DCWASA'S CERTIFIABLE GHG INVENTORY AND PROJECTED GHG REDUCTIONS FROM CAMBI/ANAEROBIC DIGESTION UPGRADES

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ABSTRACT
DC WASA provides water distribution and wastewater collection and treatment services to the greater Washington, DC metropolitan area serving a population of approximately 2.1 million people. Wastewater is treated at the 370-million-gallon-per-day (mgd) Blue Plains Advanced Wastewater Treatment Plant (AWTP). DC WASA will soon replace the aging lime stabilization sludge-treatment process at the AWTP with Class-A anaerobic digestion using Cambi™ thermal hydrolysis. This upgrade will produce electricity and process heat from a renewable fuel (digester gas) while reducing the mass of produced biosolids by 50 to 60 percent.

This paper will document DC WASA's GHG inventories for 2007 and 2008 and show how the proposed digestion upgrades will reduce the utility's overall inventory by an estimated 28 to 39 percent or 46,816 to 73,340 MT of CO_2e per year.

Keywords
DCWASA; GHG Inventory; Cambi; Anaerobic Digestion; Carbon Reduction

INTRODUCTION

The DC WASA Board of Directors, management, and engineering and operations staffs are motivated to advance their role as stewards of the environment beyond regulatory compliance. As such, they wished to evaluate this project in the broader context of global GHG emissions. The first, context-critical step was to determine the utility's overall GHG inventory. Developing the utility-wide inventory provided an understanding of how much each element of DC WASA's business contributes to their overall GHG emissions and how the proposed solids-handling upgrades would reduce those emissions.

OVERVIEW OF SELECTED GHG INVENTORY PARAMETERS

The inventory presented herein has been developed using available factors and according to The Climate Registry's General Reporting Protocol (GRP) (The Climate Registry, 2008). The GRP is in turn based off of two other primary references, namely the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), and the World Resources Institute (WRI)/World Business Council for Sustainable Development (WBCSD) GHG Protocol calculation tools and calculation guidance(World Resources Institute/World Business Council for Sustainable Development, 2007). The GRP requires that all of an entity's Scope 1 (direct) and Scope 2 (indirect associated with purchased energy use) emissions be reported in the GHG inventory. Scope 3 emissions are not required to be submitted. The global warming potentials used for nitrous oxide (N_2O) and methane (CH_4) are 310 and 21, respectively, for conversion to carbon dioxide equivalents (CO_2e) (The Climate Registry, 2008).

Scope Definitions
DCWASA has included all Scope 1 and Scope 2 emissions in their inventory, as well as significant Scope 3 emissions. Significance was ascribed to those elements that potentially represented more than one percent of the overall inventory. The Scope 3 elements in the inventory include:

1. Fuel emissions from contracted biosolids hauling.
2. Manufacture of lime for lime stabilization of biosolids.
3. Manufacture of methanol for denitrification.
4. N_2O evolving from biosolids land application.
5. CH_4 emissions evolving from landfill disposal of biosolids.

Scope 3 emissions are not required for certification as they have potential to be Scope 1 or 2 emissions for another entity. It is interesting to note that DCWASA could potentially reduce the impact of these Scope 3 factors with either operational or constructed improvements. The following are presented as examples:

- Biosolids-hauling, fuel-related emissions could be claimed as a Scope 1 direct emission by the contract hauler. By reducing the amount of biosolids produced, the amount of truck trips and fuel required would also be reduced.
- Electrical and fuel required to manufacture either methanol or lime would be Scope 2 and Scope 1 emissions, respectively, for the chemical manufacturer. DC WASA is considering the use of alternative, renewable carbon sources for denitrification; use of these materials would reduce the AWTP's Scope 3 GHG emissions related to methanol production. Similarly, reducing or eliminating the use of lime for sludge treatment reduces DC WASA's Scope 3 emissions.
- N_2O or CH_4 from land application or land filling could be claimed as Scope 1 emissions by the farmer or the landfill operator. The evolution of either gas could be affected by changes in the amount of nitrogen or carbon in the land-filled or land-applied biosolids.

The inventory presented herein also considers offsetting, negative GHG emissions from the disposal or reuse of biosolids in land application (either as compost or dewatered cake) or land filling (Bronw, 2009). These negative emissions arise from either A) the understanding that the use of biosolids nutrients avoids the use of energy or fossil fuels to produce nitrogen and/or phosphorus chemical fertilizers or B) that biosolids contain carbon in various forms and while some carbon may evolve as carbon dioxide (CO_2), some of the carbon will be permanently stored in the soil and essentially "re-sequestered."

