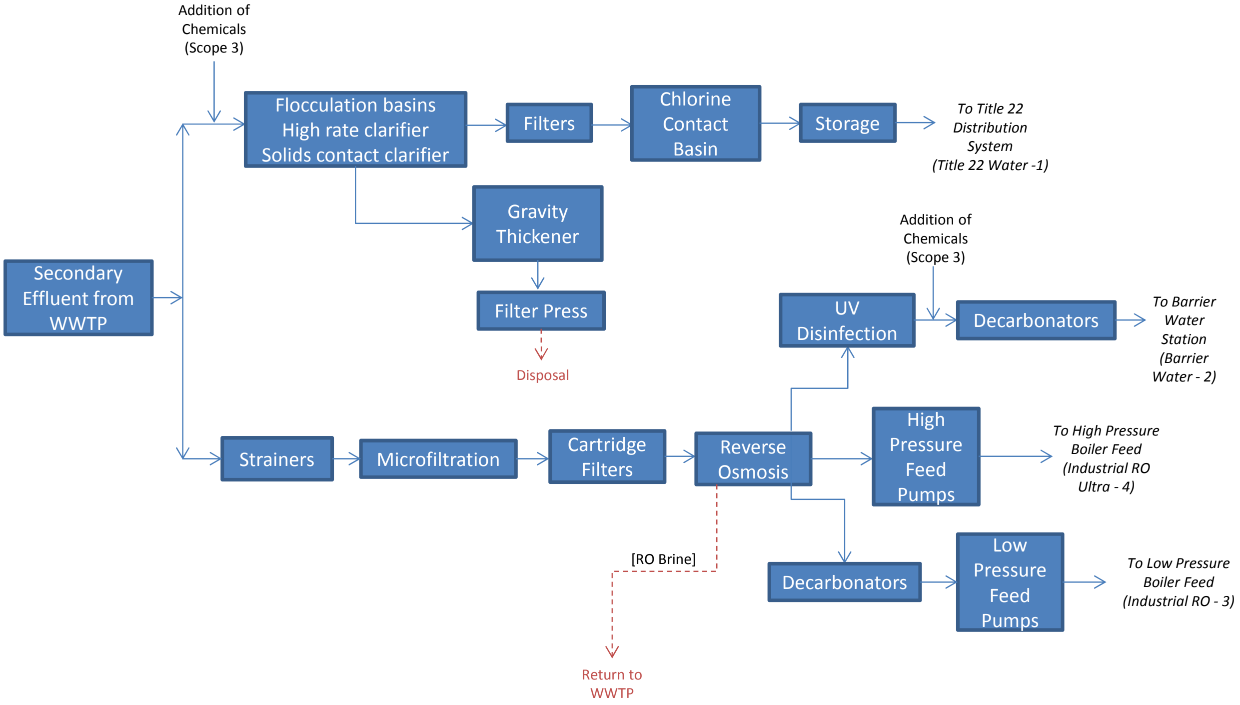


**Figure 7.17 Utility case study treatment scheme flow-chart.**

**First Step: Plan.** This utility was not required to perform GHG emission monitoring or reporting by a national regulatory agency (such as US EPA) since the amount of direct emissions is less than the 25,000 metric ton reporting requirement. The utility's planning for GHG accounting was driven by the following reasons:

- Requirement to comply with California Air Resources Board (CARB)
- Choice to voluntarily report to The Climate Registry (TCR)

**Second Step: Set Boundaries and Flowchart Facilities.** Major GHG emissions sources for this water reuse facility include:

- Stationary combustion ($CO_2$, $CH_4$, $N_2O$)
- Purchased electricity for pump station, reuse facility, and administration buildings ($CO_2$, $CH_4$, $N_2O$)
- Water treatment process ($CO_2$)
- Fugitive sources ($CO_2$)

**Third Step: Select Reporting Protocol.** The project team reviewed the logic utilized by this water reuse utility and compared that with the framework. The protocol selection procedure that was used by this utility was mapped to the conceptual framework shown in Figure 7.3. The comparison suggested that the framework would have been effective in identifying the appropriate protocol and methodologies for this utility.

**Fourth Step: Find and Enter Data and Prepare GHG Report**. The project team compared the data collection and report preparation procedure utilized by this water reuse utility to the decision flow paths shown in Figure 7.4. It should be noted that since the major source of GHG emissions from the reuse utility was purchased electricity (Scope 2), the decision flowchart of this reuse utility was similar to that of the water utility case study presented in the previous section. The comparison illustrated that the framework developed in this study would have been effective in identifying appropriate methodologies.

The overall energy consumption of the main recycling facility was 34,333,445 kWh in 2009. Renewable energy sources of natural gas and solar cells supply about 1% of the total energy demand, with 3.14 GW of solar energy produced. The GHG emission offset by the plant's solar panels was estimated to be 1,173 $CO_2e$ metric tons.

In 2010, the utility reported $CO_2$, $CH_4$, and $N_2O$ emissions using the Climate Registry provided software. The annual GHG emissions as $CO_2$ equivalents for the reuse facility, wastewater treatment pump station, and facility headquarters totaled 13,223 metric tons. As seen in Figure 7.18, the majority of the GHG emissions reported for this district were indirect emissions (Scope 2). Scope 1 and Scope 2 emissions from this district were 785 and 12,114 metric tons, respectively. An additional 323 metric tons were reported for Scope 3 emissions.

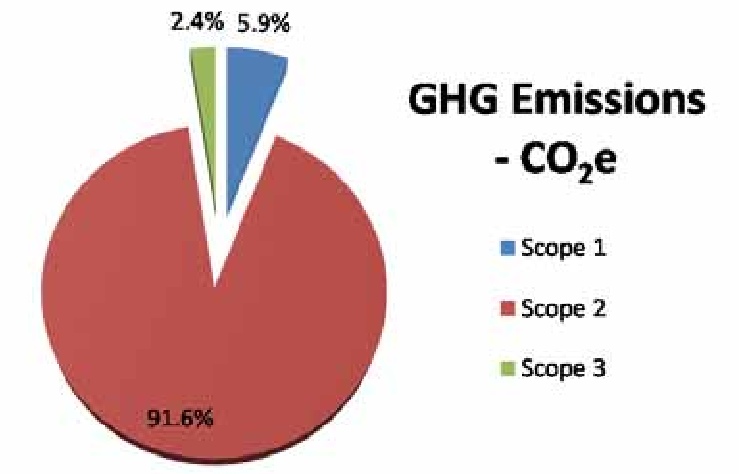


**Figure 7.18 Percentage of GHG emissions (in $CO_2$ equivalents) per each scope**

The primary GHG emissions sources related to the water reuse treatment process are energy use associated with building electricity consumption, pumping of the source water from the wastewater treatment plant and within the treatment process, and stationary combustion. Figure 7.19 presents a percentage of this breakdown in terms of indirect and direct GHG emissions. The data shows that over 91% of the energy usage is from electricity usage. Negligible GHG emissions were from fugitive sources in the water reuse facility.

