Summary of Pre-conference Workshop at WEFTEC 08

Wastewater Treatment in Tomorrow's Climate Change-Driven World

Organized by the American Academy of Environmental Engineers (AAEE)
and
The Air Quality and Odor Control Committee of WEF
October 18, 2008

The wastewater industry is beginning to address the challenges posed by climate change, including regulatory burdens, pressure to reduce emissions and the challenge of adapting to a changing climate. This workshop was designed to establish a foundation by first introducing the participants to climate change fundamentals and regulatory concerns. The discussion then explored potentials in the industry for mitigating and adapting to climate change impacts. Real world examples were provided, and the first workshop segment concluded with a discussion of current research and emerging research needs. Throughout, participants were encouraged to compose questions for the next segment, an interactive panel discussion featuring the ten speakers. The workshop concluded with an interactive breakout session designed to provide input to the industry on the issues and questions surrounding climate change and its impacts on the wastewater industry.

This summary provides a brief review of the technical presentations and the input received from the workshop attendees both in the form of panel discussion questions and the breakout session output. Each of the presenters is credited with the content of their presentation and has been provided an opportunity to review and comment on the brief summaries provided in this report. WEF's Air Quality and Odor Committee, chaired by Raymond Porter, was instrumental in conducting the workshop. This summary was prepared by Michael Selna and reviewed and edited by Patrick Griffith, both representing AAEE in this workshop.

Climate Change Challenges for Waste Treatment, Dr. Perry L. McCarty, 2007 Stockholm Water Prize Laureate and Silas H. Palmer Professor of Civil Engineering, Stanford University

Citing the historic work of Dr. Charles Keeling of the Scripps Institute Observatory Station at Mauna Loa, Dr. McCarty displayed the atmospheric CO_2 concentration increase from approximately 315 ppm in 1958 to approximately 350 ppm in 2002, a change of approximately 11 percent in 44 years. Most of the observed average temperature increase since the mid-20th century is very likely driven by the observed increase in anthropogenic greenhouse gas concentrations according to the Intergovernmental Panel on Climate Change (IPCC). Ice core sampling results suggest atmospheric concentrations of CO2, CH4, and N2O are dramatically higher than they have been in the last 10,000 years. Global temperatures have increased about 1 degree C in the last 150 years, sea level about 8 inches, and snow cover has declined about four percent. Presenting a carbon cycle graphic generated by IPCC, Dr. McCarty showed that terrestrial/atmospheric and marine/atmospheric carbon fluxes are nearly balanced, but fossil fuel combustion and industrial processes add a net 7.2 gigatons of carbon to the atmosphere yearly from the U.S., and over 50 gigatons globally. Concluding this background information, which was useful in framing a global perspective, McCarty posed the question: “What is impact of wastes and waste treatment on greenhouse gas emissions?”

The principal greenhouse gases of concern for POTWs are CO2, CH4 and N2O; each varies in its ability to absorb reflected heat from the earth. Methane (CH4) has 21 times as much global warming impact, and nitrous oxide (N2O) has 310 times as much impact as the same mass of CO2 released to the atmosphere. Dr. McCarty then focused on how these gases are formed in wastewater treatment processes. CH4 is formed in anaerobic treatment, and N2O is formed in nitrification and denitrification processes that are becoming more prevalent as the industry moves toward more complete nutrient removal. In the US, CH4 and N2O represent about 3.6 percent of the total greenhouse gas (GHG) emissions on a CO2 equivalent basis and within this 3.6 percent, only 0.6 percent is due to wastewater treatment.

In the US, electricity production, transportation and other power production result in approximately 85 percent of the green house gas emissions, and all forms of waste management only represent about three percent of the total. Dispelling the conventional thinking that water and wastewater management consume 19 percent of California’s power, Dr. McCarty showed a graphic revealing that most of this power demand is for heating and cooling and that transportation and treatment of water and wastewater consume about three percent of California’s electricity.

To answer the question: “How can we reduce energy consumption and greenhouse emissions from wastewater treatment?” he compared the GHG emissions and power consumption for three wastewater treatment plants in the South San Francisco Bay area near Stanford. Two plants utilize aerobic activated sludge treatment including nitrification, one with digestion of biosolids and the second with incineration of biosolids. The third plant utilizes algae ponds to convert soluble BOD to particulate material (algae), which is recovered by flotation and then anaerobically digested. The two activated sludge plants consume power to compress air used to aerate the activated sludge process which itself generates biogenic CO2; whereas the algae pond plant uses algae and bacteria, with the sun as the energy source, to convert BOD to biomass without consuming power and with no net production of CO2. Comparing the GHG emission potential of the three plants, the algae pond plant produces roughly one-half the GHG emissions of the activated sludge/digestion plant and roughly one-fifth the GHG emissions of the activated sludge/incineration plant. Comparing the energy costs of the three plants on a consistent basis of 10,000 kg BOD5 treated per day and a hypothetical CO2 equivalent emission penalty of $20 per ton C, the activated sludge/incineration plant would have an annual energy cost of $236,000 per year compared to net incomes from energy production of $97,000 per year for the activated sludge/digestion plant and $366,000 per year for the algae pond/digestion plant. All three plants were assumed to convert methane from digestion to power in cogeneration systems.