Data Quality Tiers
The GRP identifies tiers for data accuracy and provides direction on the preferred methods for emission qualification as follows: "In this system, "Tier A" designates the preferred, or most accurate, approach for a given emissions source; "Tier B" represents an alternative second-best approach; and "Tier C" represents the least accurate, but still acceptable approach." (the Climate Registry, 2008). Tier A usually represents directly measured emissions data, whereas lesser tiers represent application-specific emissions factors that are based on fuel carbon content (preferable), fuel heating value (less preferable), or even population served.

In a number of cases lower-tier options were chosen to avoid potentially-erroneous application of relatively limited data sets that might overemphasize their significance. One example of using lower-tier quantification is the use of a population-based N_2O emission factor for process-evolved N_2O instead of extrapolating data collected over 3 days in March and 3 days in August of 2009. This approach was deemed prudent as the correlations between operational modes and monitored liquid-stream parameters are not yet certain. As our understanding of the direct measurements and their relationship to historical trending data improves, lower-tier, assumption-based quantifications will be replaced with higher-tier, directly-measured values.

DC WASA GHG INVENTORY DEVELOPMENT AND FINDINGS

The overall GHG Scope 1 and 2 emission inventories for 2007 and 2008 are 160,620 and 169,176 MT of carbon dioxide equivalents (CO_2e), respectively. If Scope 3 sources and offsetting negative emissions are included, the inventories are reduced to 137,936 and 144,887, respectively. Table 1 shows the overall annual emissions totals for those calendar years, disaggregated by reporting Scope.

Table 1. DC WASA GHG Inventory

Emission Source	2007 Annual Emissions Estimate Metric Tons CO_2e	2008 Annual Emissions Estimate Metric Tons CO_2e
Scope 1		
Natural Gas		
CS	286	197
DSS	209	371
DWS	346	441
DWT	2,113	1,924
FLEET	30	34
Vehicle (fuel usage)		
Compressed Natural Gas (CNG)	0.040	0.064
Diesel Fuel No. 1 and 2	1,190	1041
Motor Gasoline	1,799	1545
Refrigerants	109	142
Nitrification/Denitrification (process emissions)	3,472	3,472
Effluent Discharge (process emissions)	1,462	2,010
Total of Scope 1	**11,017**	**11,176**
Scope 2		
Electricity		
DSS	8,587	11,887
DWS	10,502	9,854
DWT	130,515	136,259
Total of Scope 2	**149,604**	**158,000**
Total with Scopes 1 and 2	**160,620**	**169,176**
Scope 3		
Biosolids Hauling (fuel usage/distance traveled)	4,201	4,107
Lime Production	14,210	14,883
Methanol Production	7,588	6,747
N2O Emissions from Land Application	48,326	52,548
Methane Emissions from Land filling Biosolids	573	7
Total Scope 3 Positive Emissions	**74,898**	**78,292**
Scope 3 GHG Emission Offsets		
Carbon Sequestration Land Application*	-30,928	-26,844
Carbon Sequestration Land Application with	-12,097	-13,576
Carbon Sequestration Landfill*	-111	-2
N2O Offsets from Avoided Chemical Fertilizers	-48,326	-52,548
Fertilizer Credits Direct Applied Biosolids (N and P)	-5,705	-7,919
Fertilizer Credits Composted Biosolids (N and P)	-416	-1,692
Total Scope 3 Emissions Offsets	**-97,583**	**-102,581**
Total Net Scope 3 Emissions	**-22,685**	**-24,289**
GRAND TOTAL (Scopes 1, 2, and 3 reduced by identified carbon credits)	**137,936**	**144,887**

Elements for proposed (non-accepted) methodologies are designated with an asterisk (

