

**ENVIRONMENTAL MONITORING, EVALUATION AND
PROTECTION: LINKING SCIENCE AND POLICY**

NOVEMBER 15-16, 2007

SPEAKER ABSTRACTS



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Thursday, November 15, 2007

Climate Change Science and Policy: 9:00am-12:00pm

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE: STATE OF THE SCIENCE

David H. Rind
NASA Goddard Institute for Space Studies

The presenter reviews the “State of the Science” as determined by the Intergovernmental Panel on Climate Change (IPCC). The IPCC has concluded that the climate is warming and humans are causing it; that the warming will continue and intensify as long as greenhouse gases continue to be emitted by anthropogenic activities; and that impacts of this warming are already visible in specific ecosystems and broad-scale locations. The IPCC further argues that these impacts are likely to become greater and more widespread in the future, affecting coastal regions, boreal and Mediterranean regions, water resources and human health, as well as many other sectors; that a combination of mitigation and adaptation will be necessary to minimize future damages; and that the longer society waits to act, the greater the danger and the more draconian the required prescriptions.

CONFRONTING CLIMATE CHANGE IN NEW YORK

Peter C. Frumhoff
Union of Concerned Scientists

This presentation provides an overview of the findings of the Northeast Climate Impacts Assessment (NECIA) – a collaboration between the Union of Concerned Scientists (UCS) and more than 50 independent scientists and economists -- with a specific focus on the observed and projected impacts of climate change in New York State. NECIA findings describe conservative projections of impacts on coastlines, marine resources, public health, water resources, forests, agriculture, and winter recreation across New York and the Northeast. The presentation will outline how the cost and feasibility of adapting to future change in New York depends upon the effective enactment of timely policies to reduce emissions of heat-trapping gases. Copies of the NECIA Synthesis Report, a NY State Summary, and additional information are available at www.climatechoices.org/ne.

RGGI UPDATE AND AUCTION PLANS

Peter M. Iwanowicz, Office of Climate Change, Director
New York State Department of Environmental Conservation
William Shobe, Director of Business and Economic Research,
University of Virginia

On December 20, 2005, New York State entered into a historic regional agreement to reduce greenhouse gas (GHG) emissions from power plants, an important step to protect our environment and meet the significant challenge of climate change. Under the agreement, the governors of 10 Northeastern and Mid-Atlantic states have committed to propose the Regional Greenhouse Gas Initiative (RGGI), a program to cap and reduce carbon dioxide (CO₂) emissions from power plants in the region by 10 percent by 2019, for adoption in their states. In order to carry out the State's commitment, the Department of Environmental Conservation is proposing to establish the CO₂ Budget Trading Program by promulgating 6 NYCRR Part 242, and to revise 6 NYCRR Part 200, General Provisions. The presentation will provide an overview of the proposed rules and will provide some insight into how the proposal will reduce the impacts of climate change.

ELECTRICITY TECHNOLOGIES IN A CARBON-CONSTRAINED WORLD

Ronald E. Wyzga
Electric Power Research Institute

The analyses summarized in this presentation address the technical feasibility to achieve large-scale CO₂ emissions reductions, the technology development pathways and associated RD&D funding needed to achieve this potential, and the economic impact of realizing emissions reduction targets. Given the 20-to-30-year lead-time needed to fully research, develop, and commercially deploy technologies, it is critical to define priorities and initiate RD&D activities as soon as possible.

The assessment involves three related EPRI studies: 1) the PRISM analysis, which determined the U.S. electricity sector's potential for reducing CO₂ emissions from a purely technical perspective, based on deployment of a portfolio of advanced technologies; 2) a technology development pathways analysis, which identified the sequence of research, development, and demonstration (RD&D) steps needed to achieve the necessary technology performance and deployment; and 3) the MERGE analysis, which assessed the economic value of deploying the full technology portfolio analyzed in the PRISM analysis.

LOCAL CLIMATE CHANGE INITIATIVES IN NEW YORK STATE

Jennifer Cox
Regional Plan Association

Climate change reduces the predictability of our weather, exacerbates existing social vulnerabilities, and raises concern over the sustainability of our current land use, transportation, and energy policies. Local community actions have enormous potential to reduce climate change and provide for local benefits, including minimization of energy costs, managing storm water runoff, strengthening of the local economy, creating jobs, and reducing automobile dependency.

Local communities are creating a lasting legacy of leadership for cities and communities across the region. However, additional reductions in GHG emissions can be realized and achieved by implementing regional transportation and smart growth policies.