Dr. McCarty concluded by stating that a reevaluation of waste treatment alternatives is needed because of climate change concerns, and that desired alternatives will reduce both greenhouse gas emissions and power consumption. He stated that anaerobic treatment is likely to be an attractive component of the alternatives.

National Water Program Strategy: Response to Climate Change, Michael Shapiro, Deputy Assistant Administrator, Office of Water, U. S. EPA

According to USEPA's Office of Water, climate change will affect broad areas of EPA's Clean Water Act and Safe Drinking Water Act missions. Warmer water temperatures will reduce assimilative capacities of surface waters and increase the impacts of certain pollutants, leading to more impaired waters and more complex TMDL and permitting challenges. Rain amounts and snow levels and distribution will be nonuniformly altered with the northeast becoming wetter and the southwest becoming drier. Because of redistribution of precipitation, areas with less rainfall will experience drinking water supply challenges, lower stream flow conditions that will make effluent discharges more difficult, and wildfires that could exacerbate runoff and flood impacts. Intense storms will occur more frequently with a greater percentage of annual precipitation occurring in very intense events. Areas with greater precipitation will see more sewer overflows, more runoff and nonpoint pollution, and infrastructure overloading. Predicted changes in storm intensity and sea level rise create the need for integrated water, storm water, and wastewater infrastructure planning and greater interagency coordination. Inundation of water and wastewater infrastructure can be anticipated as well as loss of wetlands habitat. Ocean pH is dropping in equilibrium with higher atmospheric CO_2; salinity increases are also anticipated causing the need for consideration of new coastal programs. More of the nation's waters will be impaired and TMDLs will be required more frequently. With this background, the Office of Water's Draft Climate Strategy has established five major program goals for addressing climate change within its areas of responsibility:

Goal 1: Mitigation of Greenhouse Gases
Goal 2: Adaptation to Climate Change
Goal 3: Climate Change Research Related to Water
Goal 4: Education on Climate Change
Goal 5: Management of Climate Change

Distributed among these goals, 46 specific actions have been outlined. Key among mitigation strategies are improved energy efficiency and conservation at water and wastewater facilities, and by residential and commercial users. In addition, geologic sequestration of carbon dioxide is a leading candidate for reducing greenhouse gas emissions from the combustion of coal, and the Office of Water will play a significant role in regulating these activities. Adaptation strategies under review include evaluating the need for changes in drinking water, clean water, and effluent standards; creating new tools to assist watershed and wetland protection; and enhancing water infrastructure initiatives, which include sustainability guidance, clarification of the use of revolving loan funds, and the development of emergency response planning tools. EPA plans to expand its role in water research planning, improve outreach to stakeholders by creating a water and climate change clearinghouse, and partner with other Federal agencies by establishing a Federal Agency Water/Climate Coordination Group. EPA is preparing for implementation by supporting state and regional efforts, and encouraging integrated adaptation planning through coordination among states. Ongoing progress by EPA can be tracked at www.epa.gov/water/climatechange/.

The Climate Registry and GHG Reporting, Ann McCabe, Midwest Regional Director, The Climate Registry

The mission of The Climate Registry is to standardize and centralize high quality greenhouse gas (GHG) data in a North American GHG registry that supports voluntary and mandatory reporting programs. Presently, 39 U.S. states, 12 Canadian provinces, six Mexican states, and three tribal nations are participating in the Registry, and there are over 280 entities reporting data. The Climate Registry is the largest climate initiative in North America. Recording accurate, consistent data based on internationally recognized standards is the primary goal of the Registry. In carrying out its mission, the Registry coordinates with state/provincial, regional, and federal policy makers, however, it aims to be policy-neutral, reaching no conclusions on where emissions reductions should be targeted.

Entities participating in the Registry follow several basic principles that include:

- Entity-wide, facility-level reporting
- All six Kyoto GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6)
- All direct and indirect emissions from electricity are reported
- North American emissions only
- Independent, third-party verification

The Registry has value to states, provinces, and tribes in creating consistent cost-effective accounting infrastructure, allowing collaboration with other entities and a voice in establishing national standards. Entities reporting to the Registry benefit because they are provided with a cost-effective means to measure GHG emissions. Importantly, they are able to document early actions that may precede federal, state, or regional regulations on GHG reductions. Employees of entities using the Registry become educated on GHG emissions and highlight ways to save money through energy conservation. The Registry also provides access to software and technical support. Those entities participating in the Registry are recognized as environmental leaders.