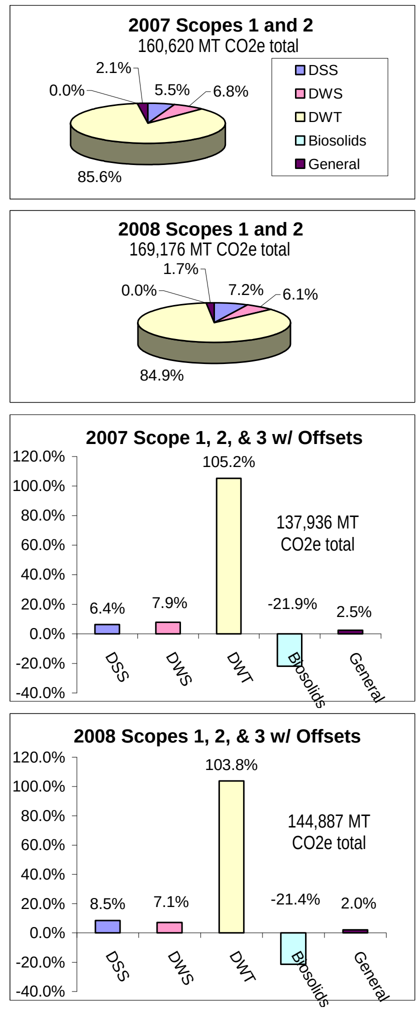
Figure 1 shows the total GHG emissions disaggregated by DC WASA operation/facility. In particular, the following operations/facilities are represented:

- **Department of Sewer Services (DSS):** This facility grouping includes the sanitary sewer pumping stations that are not powered off the Blue Plains electrical meter. Only natural gas and electrical emissions are included in these totals.
- **Department of Water Services (DWS):** This facility grouping includes all of potable water distribution booster stations. Again, only natural gas and electrical emissions are included in these totals.
- **Blue Plains AWTP (DWT):** This total includes electrical power at the AWTP as well as consumption of methanol and natural gas. Process emissions of N_2O from nitrification and denitrification and from evolution of N_2O from nitrogen species discharged in the plant effluent

are also included under the Blue Plains/DWT group. Biosolids treatment loads within the plant boundary are also included in this group.

- **Biosolids:** This category includes contracted biosolids hauling, lime consumption, and methane (CH_4) and N_2O evolution from land-filled and land-applied biosolids. All of the carbon credits for DC WASA are also included in this operation, namely nitrogen and phosphorus fertilizer offsets, and carbon sequestration under the various practices. All in-plant electrical and fuel uses are attributed to DWT rather than this Biosolids operational grouping.
- **Fleet/General:** This group summarizes all of the general uses that are not captured by one of the other operational groups. Central services (CS) and non-assigned "fleet" vehicles are specifically included. This group includes Scope 1 direct emissions associated with combustion of vehicle compressed natural gas (CNG), vehicle diesel fuel no. 1 and 2, and vehicle motor gasoline, as well as all DC WASA refrigerants.

Figure 1. GHG Inventories by Operation/Facility



The AWTP represent the most significant source, accounting for between 85 and 105 percent of the inventory. Water distribution, wastewater collection, and fleet/general services each represent less significant sources, from 2.0 to 7.9 percent. All of the biosolids emissions fall under Scope 3 and as such have no Scope 1 or 2 inventories; when Scope 3 and carbon credits are taken into consideration, the current biosolids operation accounts for between negative 21.4 and 21.9 percent; representing a significant reduction in the overall utility-wide inventory.

PREDICTED REDUCTIONS IN GHG FROM IDENTIFIED BIOSOLIDS PROJECTS

The sustainability of the Cambi/Anaerobic Digestion Program has been a motivating factor for the identified upgrades. The development of the DC WASA, utility-wide GHG inventory allows quantification of the predicted benefits and provides context for the overall degree of improvement to DC WASA's carbon footprint. Predicted GHG reductions are provided for the future facilities.

Full-Scale, Full-Program GHG Reductions

The Cambi/anaerobic digestion upgrades, inclusive of the CHP elements fueled by digester gas are the basis for this comparison. Table 2 provides a comparison of the current (using the averages of the 2007 and 2008 GHG emissions inventories) and predicted DC WASA-wide GHG inventory after completion of the Biosolids Upgrades. The presented reductions are made relative to the current lime stabilization operation supported by less-frequent composting and occasional land filling. The upgrades will provide the following changes from a GHG perspective:

- **Generation of Digester-Gas-Fueled "Green Power."** Digester-gas-fueled CHP represents a carbon-free source of electrical power. The predicted 13 MW of power generation represents over one-third of the 2008 DC WASA use. The new facilities will have an average electrical consumption of 2.2 MW compared to 1.3 MW for the existing lime stabilization equipment.