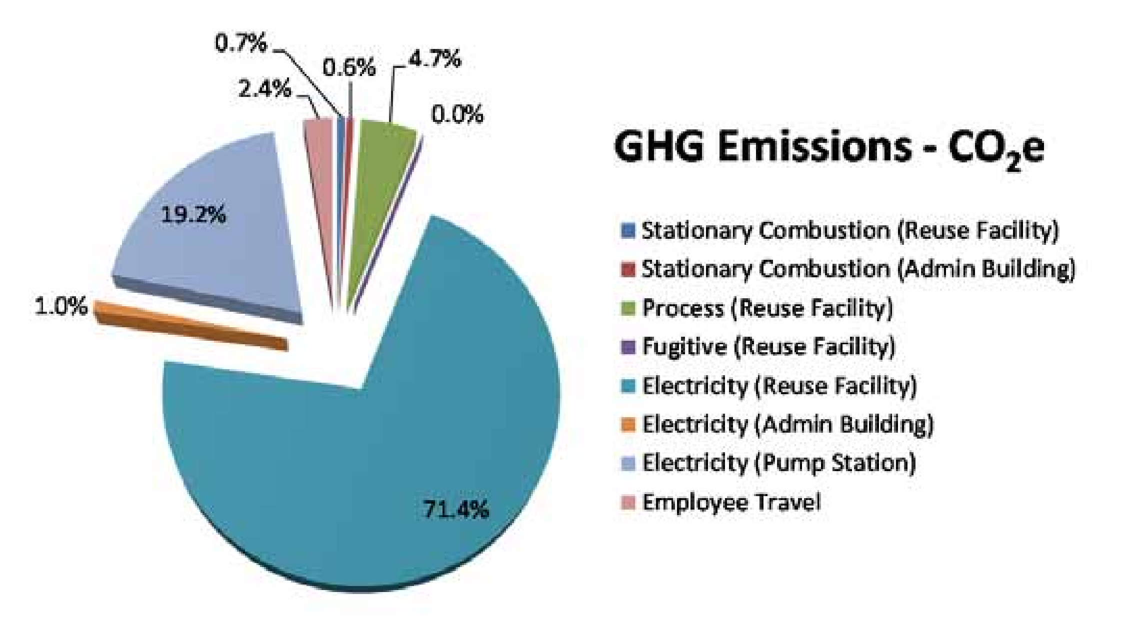


**Figure 7.19 Breakdown of GHG emissions (in $CO_2$ equivalents) for each reported category**

The primary emissions for this facility come from the purchase of electricity. These emissions are estimated based on a summation of the meter readings and energy bills for the calendar year, with emissions factors applied according to The Climate Registry LGOP. Fugitive sources of $CO_2$ were detected from refrigerators and freezers in the water quality laboratory at the water reuse facility, but these emissions are effectively *de minimis*. Stationary combustion sources include an emergency back-up generator that uses natural gas fuel. Carbon and heat content were calculated according to LGOP for $CO_2$, $CH_4$, and $N_2O$ emissions due to fuel consumption. The process emissions are due to $CO_2$ emissions from the decarbonation step.

From the main water recycling plant, the Title 22 water is sent off to the distribution system for delivery to customers, as well as to four other treatment plants for subsequent treatment. These facilities each have a different treatment process that results in different end product water quality and GHG emissions. The comparative evaluation of GHG emissions vary for different quality processes as shown in Figure 7.20.

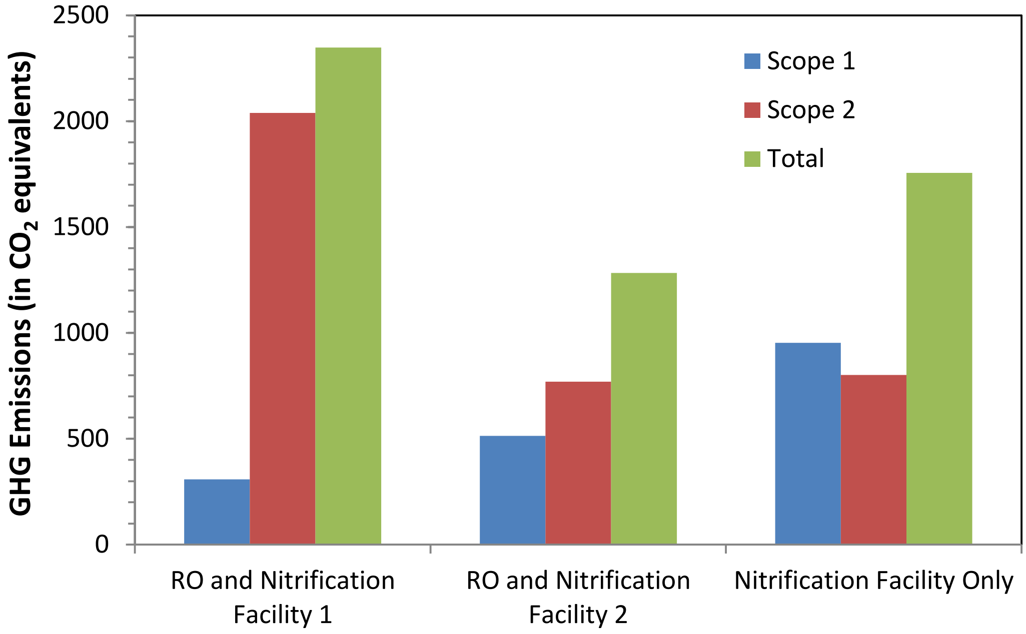


Figure 7.20 GHG emissions for water reuse treatment facilities (in $CO_2$ equivalents)

## Summary of the Framework and Case Studies

The chapter focused on utilities that exist in the most difficult of regulatory circumstances, without clear regulation. This includes either regions of the world that have pending regulations, have regulations which apply to some facilities but not others (typically due to an emissions threshold), have strong pressures for voluntary reporting but many options under which to do so, or have no regulation but where the utility may wish to report anyway. The analysis framework and case studies show a systematic means of working through the challenges of determining which standards and equations should be used for utilities with different asset profiles within the urban water cycle. Each situation is unique, and it is essential for any utility conducting an energy footprint or energy baseline exercise to rigorously research and document all standards and equations used

.

# CHAPTER 8
# SUMMARY AND RECOMMENDATIONS

This chapter summarizes the major findings of the report, and the water and wastewater industry needs regarding energy use and GHG emissions analysis. It also identifies the remaining knowledge gaps and harmonization needs, and recommends a roadmap for moving toward a sector specific protocol for unified reporting. The chapter is divided into two main subsections: a summary of findings, and a series of key recommendations.

## SUMMARY OF FINDINGS

Regulation absolutely drives the nature of the protocols, methodologies and tools in use around the world. The variability in reporting minimizes possibilities for global harmonization. However, a framework for global best practice and good data, as driven by the water sector and specifically for the water sector is still very much needed.

**Key Finding 1: GHG regulation absolutely drives the nature of GHG accounting. There are three basic regulatory states in the world now**:

1. Regulated: Clearly mandated regulation for either/both GHG and energy, such as in the UK
   - Reporting standards are clear and tools are in place to enable this reporting
   - All utilities use these methodologies and tools exclusively
2. Semi-Regulated: Uncertain or complex regulation creates a mixture of standards and reporting requirements, such as in the US
   - Variety of options for protocols, methodologies and available tools
   - Utilities use a mix of standards, research findings, and mostly home-grown tools
3. No Regulation: No regulation, such as South Africa and Singapore.
   - Either use IPCC CDM/JI, a global voluntary protocol, or nothing at all
   - Utilities are either doing nothing, or using UNFCCC/CDM

**Key Finding 2: As a consequence, GHG accounting is very regionally driven.**

- **Research** on emissions factors has been very specific to the operating conditions of a given geography
- **Methodologies** have been tailored to the specific regulatory needs of a country or region
- **Tools** have then been molded around that research, regulation and the specific units of measure (e.g. Metric or Imperial) in use in that area.

**Key Finding 3: There are two fundamentally different ways of calculating GHGs in the water sector**:

- **Top-Down**
  - Most GHG Equations derived from a top-down approach, based on IPCC:

    *Emission Rate (MT) = Emission Factor (MT CO2/MGD) x Activity Data (MGD)*

  - Activity Data is based on site records
  - Emission Factor is usually based on a national average

- **Bottom-Up**
  - The most specific is based on measured data from a facility-level
  - Bottom-Up based averages by process, at least, are more attractive for the W/WW sector than national averages across all process types.