The USEPA is scheduled to publish a mandatory GHG emissions reporting rule by June 2009 with first year reporting likely in 2010 or 2011. The Registry and EPA are in frequent discussions of the draft reporting rules, protocols and consolidated emissions reporting schema (CERS).

The Registry supports both voluntary and mandatory GHG reduction programs. Tools provided by the Registry include general reporting and verification protocols, the Climate Registry Information System (CRIS) for online GHG calculation and reporting, a verification tool, and entity training and technical assistance services.

Entities can participate in the Registry by entering data on a calendar year basis using web-based software for all six Kyoto gases. Direct emissions from stationary, mobile, process and fugitive sources, and indirect emissions from electricity and steam utilization are entered. Data are then verified by an ANSI-accredited verifier that ensures accuracy and consistency. Costs of participation include annual participation and verification fees. Annual participation fees are scaled against annual revenues for private entities and budgets for non-profit, governmental and academic organizations. Verification fees are based on factors such as the complexity and scope of emissions, organization of emissions data inventory and management systems, and use of the CRIS software. Of the 280 reporters participating as of October 2008, slightly over half are private entities, 20 percent are governmental organizations, 15 percent are power utilities, 13 percent are non-profits and three percent are academic institutions.

More information on how to participate is available at the Climate Registry's website: www.theclimateregistry.org

Climate Change and Wastewater Utilities: Assessing Vulnerabilities and Evaluating Adaptation Strategies, Robert S. Raucher, Stratus Consulting Inc., Boulder, CO

Dealing with climate change is an exercise in considering risk and uncertainty when making management decisions. The challenge can be addressed using a "Risk Management" approach that includes (a) risk identification, (b) risk assessment, and (c) risk management. Risk identification involves recognizing impacts that may arise; risk assessment encompasses characterizing the size, nature, probabilities, and consequences of various risks; and risk management includes developing, selecting, and deploying strategies to address those projected consequences.

Key questions that should be asked as part of a climate change risk approach are (a) what changes in climate are expected, (b) how will these changes impact the watershed environment in which wastewater utilities operate, (c) how vulnerable are communities and utilities to the changes in the watershed environment, and (d) what can and should wastewater utilities do to manage their high risk vulnerabilities?

Expected Future Climate Changes: Higher ambient temperatures, more so in summer than winter, and changes in seasonal precipitation with drier summers are likely changes. Precipitation events will be more intense, and more extreme droughts are expected. These changes will create stresses on watersheds and recharge areas as well as sea level rise. Observed precipitation trends in the 20th century show that extreme rainfall events are becoming more common and that associated stream flow impacts are magnified.

Impacts on the Watershed Environment: The expected climate changes will impact watersheds within which wastewater utilities operate by creating vulnerabilities such as pest infestations due to drought stressed trees and wildfires followed by intense storms resulting in increased storm water and non-point runoff. Water quality vulnerabilities will also occur such as increased algae growth, higher levels of water quality indicators such as coliform and turbidity, pH changes and higher water temperatures. Aquatic life will be impacted by the change in water temperature, changes in seasonality and reduction of minimum stream flows, changes in nutrient loading and increased eutrophication. Increased flooding of critical water and wastewater facilities can be anticipated. For example, in Atlantic City, New Jersey, today's 100-year flood (a flood frequency many, although not all, water and wastewater facilities are designed to withstand) is projected to occur every two years by 2100.

Vulnerability of Wastewater Utilities to Watershed Changes: Two general approaches were presented for assessing climate change risks. The first is the "top down" climate-driven scenario approach in which plausible changes in climate are used to estimate the broad range of watershed impacts and functional concerns they create. The second "bottom up" approach applies a systematic watershed management view corresponding to agency functional activities. The latter approach is aligned with utility-oriented vulnerability assessments. A "triple bottom line" context that considers environmental and social benefits as well as financial impacts is recommended for developing adaptive solutions to climate change.

Wastewater Infrastructure and Climate Change in Metro Vancouver, Brent Burton, M.A.Sc., P.Eng. Metro Vancouver

Metro Vancouver (Metro) is the common name of several legal entities including the Greater Vancouver Sewerage and Drainage District which operates five wastewater treatment plants. Metro has been proactive in planning for climate change impacts and has been working closely with the Public Infrastructure Engineering Vulnerability Committee (PIEVC). The PIEVC has developed a climate change vulnerability assessment protocol derived from standard risk management techniques to assess the impacts of climate change on infrastructure. This protocol was applied in seven national cases, including Metro's Vancouver Sewerage Area (VSA).

About 60 percent of the VSA is served by combined sewers. The main treatment plant in the system, the Iona Island Wastewater Treatment Plant, currently utilizes primary treatment with upgrading to secondary treatment currently scheduled for 2020 in Metro's

2001 Liquid Waste Management Plan. Annual rainfall in the area is approximately 75 inches, and, as a result, the combined sewer system can become stressed during wet weather, leading to combined sewer overflows.