- **A significantly reduced mass of finished biosolids.** This mass reduction (estimated at 55 percent) results in a corresponding reduction in the Scope 3 emissions from biosolids hauling.
- **The nutrient balance of the biosolids will change significantly.** The biosolids themselves will

Table 2. Predicted Improvements in GHG Inventory with Cambi™/Digestion Upgrades

Emission Source	2007-2008 Average Annual Emissions Estimate, Metric Tons CO_2e	Projected Annual Emissions after Cambi Digestion Upgrades[A], Metric Tons CO_2e	Overall Predicted Reduction, Metric Tons CO_2e
Scope 1			
Natural Gas	2,976	2,976	0
Vehicle (fuel usage)	2,788	2,788	0
Refrigerants	125	125	0
Nitrification/Denitrification (process emissions)[B]	3,472	4,687	-1,215
Effluent Discharge (process emissions)	1,736	1,736	0
Total of Scope 1	**11,096**	**12,312**	**-1,215**
Scope 2			
Electricity[C]			
DSS	10,237	10,237	0
DWS	10,178	10,178	0
DWT [D, E, F]	133,387	85,356	48,031
Total of Scope 2	**153,802**	**105,771**	**48,031**
Total of Scopes 1 and 2	**164,898**	**118,083**	**46,816**
Scope 3			
Biosolids Hauling (fuel usage/distance traveled)[G]	4,154	1,853	2,301
Lime Production	14,547	727	13,819
Methanol Production[B]	7,167	9,676	-2,509
N2O Emissions from Land Application[H]	50,437	35,306	15,131
Methane Emissions from Landfilling Biosolids	290	149	142
Scope 3 GHG Emission Offsets			
Carbon Sequestration Land Application[K *]	-28,886	-28,886	0
Carbon Sequestration Land Application with Composting[K *]	-12,837	-12,837	0
Carbon Sequestration Landfill[K *]	-56	-56	0
N2O Offsets from Avoided Chemical Fertilizers	-50,437	-35,306	-15,131
Fertilizer Credits Direct Applied Biosolids (N and P)[H]	-6,812	-4,768	-2,044
Fertilizer Credits Composted Biosolids (N and P)[H]	-1,054	-738	-316
Total Scope 3 Emission Offsets	**-23,487**	**-34,880**	**11,393**
GRAND TOTAL (Scopes 1, 2, and 3 reduced by identified Scope 3 GHG Emission Offsets)	**141,412**	**83,203**	**58,209**

Elements for proposed (non-accepted) methodologies are designated with an asterisk (*).

[A] Lime stabilization will be used to process 5 percent of the sludge production.

[B] Nitrification/denitrification N_2O emissions and methanol consumption are estimated to increase by 35% to treat additional ammonia recycle from dewatering of digested biosolids.

[C] Based on 1,145 MT CO2e/MWh consolidated carbon intensity of power.

[D] Effluent N_2O Reductions or electricity and/or methanol increases from ENR are not included in comparison.

[E] Blue Plains electrical consumption averaged 29.26 MW in 2007 and 2008. Assumptions include addition of 2.2 MW of new load associated with the Cambi digestion upgrades; 1.5 MW of aeration energy for recycle nitrification; and 1.3 MW of load reduction associated with lime equipment that will no longer be in service. For the relatively small fraction of sludge processed using lime stabilization, it is assumed that the lime processing electrical load is added to the digestion facility load.

[F] 13MW will be produced from digester gas, having entirely biogenic CO_2 emissions.

[G] Truck trips of biosolids will be reduced from 65 to 29 trucks per day.

[H] Assumes 30 percent reduction land-applied nitrogen and no reduction in phosphorus.

[K] Assumes no change in sequestered carbon on a mass basis.

have less nitrogen, resulting in reduced fertilizer offset carbon credits (estimated as a 35 percent reduction in applied nitrogen). The ammonia nitrogen that will be recycled to the plant is conservatively estimated to demand 35 percent more methanol and to release 35 percent more process-related N_2O. The land-applied biosolids, however, are predicted to evolve 35 percent less N_2O. Electricity to treat recycled ammonia is estimated at 1.5 MW.

- **A near-complete elimination of lime use.** It is assumed that some lime will be required for periods of peak solids loading and of Cambi downtime but this is estimated as a 95 percent reduction in the mass of lime required. Lime production is energy-intensive and as such has a Scope 3 emissions impact. For the 5 percent of the time when the lime system is in use, the electrical load to run these facilities is added to the electrical load for the new systems.
- **Carbon sequestration is predicted to be unchanged.** This assumption is based on the premise that sequestered carbon is the "inert" or bound carbon that once placed will remain indefinitely. Because the mass reduction in digestion reduces "volatile" carbon, the land-applied inert or predicted-sequestered carbon is assumed to be unchanged.