GEOLOGICAL CARBON SEQUESTRATION POTENTIAL IN NEW YORK STATE

Langhorne (Taury) Smith, Richard Nyahay and Alexa Stolorow
Reservoir Characterization Group, New York State Museum

Members of the staff from the Reservoir Characterization Group of the New York State Museum are in the midst of an on-going NYSERDA and DOE-funded study of geological carbon sequestration potential in New York State. Geological sequestration refers to storing CO₂ captured from point sources underground in subsurface geological formations in such a manner that it will not escape for thousands of years.

CO₂ occurs in four phases: liquid, gas, solid and supercritical fluid. Most geological sequestration should be done in the supercritical phase, which requires higher pressures and temperatures only found at depths of at least 2500 feet. In the onshore New York region, the best options for geological sequestration currently available are deep saline aquifers, and depleted oil and gas reservoirs. These all occur in sedimentary rocks of western New York. The number of potential formations for sequestration increases from north to south because the layers become deeper to the south. There is little potential for geological sequestration north of the Mohawk River or east of the Hudson River. The Southern Tier offers the most potential sequestration opportunities. Even in the area with the highest potential, the rocks have generally low porosity and permeability and much research needs to be done to determine if, and to what extent, carbon sequestration is feasible.

The greatest potential for storage of significant CO₂ underground lies in areas more than 20 miles offshore of New York (in the area from Baltimore Canyon to George's Bank) in saline aquifers or in the sediments directly underlying the ocean floor. Onshore sequestration has lower potential and greater regulatory hurdles, but the infrastructure is likely to be more expensive offshore.

Other more theoretical options include shale storage and mineral carbonation. These require more study before they can be considered realistic options. Some of these ideas could open up a wider area of potential sequestration opportunities if they can be demonstrated to work on the scale necessary.

CO₂ has been used successfully in other states for enhanced oil recovery (EOR). EOR is not likely to be a major sink for CO₂ in New York because most of the oil reservoirs in the State are less than 2500 feet deep and have many old unplugged and decrepit wells where the CO₂ might escape to the surface or into potable groundwater. There is some potential in the State for enhanced gas recovery (EGR) using CO₂. This technology could be part of the solution and provide some economic benefits. However, it is not currently known how much CO₂ could be disposed of in this manner and if producers would be willing to try this unproven concept.

Lunch, Poster Session and Keynote Address: 12:00-2:00pm

**CLIMATE CHANGE AND NEW YORK:
THE NEED FOR QUICK SCALE IN POLICY SOLUTIONS**

Peter Lehner
Natural Resources Defense Council

The immense environmental threat presented by climate change is no longer in reasonable political or scientific dispute. The science tells us that we have a short window of time, perhaps eight years or less, in which to head off the worst harms. We have therefore entered a critical period where we have to implement the necessary policy solutions at a pace and scale that will result in meaningful CO₂ reductions in the necessary timeframe. With RGGI and the Governor's 15 by '15 initiative, the State of New York has rightfully gained recognition for its willingness to adopt bold solutions. However, much more can, and needs, to be done by New York.

We need to transform our carbon-intensive state economy into a low-carbon, sustainable one through an economy-wide cap on global warming pollution that seeks to reduce greenhouse gas emissions by 25% from current levels by 2025. There are other important measures that would complement this cap, including a requirement to meet 25% of our energy needs through low carbon renewable energy by 2025 (an increase from the current level of almost 10%). We believe such a transformation is achievable, but certainly, a key component to its success will be scientific research. The State's researchers can help drive innovative, low-carbon policy solutions forward by focusing their research on particular technologies and issues that appear promising, but also potentially problematic. Examples abound, including biofuels, carbon capture and sequestration, and wind power siting, among others. We need to do these things, but we need to do them right, in an environmentally protective way, and New York's scientists, researchers, and engineers can play a pivotal role in making that happen.

**Environmental Issues Related to Alternative Energy and Emerging Technologies:
2:00-4:00pm**

**ENVIRONMENTAL MONITORING FOR A NEW CLEAN ENERGY TECHNOLOGY: KINETIC
HYDROPOWER AND THE ROOSEVELT ISLAND TIDAL ENERGY (RITE) PROJECT**

Ron Smith
Verdant Power, Inc.

The Roosevelt Island Tidal Energy (RITE) Project is the first application of kinetic hydropower systems (KHPS) in the United States. These systems use "free-flow" turbines or other energy conversion devices deployed underwater to capture the kinetic energy in natural flowing water currents (kinetic hydro) of tides, rivers, or manmade channels to generate electricity. Mechanical power from the turbines is applied through speed increasers, generators, and underwater cables to shore-based switchgear and transformers for grid connection or on-site power. The energy systems do not require dams, impoundments, or major civil works and are expected to have minimal environmental impacts.