Climate change impacts estimated to occur by 2050 include a 17 % increase in intense rain events and 14 % increase in annual rain. Sea level increases of from 0.3 to 1.6 meters are projected which is significant because the wastewater treatment plants are located in low-lying areas subject to significant ongoing subsidence.

In performing its vulnerability assessment, Metro conducted a full-day workshop including operators, planners and engineers. Using climate scale probability factors and severity scale factors, impact evaluation matrices were developed. These results revealed key vulnerabilities, which include increased combined sewer overflows, wastewater treatment plant flooding as a result of sea level increases and subsidence, and wave damage to effluent disposal infrastructure. In particular, it is noted that the anticipated service life of infrastructure becomes an increasingly important consideration given anticipated climate change. Given these vulnerabilities, Metro is continuing its sewer separation program, moving toward secondary treatment upgrades that incorporate the effects of anticipated climate change and is also evaluating options for decentralized wastewater treatment. A variety of other recommendations are currently being incorporated into a revised draft Liquid Waste Management Plan.

Wastewater Net Greenhouse Gas Burden, Professor Diego Rosso, UC Irvine and Professor Michael Stenstrom, UCLA

In 2005, US emissions of anthropogenic greenhouse gases were composed of approximately 82 percent CO2, nine percent CH4, and five percent N2O with the remaining four percent distributed among several compounds. Wastewater treatment contributes CO2, CH4, and N2O in quantities totaling approximately 3.4 percent of total US GHGs. CO2 and N2O are generated in aerobic (e.g. activated sludge) treatment. CH4 and CO2 are generated in anaerobic (e.g. biosolids digestion) treatment. The CO_2 generated in these processes for municipal wastewaters is largely biogenic.

Profound socio-economic changes in Asia are driving a rapid increase in the quantity of wastewater produced and consequently the amount of GHG potentially released. In North America and Europe, population and economic activity increases are eclipsed by Asia, and the expected increase in wastewater quantity is far less. For example, by 2025, it is estimated that Asia will produce nearly 480 million cubic meters of wastewater per day compared to approximately 420 million cubic meters per day for the remainder of the world. A much lower percentage of wastewater produced in Asia, Africa, and South America is collected, creating a large potential for mitigation of GHG release by construction and operation of wastewater treatment facilities. Because North America and Europe collect and treat virtually all wastewater produced, GHG capture and sequestration is much higher. For example, by 2025, the production of CO_2 equivalent emissions from biomass and biogas production related to wastewater in Asia will be an estimated 55 kilotonnes per day, but only 5 to 10 ktonnes/day will be captured and sequestered if current trends continue. By comparison, Europe and North America are projected to produce about 25 ktonnes/day of CO_2 equivalents in biomass and biogas, all of which is recovered and sequestered. Therefore, significant potential GHG credit will exist in the form of implementing wastewater treatment in Asia and developing countries in Africa and South America.

Greater power consumption efficiency in wastewater treatment can significantly lower GHG emissions. The greatest consumption of energy occurs in activated sludge aeration, where 45-75% of a plant's energy is consumed. Much is to be gained by utilizing more efficient aeration systems and in keeping them cleaned and well maintained. To a much lesser extent, digester heating and disinfection processes provide opportunities for GHG mitigation as well. Energy recovery from biogas produced in wastewater treatment, while well established in North America and Europe, lags far behind in Asia, Africa and South America. Energy production from biogas can largely offset a treatment plant's power consumption. Because aeration may actually be reduced in full nitrification/denitrification (N/DN) activated sludge processes compared to conventional activated sludge, the energy footprint of and N/DN plant may be lower than a conventional plant.

N_2O is emerging as a GHG of significant concern primarily because its global warming potential is approximately 300 times that of CO_2. Difficult both to measure and mitigate, N_2O is produced in small quantities in both nitrification and denitrification. By some estimates, the impact of this N_2O release may be as great as CO_2 in activated sludge treatment plants with nitrification/denitrification.

GHG credits available in wastewater treatment plant operations are associated with biomass sequestration (e.g. landfilling of digested solids) and use of biogas created in anaerobic digestion of solids to offset fossil fuel consumption. Factors to be considered in evaluating the carbon footprint of wastewater treatment include:

Mechanical efficiency
Aeration Efficiency
Equivalent (life-cycle) emissions due to chemical use
Volatile solids destruction
Fugitive emissions
N_2O emissions
Biogas conversion to energy
Transportation of biosolids
Carbon sequestration potential in final disposal/utilization of biosolids

Finally, much lower carbon footprints are associated with activated sludge plants employing shorter mean cell residence times as compared to plants with long cell residence times, and anaerobic treatment systems produce much lower carbon equivalent emissions for high strength wastes (> 700 mg/l BOD5).