**Key Finding 4: The variability in reporting, summarized in the above points, minimizes possibilities for global harmonization. However, a framework for global best practice and good data - as driven by the water sector and specifically for the water sector - is still very much needed. The following summarizes our key recommendations in this regard:**

- Continue research into biological and chemical process and conveyance related GHGs, both anthropogenic and biogenic.
  - Refine equations to more accurately reflect measured GHG's
- Create a formal water sector best practices guidance for GHG emissions specific to the needs of the water and wastewater industry.
- Periodically update water sector best practices on energy efficiency and management specific to the needs of the water and wastewater industry.
- Advocate best practice – on both the use of appropriate emissions factors & equations based on process research, and practices appropriate for the water sector - to regulators around the world

The following section includes a more in depth concluding discussion of the above findings.

## Urban Water Cycle GHG Emissions and Energy Use

### *Scopes of GHG Emissions*

There are three scopes of GHG emissions, described as follows:

***Scope 1*** includes direct emissions that come from all assets within an organization's operational or legal control. Where reporting of GHGs is required, the inclusion of scope 1 emissions is mandatory, unless those emissions fall below the regulator's reporting threshold or are considered *de minimus*. Scope 1 for the UWC includes GHG emissions from the combustion of fossil fuels for both stationary and mobile sources, anthropogenic emissions from biogenic fuels, all process-related anthropogenic GHG emissions, and any HFCs or PFCs from building HVAC.

***Scope 2*** includes indirect emissions from purchased energy sources. Where reporting of GHGs is required, inclusion of scope 2 emissions is usually not mandatory. For most wastewater utilities and all water utilities, scope 2 emissions will be the largest contributor to the total footprint. The principle sources are the high energy use processes, such as pumping and aeration.

***Scope 3*** includes all indirect emissions from sources that the utility does not own or operate but which are directly impacted by their operations through, for example, procurement, employment, or end of life disposal. Scope 3 is comparable to a life cycle assessment, cradle-to-grave approach to GHG emissions.

### *Energy Use and Tools in the UWC*

Energy use in the water sector has been heavily studied. As a result there are sound methodologies, best practices and tools for measurement, reduction and management of energy at water utilities. The best metric for comparative analysis of energy use is the kWh per volume use (MGD or LPD). This metric is employed by numerous studies and tools to understand how a facility is performing and whether there is potential for improvement. The greatest opportunities for energy use reductions for potable water systems that are not gravity fed are typically in the pumping systems, and for wastewater in the aeration or pumping systems. In all cases, the approach for energy reduction involves: replacement of aging equipment, replacement of inefficient equipment, and better operating or management practices. In addition, demand management and a billing and rate analysis can reduce the cost of energy. The best practices for energy management at water facilities are relatively consistent across geographies; however, the extent to which energy reduction strategies have been put in place varies dramatically. This variance is driven primarily by the following three factors: (1) the cost of energy; where energy costs are high, utilities are most likely to have taken action; (2) the energy intensity of the processes required for treatment; where higher energy requirements are necessary to meet water quality needs, the resultant costs will cause utilities to take action; and finally (3) by any regulatory requirements for energy efficiency, such as those that exist in the UK.

Accurate GHG emission accountancy is dependent upon accurate assessment of the amount of energy used and the corresponding real-time mix of fuels used to produce the energy. Well established tools exist for optimizing both pumping and aeration systems, including Biowin and DOE’s PSAT among others. There are also a number of energy management tools such as Derceto Aquadapt, Innovyze IW Live, and Optima™. Most of these software programs are focused on identifying energy-cost saving strategies, but these strategies are usually derived from analysis of underlying models of energy use assessment.

## GHG Estimation Protocols and Associated Tools

Our research has shown that there are three distinct levels of GHG accounting, as well as three distinct stages of modeling within the UWC. These are discussed as follows.

### *Levels of GHG Accounting*

- **Level 1:** This level represents the highest, most general level of reporting. The methodologies that are used are typically designed for top-down estimating calculations for specific sectors, or are broad guidance frameworks. There are three sub-levels of reporting in Level 1:
    A. Global Accounting Standards include WRI, ISO and ANSI, which provide a best practice framework for conducting GHG accounting.
    B. Global Voluntary Standards, such as the Carbon Disclosure Project (CDP) and the Global Reporting Initiative (GRI) exist to provide a transparent and publicly accepted international forum for the reporting of GHG emissions by a variety of entities.
    C. IPCC/UNFCC is applicable to all countries that are signatories. Methodologies for GHG accounting exist at two levels: (1) a strict top-down approach for country level reporting by the IPCC, and (2) a strictly projectized bottom-up approach to enable

controlled trading of carbon credits.

- **Level 2**: Within this level of standards particular efforts have been made to customize the reporting methodologies to a specific country and sectors within that country. There are three sub-levels:
  - A. National Governmental Regulatory Agencies collect bottom-up data of direct emissions from the most polluting segments of the economy.
  - B. Regional Voluntary Registries such as The Climate Registry and ICLEI/LGOP exist for those sectors of the economy that are not required to report to a national regulator, but wish to provide a transparent and full organizational GHG accounting.
  - C. Region- or Sector-Specific Government Regulatory Agency such as Defra are tailored to the reporting requirements of a specific segment of the economy.
- **Level 3:** At this level, research is being conducted and data collected around the specific variability of GHG emissions due to different technologies, processes, or regional use patterns. The main body of work lies within industry association standards and research papers, such as ICLEI/LGOP, WERF, WEF, WaterRF, GWRC and others.

### *Stages of GHG Modeling for W/WWTPs*

Modeling for wastewater is currently occurring at three distinct stages:

- **Stage 1** - Empirical modeling: suitable for IPCC, LGOP, NGER. In other words, this stage of modeling is suitable for Level 1 accouting.
- **Stage 2** - Comprehensive steady-state process models for wastewater and biosolids treatment. These include for example CHEApet for wastewater treatment, and BEAM for biosolids processing. This stage of modeling is appropriate for Level 2 accounting.
- **Stage 3** - Mechanistic process models: including IWA ASM models with $CO_2$, $N_2O$, and $CH_4$ mass balance equations within a dynamic simulator, and facility specific methodologies. This stage of modeling is appropriate for Level 3 accounting.

## RECOMMENDATIONS

### Knowledge Gaps

There are three types of knowledge and tool gaps that currently exist:

1. **Accuracy of GHG Equations for the Full UWC.** Several sources of GHG emissions in the UWC have insufficient empirical data and certitude about both the actual emission ranges as well as the manner in which operational parameters impact those emission values. The result is that the current set of equations in use are considered to be not fully representative of the actual process. In such areas, additional research is adding knowledge to the initial study efforts and has begun to elucidate emission ranges. However, this work has not completed measurements of the full range of design and operational variables or fully modeled their impact on emission outputs. Examples of this type of knowledge gap include: (1) $N_2O$ emissions from nitrification/denitrification process; (2) $CH_4$ emissions from gravity sewers and force mains; and (3) emissions from certain aspects of biosolids

processing, handling, and disposal. The reality is that this research is significantly complicated by:

  - the input wastewater characteristics tend to vary dramatically over time and by location,
  - the processes used for cleaning the wastewater are dynamic in response to this input variability,
  - thus the resultant emissions are highly variable,
  - and in addition there is often not a single point source for output GHG emissions measurement, making the collection of this data challenging.