Verdant Power has been involved in developing KHP tidal systems for the past seven years and has two KHPS projects currently underway. In partnership with the New York State Energy Research and Development Authority (NYSERDA), Verdant Power has been working on the RITE Project for the past 5 years. In December 2002 and January 2003, Verdant Power deployed a prototype, axial-flow free-flow turbine (the Kinetic Hydro Energy Conversion System or KHECS) in the East River of New York City for 21 days to assess turbine operational performance and East River tidal flows. After significant redesign and gradually navigating the permitting process, Verdant Power deployed a test array of six free-flow turbines during the spring of 2007 in the East River delivering a peak of approximately 150-200 kilowatts of electricity for use by customers on Roosevelt Island, New York City. Following project licensing from the Federal Energy Regulatory Commission (FERC), the project will be built-out to 5-10 megawatts. This project aims to be the first application of a multi-turbine kinetic hydropower system in the world.

This presentation describes the environmental monitoring process for permitting and, ultimately, licensing the RITE Project, focusing on the deployment of the initial six turbine study array to empirically assess the environmental and aquatic impacts of these new slow rotating turbines.

POST CONSTRUCTION WILDLIFE MONITORING AT MAPLE RIDGE WIND FARM

David Mizrahi, New Jersey Audubon Society
William Evans, Old Bird, Incorporated
D. Scott Reynolds, Northeast Ecological Services
Robert Fogg, New Jersey Audubon Society

The presentation provides an overview of the project. The project goals are to provide data and analyses that assist in the accurate and cost-effective determination of impacts to birds and bats (e.g., collision mortalities) at wind sites in New York, relate those impacts to forecasted numbers based on pre-construction monitoring, and provide findings to others interested in assessing impacts on wildlife at wind facilities.

Specifically, the project objectives are to: 1) quantify relationships between risk (i.e., potential of birds/bats colliding with a wind turbine) and effect (i.e., mortality); 2) determine relationships between pre- and post-construction risk assessments; and 3) evaluate the accuracy and efficacy of assessment methods. The focus of the project is the wind power facility at Maple Ridge, Lewis County, NY that operates 196, 1.65 MW, wind turbine generators.

To meet the project's objectives, we use a dual radar system that collects data in the horizontal and vertical planes simultaneously. Collecting data in the two planes is a widely used method for assessing passage densities/rates (horizontal, vertical), flight direction and velocity (horizontal), and altitudinal distribution (vertical). Our system automatically archives radar images to a computer, which allows for greater amounts of data to be collected with reduced effort, post collection data processing and analysis, and a mechanism for post collection verification of target origins (e.g., bird, bat, insect) and analysis results.

Although radar is very efficient at documenting the passage rate, altitude and flight direction of flying animal targets, typical marine radar configurations are not effective at distinguishing between target types (e.g., birds and bats). To address this shortcoming, we use state-of-the-art acoustic detection equipment to obtain independent indices of passage and relative proportions of

migratory birds and bats. Acoustic detection also provides an independent index for relative migration altitudes of birds and bats in the lower stratum of the atmosphere. We also use night vision enhancing optical equipment, designed to military specifications, to estimate passage, flight direction, and the relative proportions of migratory birds and bats flying through the study area. The latter provides a method for discerning the relative contribution of birds and bats to radar passage estimates. Finally, we employ a recently developed and promising acoustic system to detect flying animal collisions with wind turbines, which potentially offers an independent mechanism for estimating mortality from wind turbines.

The strength of this project is in its pairing of independent methods for assessing passage rates and relative altitudes of birds and bats, and the testing of an independent method for monitoring mortality. Redundancy in methods was a priority recommendation from experts at the August 2006 New York Wind/Wildlife Technical Workshop because this can improve confidence in the data from specific monitoring methods and strengthen the overall conclusions of a study.

To date the study has collected data during spring and fall 2007 migration periods. Researchers will provide several examples that demonstrate the efficacy of a multi-methodological approach to monitoring potential affects of wind power development on aerial vertebrate biota.

COMPARATIVE ANALYSIS OF ELECTRICITY GENERATION EFFECTS ON WILDLIFE POPULATIONS: A SYNTHESIS (WORK IN PROGRESS)

James R. Newman, Environmental Bioindicators Foundation and Pandion Systems, Inc.
Ed Zillioux, Environmental Bioindicators Foundation
Christian Newman, Pandion Systems, Inc.
Bill Warren-Hicks, EcoStat, Inc.