Facility Design Options: Creating New Mitigation Possibilities, Jay R. Witherspoon, BCEE, V.P. and Fellow Technologist, CH2MHill

Design of mitigation strategies for greenhouse gas (GHG) emissions is driven by rising fossil fuel energy costs, renewable/biofuels energy options, carbon footprint neutrality goals, mandatory and/or voluntary GHG reductions, creation of sustainable facilities, and water availability stresses created by climate change and surging demand. Sustainable design involves balancing social, economic, environmental, and technical performance. Adaptation, which involves designing systems to cope with the impacts of climate change, and mitigation, which involves designing systems to reduce GHG emissions, are both important sustainability concepts co-mingled in an integrated framework. Urban water management has historically been based on single use approaches but must in the future focus on multiple use systems. Advantages of a multiple use or hybrid system include secure water supplies through water reclamation and reuse, diminished resource consumption through reduced conveyance and less potable water demand, and increased water supply availability through reduced per capita consumption. Models such as VOYAGE™ can create system planning scenarios that optimize for climate change impacts. The VOYAGE™ model consists of a multi-layered approach in which resources (e.g. water, energy) are balanced at the first level, followed by performance analysis in which costs and social/environmental benefits are balanced, and finally, performance, as measured by life cycle cost and project benefits, is optimized.

GHG emissions produced by unit processes within a typical wastewater treatment plant include CO_2, CH_4, and N_2O. Primary treatment is not expected to produce significant GHGs. Secondary treatment is anticipated to produce all three gases. Anaerobic digestion and subsequent biosolids dewatering and combustion of digester gas can be expected to produce CO_2 and CH_4. Stationary and mobile sources associated with the wastewater treatment plant operation account for additional GHG emissions. Putting wastewater power consumption in perspective, the per capita power consumption for wastewater management is approximately 5 watts.

A case study involving Sydney, Australia's Water Corporation was presented in which a 2020 carbon neutrality goal is to be achieved by improving energy efficiency, using renewables and biofuels, and consuming carbon credits to make up any shortfall. As a first step, all of Sydney Water's energy consumption was inventoried. Energy efficiency projects were then identified in an energy management plan. Projects include optimization of sewage pumps, improved aeration controls, adjustment of fill cycles and levels, and fleet management. Renewable energy generation efforts were then outlined including cogeneration using digester gas at sewage treatment plants and hydroelectric projects including pressure reductions and gravity flows in water and wastewater streams.

GHG regulations and carbon trading will present challenges and opportunities. In addition to the impacts on water supply and sea levels mentioned previously, economic impacts such as rising energy, material, and commodity prices can be expected. Opportunities include renewable energy incentives, carbon trading and increased demand for reclaimed water. Examples of renewable energy action include beneficial reuse of biosolids for soil amendment, conversion of landfill gas to energy, and use of digester gas to produce power to operate treatment plants. Conversion of biosolids to energy and biosolids composting are additional avenues for sustainable design.

Future sustainable design approaches will involve consideration of new urban water management paradigms in which hybrid centralized and decentralized systems are utilized and in which triple bottom line metrics are used in evaluating outcomes of planning and design processes. The path forward will incorporate technical, policy and stakeholder elements in the final design.

Demonstrating Carbon Benefits of Biosolids Land Application, Chris Peot, P.E., District of Columbia Water and Sewer Authority

Biosolids recycling should be portrayed to the public as an activity that recovers valuable nutrients, energy, and carbon. The public is increasingly energy and climate change conscious and needs to hear the message regarding the benefits of biosolids recycling. A large part of the energy benefit accrues from the avoidance of energy intensive inorganic fertilizer production. Avoidance of inorganic fertilizer use reduces greenhouse gas releases by reducing the use of fossil fuels in manufacture and transportation of the fertilizer, both of which dwarf the release of carbon in transport of biosolids. Moreover, recycling biosolids to the land sequesters carbon in soil and plants.

Prior to the industrial revolution, atmospheric carbon was in balance between respiration by animals and consumption of CO_2 in photosynthesis. The carbon from plants and animals is considered biogenic, short cycle carbon. It cycles from atmosphere to sequestration relatively quickly. The atmospheric balance may be disrupted when carbon is released from long-term sequestration sources such as petroleum deposits. Plants cannot take up the CO_2 released from petroleum combustion quickly enough, upsetting the balance. Biogenic sources do not upset the balance because the plant life from which they originate absorbs the CO_2 produced by animals consuming the plants.

In a typical month at the District of Columbia Water and Sanitation Authority Blue Plains treatment plant, approximately 43,000 wet tons of biosolids are recycled producing a net benefit of nearly 3,000 metric tons of CO_2 avoided emissions, the equivalent of approximately 6,700,000 automobile miles. For 2007, Blue Plains biosolids recycling to soil avoided inorganic fertilizer use of over 5,000 metric ton equivalents of CO_2 and approximately 25,000 metric tons of CO_2 were sequestered in the soil. These estimates account for biosolids transportation to the recycle locations. One of the most successful recycling programs involves land reclamation through planting poplar tree forests. Poplar tree plantations reuse millions of gallons of landfill leachate per day and provide a marketable wood fiber, all while sequestering CO2.