2. **Methodologies and Tools Which Represent the Full Range of UWC GHG Emissions.** The second type of knowledge gap exists in whole systems level analysis of emissions. Many water/wastewater industry methodologies and tools do not address the full set of UWC assets that any given W/WW utility may own. In addition, the tools may not address all three scopes of emissions, regardless of UWC asset type. It is most typical that the methodologies and tools in existence address those parts of the UWC which (a) the regulator required reported, (b) are the greatest sources of GHG emissions, and (c) the equations for estimation or modeling are generally accepted. The most common omissions are the front and back end of the UWC asset classes: conveyance and disposal of biosolids. Scope 3 is the most common type of emissions inadequately addressed. The result is that utilities may have to find and use additional tools or methodologies in order to represent the entire facility's assets and scopes of emission. Much of this work has been developed internally to utilities and does not result in sector-specific tools. In part this is driven by the fact that W/WW utilities around the world own different mixes of UWC assets, and are driven by diverse regulatory reporting requirements.
3. **Integrated Energy and GHG Management Tools.** There are no tools that fully integrate GHG accounting and energy management. Where tools adequately address energy tracking, use and management, they will typically model only scope 2 emissions. This is because the scope 2 emissions from energy use are a relatively straightforward set of calculations based on energy use data. However, tools which do both, comprehensively, do not exist. This is primarily driven by the fact that energy management tools incorporate a continuous systems approach that balances cost and quality; while GHG management – though in part driven by reduction goals – is largely a static quantitative analysis exercise. It is also worth noting that energy benchmarking tools typically include a scope 2 GHG benchmark, but do not include a full GHG benchmarking capability. This latter capability would be an important addition to the field of knowledge, as it would enable facilities to understand how they compare on a holistic basis.

## Harmonization Needs

### *For GHG Quantification in the UWC*

As noted above, a GHG emissions inventory methodology covering all aspects of the engineered urban water cycle (UWC) does not presently exist. An integrated methodology would ideally provide equations for estimating GHG emissions from each UWC asset source and for each scope of emissions. The user would, theoretically, be able to select among the methodologies most appropriate to their region and for their portion of the urban water cycle.

Harmonization with respect to emissions estimation from stationary and mobile fossil fuel combustion sources has already occurred. This has primarily been driven by: the input fuels used around the world can be classified into sub-categories with relatively constant chemical compositions; the energy conversion processes are stable and can be classified into sub-sets of technologies that are common around the world; and the resulting GHG emissions are relatively constant and comparatively easy to measure at the smokestack or select tailpipes. However, as noted in the knowledge gaps section above, this is simply not the case for the UWC, particularly where wastewater is concerned. Thus the harmonization toward a single set of activity based equations with look-up factors for process and fugitive GHG emissions has been challenging. This area of research will involve considerable additional work and may ultimately lead to findings that activity based equations are not a feasible means of modeling several sources of UWC emissions.

A harmonized tool for GHG emissions quantification is feasible and would be of great use to water utilities. The GHG accounting levels and UWC modeling stages presented in this work set an important framework for this harmonization. At present, however, the unknowns and the above mentioned knowledge gaps could make the practicalities of the maintenance of a harmonized tool quite challenging. This is because the remaining areas of uncertainty in GHGs for the UWC, and future improvements to reduce those uncertainties, might require multiple iterations of a harmonized tool in the coming years. The three principle areas of uncertainty that currently present the greatest harmonization challenge includes:

1. Incomplete and not wholly accurate GHG emissions estimation equations for the UWC
2. Lack of a whole systems methodology to estimate all emissions from the UWC
3. Unkowns in future regulatory shifts. This third area is important because, as shown in Chapter 2 of this report, all countries discussed have gone through a significant evolution of their regulation in the past several years, and changes will continue to occur. (Note that this issue was not discussed in the knowledge gaps section because this is not an area where more research would necessarily lead to greater regulatory certainty.)

### *For Energy and GHG Harmonization*

As mentioned in the knowledge gaps section, there is not currently a tool that integrates both energy and GHG management and accounting, nor is there a tool that integrates energy and full GHG benchmarking. A tool that integrates both energy and GHG benchmarking could be of great use for utilities wishing to understand what their peer's performance is, and thus what reasonable targets might be for themselves.

## Strategic Roadmap for Sector Specific Reporting

The specific areas of activity to address the remaining uncertainty and harmonization needs in GHG accounting and energy use should include the following:

- Address the remaining uncertainties in GHG estimation equations and modeling for the UWC. Since there are several working groups in the broader water and wastewater research communities addressing these issues, a specific activity of additional use to the community might be to assess and create a compendium of those research efforts. A rating system could be established to designate the level of completeness and accuracy of selected research and methodological approaches.

- Create a technical compendium of GHG emission methodologies that also provides guidance on the handling of calculation methodologies in remaining areas of uncertainty.
- Consolidate a methodology that covers GHG emissions for the full UWC system and all three scopes of emissions. This is closely related to the above item and should occur in sequence.
- Create a combined energy and GHG benchmarking tool. The first priority would be to establish scope 1 GHG benchmarks to potentially add to an existing benchmarking tool that includes energy and scope 2 GHGs. A later priority would be to add scope 3 emissions benchmarks, perhaps with an initial specific regional focus on areas of the world that either require this or tend to report it voluntarily, such as the UK and Australia.

# APPENDIX A
# LEVEL OF GHG EMISSIONS REPORTING

**Level 1:** This represents the highest, most general level of reporting. The protocols in the three sub-levels shown below are designed to be globally applicable to any type of reporting entity. The methodologies required are also at the highest level, and are in many cases designed for top-down estimating calculations for specific sectors. The applicability of each sub-level to the water sector is described below.

A. **Global Accounting Standards include WRI, ISO and ANSI**. These bodies have each provided a protocol, or best practice, for conducting GHG accounting. The protocols are generally flexible enough to be applied and used by any type of entity, from any sector of the economy, anywhere in the world. The standards are at the organizational level, and can also be applied at a facility or project level. Methodology validation is required for ISO and ANSI. Aspects of the WRI protocol are discussed in greater detail later in this chapter under the sub-heading of scopes. *Applicability to the Water Sector:* These standards, particularly the WRI standard, are used as the overarching protocol that defines the GHG accounting done by a water treatment facility or by the broader utility or agency. The WRI standard, for example, lays out the basic scopes for reporting GHGs.

B. **Global Voluntary Standards, such as the Carbon Disclosure Project (CDP) and the Global Reporting Initiative (GRI)**. These organizations exist to provide a transparent and publicly accepted forum for the reporting of GHG emissions by a variety of entities. They are used be organizations which may not have a single regulatory entity to whom they report their full range of GHG emissions. Examples of such organizations would be utilities in an unregulated environment, corporations which span multiple regulatory zones, or utilities or companies for whom the regulator only requires reporting of one of many sources of GHGs. In other words, organizations which use these reporting bodies are seeking a place to comprehensively and transparently report their full range of GHG emissions. Specific protocols and methodologies, including equations and look-up factors, are provided in the guidance documentation for each reporting entity. Unlike level A, the methodologies do tend to only cover specific sectors of the economy, though they may be applicable to organizations which span multiple countries. The standards are at the organizational level, and can also be applied at a facility or project level. Methodology validation and data verification is required, though for GRI it is a self-audit process rather than by the reporting body or a third party. *Applicability to the Water Sector:* Water utilities in regions of the world that do not dictate a national or regional standard for GHG reporting within their sector may choose to use these reporting bodies' protocols and methodologies. Water utilities also report to the GRI, which itself recommends use of the LGOP standards.

C. **IPCC/UNFCCC**, is applicable to all countries which are signatories. Methodologies for GHG accounting exist at two levels: (1) a strict top-down approach for country level reporting by the IPCC, and (2) a strictly projectized bottom-up approach to enable controlled trading of carbon credits. There are no standards for general organizational or facility level reporting. For the projects which result in traded carbon the methodology must be validated prior to project approval, and the application of the methodology and data must be validated prior to commencement. Both efforts are conducted by an approved, independent third-party. *Applicability to the Water Sector:* From the bottom-up level only a few projects specific to the urban water cycle have been approved, and these are listed in the references section. From a top-down level, there IPCC provides a specific methodology and equations for calculating emissions for wastewater treatment processes. These equations represent the equivalent of a global normalization of collected data, and should be treated as such. None-the-less, these equations for wastewater calculations have become the foundation for many of the level D-F methodologies.