The Biosolids Upgrades are predicted to reduce the Scope 1 and 2 GHG inventory from a 2007-2008 average of 164,898 to 118,083 MT of CO_2e/year. This represents a 28.4 percent or 46,816 MT of CO_2e reduction per year. If Scope 3 emissions and carbon credits are considered, the 2007-2008 average of 141,412 would be reduced by 58,209, or 41.2 percent, to 83,203 MT of CO_2e/year.

OUTSTANDING ISSUES AND OPPORTUNITIES

A number of uncertainties exist for water and sewer utilities with respect to GHG inventories. While protocols such as The Climate Registry's GRP, IPCC, and WRI/WBCSD and their associated assumptions/ factors/criteria allow for quantification of GHG inventories today, the science is rapidly evolving and many of the fundamental assumptions are being investigated. The Climate Registry's GRP accounts for this and encourages use of direct measurement (Tier A) of emissions over use of acceptable assumptions (Tiers B and C). One benefit of certification with The Climate Registry is the "living" nature of the registered information. As higher-tier criteria and better understanding become available, they can be used to retroactively update current and previous-year inventories. Some factors that are likely to change DC WASA's GHG inventory as the science evolves include:

- **Understanding of in-plant N_2O emissions and production factors.** As direct emissions monitoring and correlation to historically monitored liquid stream parameters become better defined, then the population-based assumptions currently included in the inventory will likely be replaced. Improving our understanding of N_2O emissions is critical as the associated global warming potential of 310 increases an inventory's sensitivity to this criterion.
- **Methane evolution from a variety of potential sources** has not been included in this inventory. Similar to the N_2O discussion above, CH_4's global warming potential of 21 increases an inventory's sensitivity to CH_4 emissions. Some of the potential sources currently under investigation include:
  - **Collection system methane.** Initial studies suggest that significant methane evolves from collection systems (Guisasola, 2008 and 2009) and methods for quantifying these emissions are evolving.
  - **Process evolved methane.** Research is only beginning to consider CH_4 emissions from in-plant processes such as headworks, primary sedimentation, anoxic and anaerobic reactors, as well as other potential sources. Attention that has initially focused on N_2O due to its higher global warming potential will likely move on to CH_4 as our understanding progresses.
  - **Evolution from stockpiled biosolids.** Dewatered biosolids are stored in bunkers and silos prior to truck loading. These facilities have limited air circulation and likely foster anaerobic conditions within the pile that could produce CH_4.

- **Future digestion fugitive or uncombusted methane.** The science is also developing to better estimate potential methane emissions from anaerobic digesters. It is currently assumed that any detrimental effects of these emissions will be dwarfed by the environmental benefits derived by implementation of digester gas utilization systems.

CONCLUSIONS AND RECOMMENDATIONS

The overall GHG Scope 1 and 2 inventories for 2007 and 2008 are 160,620 and 169,176 MT of carbon dioxide equivalents (CO_2e), respectively. If Scope 3 sources and offsets are included, the inventories are reduced to 137,936 and 144,887 MT of CO_2e, respectively. The Blue Plains AWTP is by far the largest component contributing approximately 105 percent of the Scope 1, 2, and 3 emissions. The biosolids program contributes approximately 100,000 MT of CO_2e of gross emissions offsets or approximately 23,000 MT of CO_2e in net emissions offsets (once the positive, utility-wide Scope 3 emissions are considered). After considering the Scope 1, 2, and 3 emissions and associated Scope 3 offsets, the DCWASA biosolids program represents an approximately 21 percent emissions offset for the overall GHG inventory.

The biosolids upgrade improvements planned by DCWASA and discussed herein will result in GHG emission reductions. In particular, the Cambi/Digestion upgrades will reduce the inventory by an estimated 28.4 percent or 46,816 MT of CO_2e reduction per year (Scopes 1 and 2, only) or as much as 41.2 percent, or 58,209 MT of CO_2e reduction per year (Scope 1, 2, and 3, inclusive of offsets).

The next step will be to have the developed inventories audited by a Climate Registry certified auditor. After the audit is complete and any comments are addressed the inventory can then be registered. DC WASA also plans to discuss the protocols used herein for fertilizer offsets and carbon sequestration for a variety of biosolids reuse and disposal options with The Climate Registry for their inclusion into the GRP by either reference or by update.

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