Research Needs: Filling the Gap for the Future's Climate Change Challenges, Claudio Ternieden, Assistant Director of Research, Water Environment Research Foundation

The Water Environment Research Foundation (WERF) provides peer reviewed research on wastewater and water quality issues and delivers results to subscribers who, in turn, help fund the research. WERF's climate change research has two main themes: energy optimization and climate change-specific issues. As background, average power consumption in wastewater management includes 150 kWh/million gallons (MG) for pumping wastewater to treatment plants and 1050 kWh/MG for treatment, which equates to approximately 0.62 kWh/capita/day. In the US, wastewater management uses three percent of all energy generated. Key anthropogenic GHGs from wastewater are methane and N2O. Wastewater management emits an estimated five percent of the nation's methane and two percent of N2O emissions, according to EPA estimates. Within the wastewater management sector, about 76 percent of the methane emitted is from septic systems, 23 percent from anaerobic treatment systems and one percent from anaerobic digesters at POTWs.

WERF is devoting significant attention to energy efficiency in wastewater treatment and to energy and resource recovery from wastewater residuals. In the US presently, about 34 percent of digester gas is used productively for heat and power. WERF's top research issues in this area include operations optimization with a goal of improving operations efficiencies by more than 20 percent. Energy use accounts for 35 percent of treatment plant operations cost, second only to labor costs. WERF is collaborating with other organizations to develop a compendium of best energy efficiency practices, including case studies, a life cycle tool for green energy options, and a decision support system for sustainable energy management with the goal of wastewater treatment being energy self-sustaining by 2040. Other energy related projects include developing a "Life-Cycle Assessment Manager Energy Recovery Tool" for cost-effective energy recovery from anaerobically treated wastewater solids and cutting edge research on nitrifying fuel cells for sustainable wastewater treatment. Wastewater solids resource recovery work includes co-digestion of organic wastes with wastewater solids and evaluation of processes to reduce solids generation.

WERF's climate change research has two primary goals: (a) developing an improved understanding of the likely impacts of climate change on water quality, wastewater management and costs and (b) creating planning and operations management tools to cost-effectively mitigate and adapt to climate change. In collaboration with AwwaRF, WERF is reviewing the state of the science in managing GHG emissions from wastewater treatment plants, including review of process models, methods for calculating carbon footprint, and identification of gaps and research needs. GHG emissions characterization with emphasis on N_2O production in nitrification/denitrification pathways is another area of focus.

WERF has identified a long list of research needs related to climate change including energy/emissions research (carbon sequestration in biosolids, renewable energy, and energy management), infrastructure/conveyance system research, biological research (habitat issues, assessment tools), nutrient removal and management, climate change modeling, and human health implications. Finally, WERF is seeking industry feedback in the form of identification of priorities in climate change research and tools needed to make management decisions.

Summary of Panel Discussion

At the beginning of the workshop, each participant (member of the audience) was given a 3"x5" card to record one or more questions during the day to be posed to the panel for discussion. Participants were reminded several times during the day to listen for points made by the presenters that would trigger good panel discussion questions. Focusing on questions for the panel helped to keep the audience engaged. The cards were collected prior to the afternoon break. The questions were reviewed and those with broad appeal or overlapping themes were given preference. The presenters formed the discussion panel and addressed the questions.

The following is the list of questions provided by the workshop participants. Although the intent was to have the panel discuss the entire slate of questions, the interaction between the audience and the panel (and within the panel members themselves) limited what could be covered in the time permitted. All of the questions provide insight to the issues facing the wastewater industry.

1. How were the global warming potentials of CH_4 (21 times CO_2) and N_2O (310 times CO_2) determined? How does the chemistry work?
2. A factor of 298 was used in a model for N_2O to represent its relative GHG potential, but N_2O has a half-life in the atmosphere due to UV and rain washout. Shouldn't the factor be reduced because of this?
3. Do the models consider the differences between biogenic and non-biogenic CO_2 releases as well as other gases? What about chemical use such as methanol and polymer?
4. What is the timetable for implementing EPA's National Water Program strategy and how can the wastewater industry weigh in?
5. Will industry that moves ahead with reducing carbon emissions be recognized for their good efforts, or will they be penalized for this?
6. As we enter an era of carbon trading, what is the appropriate approach in giving credit for early actions? Does the Climate Registry provide an opportunity to claim and receive credit for early actions?

7. Given the budgetary pressures facing the nation, what is the likelihood that funding will be allocated to wastewater infrastructure given the greater GHG mitigation potentials in power production and transportation areas?
8. Can one consider the carbon in digested biosolids to be sequestered if it is used as a soil conditioner?
9. Carbon capture and sequestration is talked about at length. Is anyone aware of it being practiced on a commercial or even a pilot scale?
10. How would you design a brand new plant to have as low a carbon footprint as possible and make the project sustainable? Where would we have the greatest short-term and long-term impacts?