**Level 2**: Within this level of standards particular efforts have been made to customize the reporting methodologies to a specific country and sectors within that country. This tailoring of the methodologies with countries that have done the least work on specificity generally borrows heavily from the IPCC, and drill down the equations to be specific to the country in question. In countries which have done the most work, the methodologies have been tailored based on extensive research and modeling within the country in question.

A. **National Governmental Regulatory Agency**. Many countries have their own regulatory reporting requirements for GHGs. The requirement represents an effort by the government to collect bottom-up data of direct emissions from the most polluting segments of the economy. In some cases, such as the US EPA, the equations included in their guidance derive from the IPCC. For reporting purposes facility-specific data is required, and a monitoring protocol is necessary. An audit or verification of the methodology, data and monitoring reports is required; however it varies how this is conducted. *Applicability to the Water Sector:* For most countries the water sector is not included in this reporting level. The UK has this level of reporting for their water utilities, and countries in the EU are at different stages of the development of this level of reporting for their water utilities.

B. **Regional Voluntary Registries such as The Climate Registry and ICLEI/LGOP** exist for those sectors of the economy which are not required to report to a national regulator, or for organizations which do report to the regulator but wish to release a transparent and full organizational GHG accounting. The protocols are typically those of the WRI, and the methodologies may be limited to the highest emitting segments of the economy. But reporting is conducted at an organizational level, rather than facility or project specific. Verification is generally required by an approved third-party entity. *Applicability to the Water Sector:* The ICLEI/LGOP has gone to particular lengths to develop a methodology for GHG reporting in the wastewater sector. This level of reporting is primarily used by water utilities in US. This has been driven in part by the fact that some utilities, particularly those in California, have been certain that they will be required to report their GHG emissions, but that requirement has been several years in development. A second driver has been for water utilities in communities with a strong environmental stakeholder group who wish to see action taken toward a more sustainable utility.

C. **Region- or Sector-Specific Government Regulatory Agency such as UKWIR**, are tailored to the reporting requirements of a specific segment of the economy. As such both the protocol and the methodologies are very specific to that sector. It is at this level that equation appear which may not rely on the IPCC equations as the foundation methodology. *Applicability to the Water Sector:* The UK is the only country that has developed standards for the water sector at this level.

**Level 3:** At this level research is being conducted and data collected around the specific variability of GHG emissions due to different technologies, processes, or regional use patterns. This is an emerging area of work that should ultimately lead to more accurate methodologies that represent the actual emissions coming from specific plants around the world. This work is primarily in the area of biological and chemical treatment that, unlike GHG emissions from electricity production, is highly variable due to the changing nature of the input raw material and the resulting differences in the treatment processes.

A. **Industry Association Standards and Research Papers, such as ICLEI/LGOP, WERF, WEF, WRF, GWC and others**. Despite the sheer number of standards available for GHG accounting, the reality is that there are a number of technologies for which specific GHG standards do not exist. This is particularly true for the water sector, where the fact that the biological and chemical treatment of water and wastewater involves many possible technologies and applications. As such there is a significant amount of research being done on the actual emissions being released from different types of processes under varying conditions. This research will prove to be critical in understanding how actual emissions from any given process under any given condition will vary from the globally normalized equations provided by the IPCC. *Applicability to the Water Sector:* WERF,WEF, WRF, GWC and other organizations have and are currently funding specific research efforts, which are discussed later in this report. Also at this level several universities and research institutes are funding work to study and model actual GHG emissions at the plant and process level. The results of this work are highly varied and the amount of data is rapidly increasing; this work is discussed in Chapter 5.

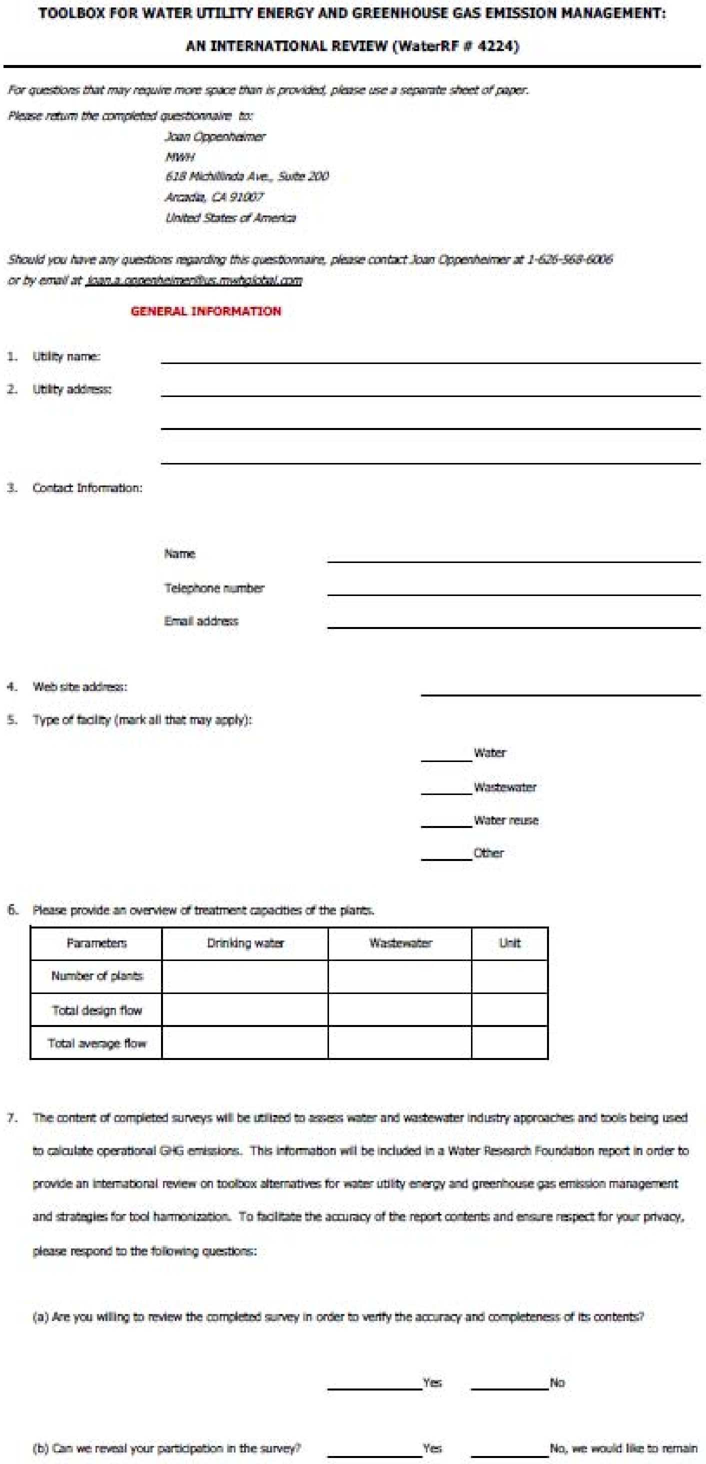
### Application of the Levels in Different Countries

Table A.1 shows how these different levels apply to the countries highlighted in this study.