Breakout Session

Workshop participants, including presenters, were broken into four groups, and each group selected a recorder and someone to report back to the seminar as a whole. The following outline was provided to stimulate thought and guide the discussions:

1. What are your major concerns related to climate change and its impact on the wastewater industry?

2. What are the major issues, gaps, and challenges related to climate change?

3. Needs: What does the industry need in the following areas to successfully cope with climate change?

    Research
    Funding
    Communication
    Regulation
    Legislation

Each group spent 45 minutes in discussion, listed issues the group believed were most important, ranked the issues outlined using a voting procedure, addressed gaps, challenges, and needs related to its first and second ranked issues, and finished with a brief verbal summary back to the entire seminar upon reconvening.

Group 1

Group 1 focused on mitigation issues. The following is an outline of Group 1's discussion:

Outline of Issues

- Wastewater – energy source - net producer
  Historical legacy – wetlands treatment, minimize aeration

- Heat/power – available in WW treatment

- Eliminate nitrification/denitrification to reduce GHG emissions
  Recycling (agricultural use)
  Separation of urine

- Greater Awareness – regulators
  Effect on CO_2
  Wastewater events/regulations haven't kept up
  Biosolids – regulators need better understanding

- Get more information on digesters (existing facilities). Get more out of existing facilities such as digesters.

- Optimize use of energy by minimizing pumping and treating waste as a resource, a net producer of energy.

Group 1 ranked consideration of wastewater as a net producer of energy and getting more information and improved performance from digesters as their most important issues.

Issue #1: Resource/Energy Optimization (wastewater as a net producer of energy)

a. Gaps

- Identification of proven technologies
- Leadership (need for)
- Models for climate change (accuracy, consistency, etc.)
- Biosolids to energy (true energy balance)

b. Challenges

- Efficiency of primary treatment i.e. clarification (coagulant issues)
- Activated sludge (partially biodegradable)
- Energy requirements to extract/utilize
- Improving digestibility

c. Needs Assessment

Legislation

- Complex leadership issue (EPA, funding, taxation)

Regulation

- Agriculture (not accounting for full costs)
- Re-evaluate risk of biosolids to agriculture (difficult to utilize biosolids)
- Triple bottom line – sustainability

Research

- New research (anaerobic membrane bioreactor)

Funding

- Incentive programs (improvement & innovative technology)

Communication

- Public education/politicians (improving understanding)
- Waste as a resource

Issue #2: Utilizing Existing Infrastructure More Effectively (Get more out of existing facilities such as digesters)

a. Gaps

- Operator Training (anaerobic more difficult to operate)

b. Challenges

- Improving digestibility (limited success), hard to compare data/consistency, (fats/oil/grease separation)

- Financial incentive
  Positive funding/negative constraints/fines (no external incentive)

- Reliability
  Methane gas (use of heat/electricity) – challenges in using efficiently, difficulties in application
- Balance (co-generation)

Group 2

Group 2 also focused on mitigation, and the following list summarizes the issues they identified.

Outline of issues:

- Efficient O_2 use
- Regulatory balance (holistic)
- Trading and baselines
- Fugitive Methane (bad covers)
- Energy Optimization
- Renewable fuel use

- HVAC cost
- Transport cost
- Cost Control (rate shock)
- N_2O control

The group chose Regulatory Balance and N2O control as the most critical issues.

Issue #1: Regulatory Balance

a. Gaps

- Where is best environmental bang per buck
- Tunnel vision – regulatory "silos"
- Apply TBL
- Basic Science

b. Challenges

- Statutory limits (e.g., land use, nps, …)
- Regulatory mandates & structure (CWA v. CAA v. other?)
- Considering costs (regulators)
- The laws (statutes that limit what can be considered)

c. Needs Assessment

Legislation

- Statues that enable flexible solutions
- Promote integrated approach (de-silo)
- Incentives vs. mandates

Regulation

- Coordinate regulatory activities (de-silo)
- Promote trading and/or accounting for tradeoffs

Research – Good case studies

- Real world
- Capture cross-media impacts/values

Funding – Yes! $700B?

Communication within industry – de-silo

- Public – across stakeholders (air, water, energy)
- ID areas of common ground
- Involve NGOs early!
- Outreach education

Issue #2: N2O

a. Gaps

- Basic science
  - monitoring – baseline
  - modeling
- where, how/why, how much release
- what happens if N released to waters?

b. Challenges

- how to monitor and control releases
- opportunities to use/reuse
- process variables to control

c. Needs Assessment

Legislation

- May need N_2O reg. relief for WWTP

Regulation

- May need N_2O reg. relief for WWTP

Research

- Size and source of program (monitoring, modeling)
- potential control strategies
- consequences of "solutions"
- energy implications of control
- Web-based tools

Funding

- Pay for research

Communication within industry

- alert to "problem"
- engage in solutions
- use WEF to educate
- get publication out

Group 3

Group 3 addressed adaptation, and the following list summarizes the issues they identified.