# Table A.1
# Levels of Reporting and Standard within a Representative set of Countries

| | | US | NL | UK | Aus | South Africa |
|---|---|---|---|---|---|---|
| **Level 1** | Global Accounting Standard | Standards such as the WRI/WBCSD, ISO and ANSI can be used by water utilties, but are not specific to the water treatment cycle or national use patterns. | | | | |
| | Global Voluntary Registrations | Includes protocols and may guide the user to a specific methodology for the water treatment cycle (such as LGOP). | | | | |
| | United Nations | Signatory. USEPA provides an annual national emissions report to the IPCC which includes wastewater. | Signatory. National reports provided annually to the IPCC inclusive of wastewater. | Signatory. National reports provided annually to the IPCC inclusive of wastewater. | Signatory. National reports provided annually to the IPCC inclusive of wastewater. | Signatory. Sells carbon credtis to Annex 1 countries. |
| **Level 2** | National Governmental Regulatory Agency | The Environmental Protection Agency's Mandatory Greenhouse Gas Reporting Rule includes methodology for wastewater treatment but does not require reporting. | Emissions caused by waste water utilities are collected on a national level by Statistics Netherlands. Methodology consists of national monitoring protocol. The taskforce MEWAT is responsible for the collected data and reports it in the national emission registry database. | | No EPA juristiction. Dept of Climate Change & Energy Efficiency, NGERS (National GHG Emissions Reporting Service) with independent audit. Facilities with >25kTon/yr threshold; Corp wi > 50 kTon/yr. Reporters will have to pay per ton for 1st year, escalating each year to 2015, then open trading after 2015. | The Department of Environmental Affairs may require reporting by significant emitters by 2013. |
| | Regional Voluntary Registries or Standards | The Climate Registry includes most US states and uses the LGOP protocol and methodology which includes wastewater. A few US wastewater utilities participate. | None | | None | None |
| | Region- or Sector-Specific Government Agency | No Industry Standard, but numerous papers on emissions measurements and equations as per references in this paper. | The Union of waste water utilities (UvW) signed on behalf of the waste water utilities an agreement on climate goals with the Dutch government. | UKWIR | Australian Water Association has provided some guidance through their Water Sector Sustainability Framework, business cases and informational toolkits. | None |
| **Level 3** | Industry Association Standards and Research Papers | - The California Air Resources Board (CARB) has several guidance documents related to water, but none are yet mandatory.<br>- The Regional Greenhouse Gas Initiative (RGGI) covers northeastern states and includes major sources of emissions but not The water treatment cycle. | UvW | OFWAT | All reporting is done at a Federal level | None |
| | Facility-Specific | This is the preferred method since many US Utilities have mixed assets some of which are known GHG emitters but for which there is not a set protocol on a mandatory or voluntary basis. Thus a mixed, 'home grown' approach has been adopted. | Accounting is in line with sector agreements. | OFWAT has created a standard spreadsheet tool for water utilities to use. This is tailored to specific utility's configurations | Many water Authorities are developing their own spreadsheet-based approaches tailored to the specific assets and ownership structures of each | No accounting or reporting is known to be done by agencies on a regulatory or voluntary basis at present. |

# APPENDIX B
# QUESTIONNAIRE SURVEY



**TOOLBOX FOR WATER UTILITY ENERGY AND GREENHOUSE GAS EMISSION MANAGEMENT:**

**AN INTERNATIONAL REVIEW (WaterRF # 4224)**

*For questions that may require more space than is provided, please use a separate sheet of paper.*

*Please return the completed questionnaire to:*

*Joan Oppenheimer*
*MWH*
*618 Michillinda Ave., Suite 200*
*Arcadia, CA 91007*
*United States of America*

*Should you have any questions regarding this questionnaire, please contact Joan Oppenheimer at 1-626-568-6006*
*or by email at joan.a.oppenheimer@us.mwhglobal.com*

**GENERAL INFORMATION**

1. Utility name: ____________________

2. Utility address: ____________________

3. Contact Information:

Name ____________________
Telephone number ____________________
Email address ____________________

4. Web site address: ____________________

5. Type of facility (mark all that may apply):

______Water
______Wastewater
______Water reuse
______Other

6. Please provide an overview of treatment capacities of the plants.

| Parameters | Drinking water | Wastewater | Unit |
|---|---|---|---|
| Number of plants | | | |
| Total design flow | | | |
| Total average flow | | | |

7. The content of completed surveys will be utilized to assess water and wastewater industry approaches and tools being used to calculate operational GHG emissions. This information will be included in a Water Research Foundation report in order to provide an international review on toolbox alternatives for water utility energy and greenhouse gas emission management and strategies for tool harmonization. To facilitate the accuracy of the report contents and ensure respect for your privacy, please respond to the following questions:

(a) Are you willing to review the completed survey in order to verify the accuracy and completeness of its contents?

__________Yes __________No

(b) Can we reveal your participation in the survey? __________Yes __________No, we would like to remain

**TOOLBOX FOR WATER UTILITY ENERGY AND GREENHOUSE GAS EMISSION MANAGEMENT:**

**AN INTERNATIONAL REVIEW (WaterRF #4224)**

Utility Name: ______________________________

## TOOL SURVEY

1. What type of tool was used to estimating GHG emission from your facility(ies)?

   ____________ Developed internally by your utility
   ____________ Provided by regulatory agency
   ____________ Commercial software
   ____________ Others (please specify)

2. Did you use more than one tool to estimate carbon inventory or footprint of your facility (ies)?

   ____________ Yes
   ____________ No

   Please provide the number of tools used ____________

3. Name of tool(s) ______________________________________________
   ______________________________________________

*For purchased tools, please provide the following information:*

4. What software platform is used in the tool you used? ______________________________
5. Who is the vendor of the commercial tool used? ______________________________
6. Did you find your tool specific to the water/wastewater industry? ____________ Yes ____________ No
7. Did you have to customize input or calculation formulas of the tool for your use? ____________ Yes ____________ No
8. Is the tool in active use by other entities of which you are aware? ____________ Yes ____________ No

*Please provide the following information for all tools*

9. Does the tool cover energy estimation? ____________ Yes ____________ No
10. Does the tool adhere to a particular standard (e.g. GHG protocol)? Please state ______________________
    ______________________

11. What are the categories of data entered e.g. fuel use, electricity use and chemicals use (Please send a list of input parameters)?

12. How is data entered? ______ manually

______ automated

______ both

How often is data entered? ______ annually ______ monthly

______ weekly ______ daily/continuously

13. If data is automatically entered into the tool, what kind of data and through what system (e.g. SCADA)?

14. If some of the data (but not all) is entered manually, which is done manually and why?

15. What are the outputs of the tool (please provide a list of output parameters)?

16. Why did you decide to buy/use this tool? Please describe.

17. Did you do any comparative study of the different tools available? ______ Yes ______ No

If yes, please describe below:

18. Has the tool met your needs? ____________ Yes ____________ No

If not, what are the remaining shortfalls?

________________________________________

________________________________________

________________________________________

19. Does this tool take inputs on Scope 1* and Scope 2* emissions only? ____________ Yes ____________ No

What other (Scope 3*) emissions can be input? ________________________

** Scope 1 emissions are those from direct combustion & process emissions; Scope 2 include emissions from purchased energy (e.g. electricity); Scope 3 emissions are everything else*

________________________

________________________

20. Does this tool accompany any guidance manual to define boundaries for different emission scopes?

____________ Yes ____________ No

If yes, please provide reference for these guidelines ________________________

________________________

21. Were you able to see the assumptions and formula used in the tool? ____________ Yes ____________ No

22. Do you have any management program to check the data and reporting accuracy of the carbon inventory?

____________ Yes ____________ No

23. Does this tool provide any guidance on checking the data and report accuracy? ____________ Yes ____________ No

24. Did you experience any double counting problem using this tool? ____________ Yes ____________ No

25. Did you discuss with the tool developer about the uncertainties or margin of error? ____________ Yes ____________ No

26. Do you have alternative energy sources (renewable) in your utility? ____________ Yes ____________ No

27. Does your tool calculate GHG offsets from using these alternative energy sources? ____________ Yes ____________ No

28. How are you using the tool to aid in non-regulatory decision making at your utility? Please describe.

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

## TOOLBOX FOR WATER UTILITY ENERGY AND GREENHOUSE GAS EMISSION MANAGEMENT:

## AN INTERNATIONAL REVIEW (WaterRF#4224)

---

**Utility Name:** ________________________________________

### ENERGY ESTIMATION/GHG EMISSIONS SURVEY

1. What are primary objectives of GHG emissions accounting for your utility(ies)? (Please mark all that apply)

____________ Environmental Leadership
____________ Cost control
____________ Internal Purpose/Goal
____________ Regulatory
____________ Other

2. Have you established a "base year" carbon emissions inventory against which subsequent annual emissions are compared?

____________ Yes ____________ No

If yes, what was the base year? ____________

3. Do you have a "base year" recalculation policy?

____________ Yes ____________ No

If so, how often will these emission numbers be updated? ____________ (annually, every 5 years, quarterly, etc)

4. Have you established "baseline" carbon emissions for different treatment processes? ____________Yes ____________No

( *"baseline" means a scenario for which GHG emissions would have been in the absence of any GHG reduction projects or activities*)

Year Established: ____________(yyyy)

If yes, for which treatment processes have you established baseline carbon emissions?

________________________________________________________________________

________________________________________________________________________

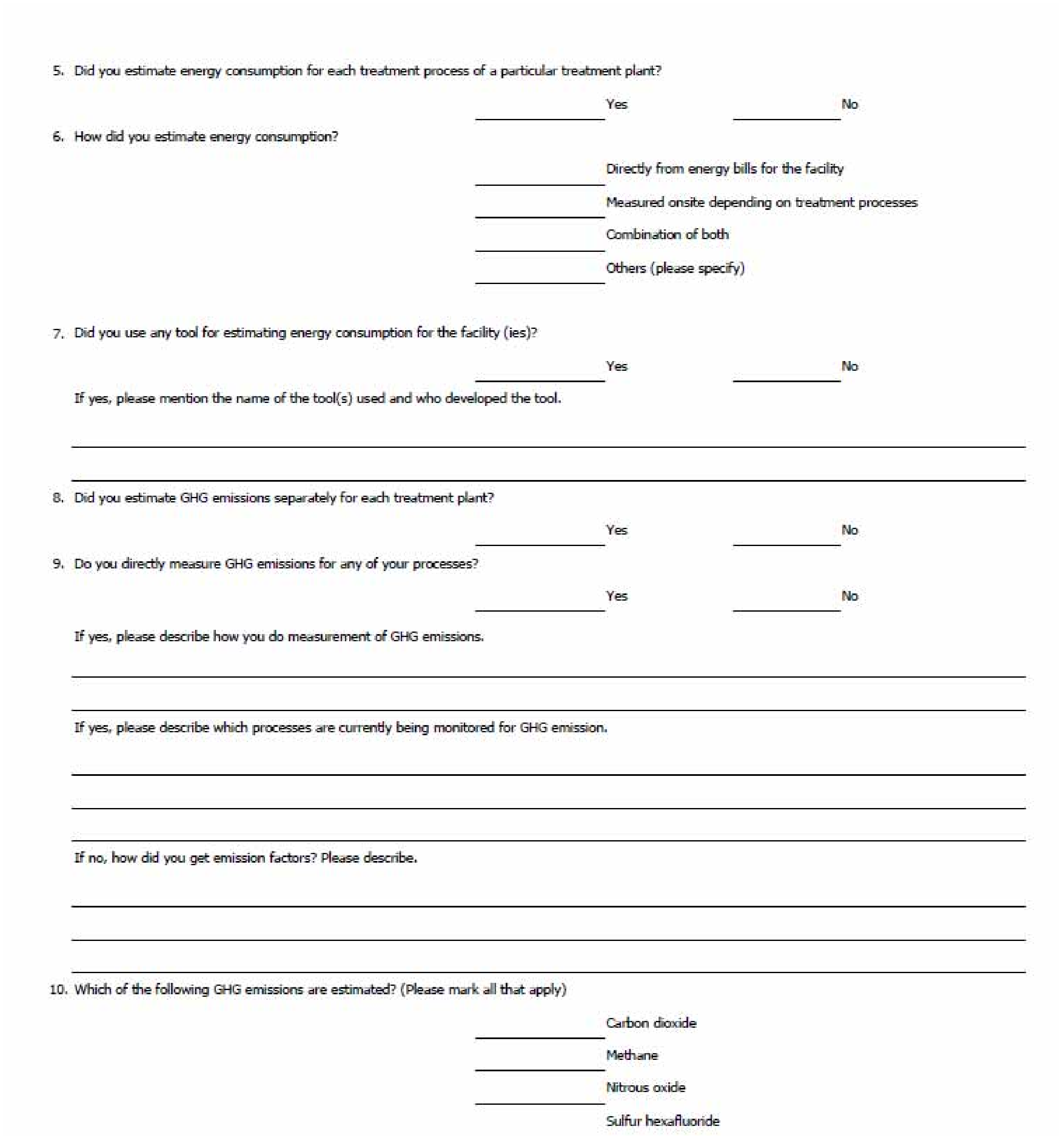
If yes, how did you establish your treatment process baseline carbon emissions, please describe.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________



5. Did you estimate energy consumption for each treatment process of a particular treatment plant?

__________ Yes __________ No

6. How did you estimate energy consumption?

__________ Directly from energy bills for the facility
__________ Measured onsite depending on treatment processes
__________ Combination of both
__________ Others (please specify)

7. Did you use any tool for estimating energy consumption for the facility (ies)?

__________ Yes __________ No

If yes, please mention the name of the tool(s) used and who developed the tool.

______________________________________________________________

______________________________________________________________

8. Did you estimate GHG emissions separately for each treatment plant?

__________ Yes __________ No

9. Do you directly measure GHG emissions for any of your processes?

__________ Yes __________ No

If yes, please describe how you do measurement of GHG emissions.

______________________________________________________________

______________________________________________________________

If yes, please describe which processes are currently being monitored for GHG emission.

______________________________________________________________

______________________________________________________________

______________________________________________________________

If no, how did you get emission factors? Please describe.

______________________________________________________________

______________________________________________________________

______________________________________________________________

10. Which of the following GHG emissions are estimated? (Please mark all that apply)

__________ Carbon dioxide
__________ Methane
__________ Nitrous oxide
__________ Sulfur hexafluoride

11. Which categories of emissions do you count and report?

| | | | |
|---|---|---|---|
| Scope 1 | On-site fuel combustion (oil, gas, etc.) | ________Yes/No | ________% of total |
| | Own vehicle transport | ________Yes/No | ________% of total |
| | Direct process emissions | ________Yes/No | ________% of total |
| Scope 2 | Grid electricity - pumping | ________Yes/No | ________% of total |
| | Grid electricity - treatment | ________Yes/No | ________% of total |
| | Grid electricity - ancillaries | ________Yes/No | ________% of total |
| | Purchased heat/steam use | ________Yes/No | ________% of total |
| Scope 3 | Chemicals | ________Yes/No | ________% of total |
| | Other consumables | ________Yes/No | ________% of total |
| | Other, please state | ________Yes/No | ________% of total |

12. (**OPTIONAL**)Total annual GHG emission as CO2 equivalent

________ tons or ________ (please specify unit)

13. (**OPTIONAL**) Breakdown of GHG emissions (based on gases)

| | | |
|---|---|---|
| Carbon dioxide | ________ tons or | ________ (please specify unit) |
| Methane | ________ tons or | ________ (please specify unit) |
| Nitrous oxide | ________ tons or | ________ (please specify unit) |
| Sulfur hexafluoride | ________ tons or | ________ (please specify unit) |
| Others (please specify) | ________ tons or | ________ (please specify unit) |

14. What, if any, are your water/wastewater carbon accounting requirements (regulations and reporting protocols) today? Please describe.