- Strategy for addressing **sea level rise (financial strategy, for example)**

- Everyone should have some sort of vulnerability assessment (measure/assess risk)

- "ID what we don't know" "Known unknowns" and how do you plan for that – resiliency and flexibility

- Early community outreach

- Communication/education

- Lack of useful models at the local level

From this list, the group chose to focus on having vulnerability assessments and early community outreach as the most important issues.

Issue #1: Vulnerability Assessment

a. Gaps

- Lack of useful models at the local level
- Need for methodology
- More robust data – statistically valid
- Funding
- Institutional – Who?

b. Challenges

- Those doing the work, for example, research, understand the needs of the industry
- Education of the customer base and decision makers (See Issue #2)
- Time limitations/urgency
- Quality vs. quantity "jurisdiction"

c. Needs Assessment

Legislation

- State Land use Legislation

Research

- Research on effects (understand "unknowns")
- Guidance on what questions to ask
- How would you set up a vulnerability assessment?
- Quantitative tools

Regulation

- Implementing regulations of the state land use legislation
- Integrating consistent approach by state agencies

Funding

- Absolutely!!!!

Communication

- Consider how to communicate your end product

Issue #2: Early Community Outreach

a. Gaps

- "Perspective" (example: Environmental groups with local focus)
- Basic capacity by utilities on how to do it (example: away from "reactionary")

b. Challenges

- Reactionary approach – not ahead of it
- Understanding of impacts – access to information

c. Needs Assessment

Legislation

Regulation

- Assess the need for regulations and/or guidance

Research

- What communication works?
- What information is most known/needed?

Funding

- Needs are different per topic/geography
- Need more than just local resources

Communication

- Information (What is that we know)

- Involve the public early/often

Group 4

Group 4 addressed adaptation, and the following list summarizes the issues they identified.

- Co-generation
- Carbon capture
- Process modification
- New process development
- Structural improvements
- Source management
- Energy Conservation
- Reuse and recovery
- Regulatory changes
- Decentralization
- Interaction w/ public
- Education
- Research

From this list the group decided to focus on reuse and recovery and process modifications.

Issue #1: Reuse and Recovery

a. Gaps

- Lack of consistent metrics
- Lack of educated information
- Protocols

b. Challenges

- Public perception
- Public health
- Boundary definition
- Cost and return on investment
- Regulatory challenges
- Physical limitations

c. Needs Assessment

Legislation

- Tax credits/incentives
- New legal definitions

Regulation

- Standard protocols
- Environmental impacts vs. carbon footprint

Research

- GWP
- Mass fluxes (N_2O, biosolids, etc)

Funding

- New applied research funding
- User fees vs. taxes
- Incentives/rebates/tax breaks

Communication

- Improved communication with public, legislators, public advocacy groups

Issue #2: Process Modification

a. Gaps

- Standardized engineering design vs. natural systems
- Conservative industry
- Lack of reliable information

b. Challenges

- Establish market-oriented drive
- Fees are proportional to capital costs, instead of to carbon savings
- In-house vs. external contracts
- Power costs

c. Needs Assessment

Legislation

- Incentives, nutrient removal

Regulations

- Incentives, nutrient removal

Research

- Innovative processes

Conclusion

It was clear from the panel discussion questions and the breakout session reports that there is a thirst for more information. Although the financial, informational and regulatory concerns are great, the consensus was to begin action sooner than later.

The workshop provided fundamental understanding of mitigation and adaptation principles in wastewater management. The potentials for mitigation offered by Dr. McCarty in his discussion of algae pond treatment and in biosolids land application as mentioned by Chris Peot are encouraging. Moreover, both Rosso and Stenstrom highlighted sequestration potentials and pointed out that significant potential GHG credits exist in the form of implementing wastewater treatment in developing countries, which would provide the important benefit of providing sorely needed sanitation improvements for those distressed communities. Jay Witherspoon exposed the benefit of modeling to open up new mitigation possibilities even before design begins.

Adaptation needs are equally of concern as the workshop participants are well aware that changes to the climate may impact POTW and collection system operations and maintenance. The seminar benefited from the contributions of Robert Raucher, who presented the fundamentals of risk assessment and management, and from Brent Burton who is putting those principles to work in Metro Vancouver.

Information will be critical to tackling the challenges presented by climate change. Ann McCabe from The Climate Registry shared what they have established as a foundation for archiving emissions and for documenting subsequent reductions. Claudio Ternieden from WERF explored on-going and planned research critical to understanding emissions, and mitigation and sequestration possibilities inherent in wastewater treatment. These research efforts are in keeping with WERF's vision for wastewater treatment to be energy self-sustaining by 2040. Finally, Michael Shapiro from the U.S. EPA Office of Water presented a glimpse of the regulatory landscape under development for both water and wastewater agencies; acknowledging the growing consensus that the two are becoming increasingly interdependent.