15. How do you anticipate these requirements to change in the future? Please describe.

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# ABBREVIATIONS

| | |
|---|---|
| ACEEE | American Council for an Energy-Efficient Economy |
| AD | Activity Data |
| AEMS | Advanced Energy Monitoring Systems |
| ANSI | American National Standards Institute |
| AOB | Ammonia Oxidizing Bacteria |
| AOP | Advanced Oxidation Process |
| API | American Petroleum Institute |
| ASDM | Activated Sludge/Anaerobic Digestion |
| ASM | Activated Sludge Model |
| ATAD | Authothermal Thermophilic Aerobic Digestion |
| | |
| BEAM | Biosolids Emissions Assessment Model |
| BSM | Benchmark Simulation Model |
| | |
| C | Carbon |
| CAAA | Clean Air Act Amendments |
| CARB | California Air Resources Board |
| CAS | Conventional Activated Sludge |
| CB | Carbon Budget |
| CCA | Climate Change Agreement |
| CCAR | California Climate Action Registry |
| CCF | Colorado Carbon Fund |
| CCL | Climate Change Levy |
| CDM | Clean Development Mechanism |
| CDP | Carbon Disclosure Project |
| CEMS | Continuing Emissions Monitoring System |
| CEMARS | Certified Emissions Measurement and Reduction Scheme |
| CEN | Committee for Standardization |
| CENELEC | European Committee for Electrotechnical Standardization |
| CEQA | California Environmental Quality Act |
| CFR | Code of Federal Regulations |
| CFU | Colony Forming Unit |
| $CH_4$ | Methane |
| CHEAPet | Carbon Heat Energy Analysis Plant Evaluation Tool |
| CHP | Combined Heat and Power |
| $CO_2$ | Carbon Dioxide |
| $CO_2$-e | Carbon Dioxide Equivalents |
| COD | Chemical Oxygen Demand |
| CR | North American Climate Registry |
| CRC | Carbon Reporting Commitment |
| CWCCG | California Wastewater Climate Change Group |
| | |
| DEA | Department of Environmental Affairs (South Africa) |
| Defra | Department of Environment, Food and Rural Affairs |

| | |
|---|---|
| DECC | Department of Energy and Climate Change |
| DO | Dissolved Oxygen |
| DOE | Department of Energy |
| Drinking Water | Refers to the specific drinking water utilities within the Urban Water Cycle |
| DWR | Department of Water Resources |
| EAWAG | Swiss Federal Institute of Aquatic Science and Technology |
| ECM | Energy Conservation Measures |
| EF | Emissions Factor |
| EF4 | Conversion factor for N that volatilizes to convert to $N_2O$ |
| eGRID | Emissions and Generation Resources Integrated Database |
| EPA | Environmental Protection Agency |
| EPRI | Electric Power Research Institute |
| ESD | Ecologically Sustainable Development |
| ETS | Emissions Trading System |
| EU | European Union |
| FracGASM | Fraction of added N that will volatilize |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GHGRP | Greenhouse Gas Reporting Program |
| GRI | Global Reporting Initiative |
| GWP | Global Warming Potential |
| GWRC | Global Water Research Coalition |
| H | Hydrogen |
| ha | Hectare (unit) |
| HAP | Hazardous Air Pollutant |
| HFC | Hydrofluorocarbon |
| $HNO_2$ | Nitrous Acid |
| hp | Horsepower (unit) |
| HVAC | Heating, Ventilation and Air Conditioning |
| ICLEI | International Council for Local Environmental Initiatives |
| IEAP | International Emissions Analysis Protocol |
| IFFAS | Integrated Fixed Film Activated Sludge |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Standards Organization |
| IWA | International Water Association |
| KP | Kyoto Protocol |
| KPTAP | Kyoto Protocol Target Achievement Plan |
| kt | Kiloton (unit) |
| kV | Kilovolt (unit) |

| | |
|---|---|
| kWh | Kilowatt hour (unit) |
| LA | Los Angeles |
| LABOS | Los Angeles Bureau of Sanitation |
| LADWP | Los Angeles Department of Water and Power |
| LCA | Life Cycle Assessment |
| LCAMAR | Life Cycle Assessment Manager for Energy Recovery |
| LGOP | Local Government Operations Protocol |
| LPD | Liters per day (unit) |
| LTA | Long Term Agreements |
| MACT | Maximum Achievable Control Technology |
| MBR | Membrane Bioreactor |
| MBBR | Moving Bed Biological Reactor |
| MF | Microfiltration |
| mgd | Million gallons per day (unit) |
| MLE | *Modified Ludzack-Ettinger* |
| MRR | Mandatory Greenhouse Gas Reporting Rule |
| MT | Megaton (unit) |
| MW | Megawatt (unit) |
| MWh | Megawatt hour (unit) |
| N | Nitrogen |
| N/A | Not Available |
| NACWA | National Association of Clean Water Agencies |
| NG | Natural Gas |
| NGERS | National Greenhouse and Energy Reporting Scheme |
| $NH_3$ | Ammonia |
| NL | Netherlands |
| NO | Nitric Oxide |
| $NO_2$ | Nitrogen Dioxide |
| $N_2O$ | Nitrous Oxide |
| $NO_x$ | Generic term for mono-nitrogen oxides |
| NOB | Nitrite Oxidizing Bacteria |
| NYSERDA | New York State Energy Research and Development Authority |
| $O_2$ | Oxygen |
| OSCAR | Online System for Comprehensive Activity Reporting |
| O&M | Operations and Management |
| OFWAT | Water Services Regulation Authority |
| PAO | Phosphorous Accumulating Organisms |
| PEM | Premium Efficiency Motor |
| PEMS | Predictive Emissions Monitoring System |
| PFC | Perfluorocarbon |

| | |
|---|---|
| PIER | Public Interest Energy Research |
| POTW | Publicly Owned Treatment Works |
| PSAT | Pumping System Assessment Tool |
| psi | pounds per square inch (unit) |
| PUP | Power Utility Reporting Protocol |
| | |
| RAD | Regulatory Affairs Department |
| RO | Reverse Osmosis |
| RSD | Relative Standard Deviations |
| | |
| SBR | Sequencing Batch Reactor |
| SF6 | Sulfur Hexafluoride |
| SRT | Solids Retention Time |
| | |
| TCR | The Climate Registry |
| tds | Tonne of dry solids (unit) |
| TJ | Terajoule (unit) |
| TKN | Total Kjehdhal Nitrogen |
| T&D | Transmission and Distribution |
| | |
| UK | United Kingdom |
| UKWIR | United Kingdom Water Industry Research |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| US | United States |
| USEPA | United States Environmental Protection Agency |
| UV | Ultraviolet |
| UWC | Urban Water Cycle |
| | |
| VAP | Voluntary Action Plan |
| VFD | Variable Frequency Drive |
| VOC | Volatile Organic Carbon |
| | |
| W | Water |
| Water Sector | Generally refers to the full urban water cycle and all utilities therein |
| Wastewater | Refers exclusively to the waste water utilities within the urban water cycle |
| WATS | Wastewater Anaerobic Transformations in Sewers |
| WBCSD | World Business Council for Sustainable Development |
| WBMWD | West Basin Municipal Water District |
| WD | Water District |
| WECC | Western Electricity Coordinating Council |
| WEF | Water Environment Federation |
| WERF | Water Environment Research Foundation |
| WEST | Water Energy Sustainability Tool |

| | |
|---|---|
| WGIA | Workshops on GHG Inventories in Asia |
| WMO | World Meteorological Organization |
| WNEE | Water Network Energy Efficiency |
| WSAA | Water Services Association of Australia |
| WR | Water Reuse |
| WRF | WateReuse Research Foundation |
| WRI | World Resources Institute |
| WW | Wastewater |
| W/WW | Water/Wastewater |
| WWTP | Wastewater Treatment Plant |