The presentation will review a New York State Energy Research and Development Authority (NYSERDA)-commissioned study of the effects of electricity generation (including wind, coal, oil, gas, nuclear, and hydro electricity) on wildlife. The Environmental Bioindicator Foundation, Inc. (EBIF) and Pandion Systems, Inc. collected, reviewed, and synthesized available scientific information on the wildlife effects, intergrading Life Cycle Analysis (LCA) and Ecological Risk Assessment (ERA) approaches. An Exposure/Effects Ranking Index was developed to identify and rank the effects and risks for each life cycle (LC) stage of these electricity generation types. The study is a “work in progress.” Therefore, the presentation will discuss only preliminary results and conclusions.

All types of electricity generation affect wildlife to some degree or another. These wildlife effects can be direct or indirect and can be manifested locally, regionally, and nationally. The primary endpoint in evaluating these effects is the degree to which wildlife populations are compromised. Effects at the individual level are important to the extent that they indicate a potential population-level effect, or if the species population is classified as endangered or threatened. Population effects to wildlife outside the New York and New England region are associated with the Extraction and Transportation LC Stages. The Operational LC Stage (i.e., electricity generation) generally results in most adverse effects to wildlife populations. These effects are also associated with global effects, e.g., climate change. Coal, oil, and gas sources of electricity generation present more wildlife risk than hydroelectric energy and wind energy generation sources, due to the greater number of wildlife stressors.

The wildlife effects of electricity generation from wind act locally, but are not considered a risk to wildlife populations with the possible exception of bats. The Transmission of Electricity, the fourth LC Stage, has both local and regional risks to wildlife but these risks are not considered population level risks. The LC Stages of wind have fewer stressors and have fewer wildlife risks than other forms of electricity generation. The specific wildlife effects and risks to individuals and populations from wind and other forms of electricity generation to New York and New England wildlife will be discussed. A synthesis report will be prepared for use by different stakeholder groups, including industry, and the public and private sectors.

**EMERGING CLEAN COAL TECHNOLOGIES:
IMPROVING THE ENVIRONMENTAL IMPACT OF COAL POWER GENERATION**

Michael Slanders
United States Department of Energy, Office of Clean Energy Systems

As world energy demand continues to increase steadily, we must look towards innovative ways to utilize our abundant resources in an ever-more-acceptable and environmentally friendly manner. Coal represents the world's most abundant fossil fuel, and is expected to play a key role in satisfying the worldwide energy demand in the future, particularly in rapidly developing Asia. The ability to cost-effectively utilize coal for power generation, while minimizing environmental impacts is critical to sustaining affordable, reliable, and clean energy. This presentation examines the challenges facing emerging clean coal technologies and their ability to achieve environmentally acceptable and economically competitive power generation. The technologies covered include integrated gasification combined cycle, advanced combustion, and sequestration. Each emerging technology offers specific advantages over conventional coal combustion, yet each also faces hurdles to overcome towards achieving commercial acceptance. The presentation will address these topics, as well as the Department of Energy's large-scale validation of near-zero emissions coal power production.

Day 2: Friday, November 16, 2007

Session A: Air Quality and Related Health Research: 8:30am-12:00pm

CARBONACEOUS AEROSOLS IN NYS AND THEIR CONTRIBUTIONS TO PM_{2.5}

Kenneth L. Demerjian
Atmospheric Sciences Research Center, SUNY, University at Albany

The presentation addresses the analyses of filter based speciation measurements of the carbon mass fraction of urban and regional PM_{2.5} across New York State. The seasonal composition of PM_{2.5} in the New York metropolitan area is compared with other major urban centers, and the source of observed differences explored. Pollutants from primary mobile source emissions measured at distances > 500m downwind of a major highway in New York City (NYC) suggest significant population exposures from a variety of chemical species, including PM_{2.5} organics. These observations suggest the potential for high exposures to air toxics within such impacted areas. In addition, we revisit the contribution of volatile organic compound precursors to secondary organic aerosol production and the potential contribution of biogenic compounds to the PM_{2.5} organic mass fraction in NYC.

SEASONAL PATTERNS OF ORGANIC MOLECULAR MARKERS IN AMBIENT AEROSOLS AROUND NEW YORK CITY AND CLUES TO THEIR SOURCES

Monica A. Mazurek, Department of Civil & Environmental Engineering
Rutgers, The State University of New Jersey

The Speciation of Organics for Apportionment of PM_{2.5} in the New York City Area (SOAP) project was conducted at four sites in New York City, New Jersey, and Connecticut from May 2002 to May 2003. The principal objectives were to expand the chemical characterization of organic compounds and to estimate the source contributions of carbonaceous fine particles at urban and background monitoring sites. Samples were collected with a Tisch TE-1202 sampler for 24 hours, from midnight to midnight every third day, following a sampling schedule that was identical to that used by the Speciation Trends Network. Seasonal sample composites were obtained by combining five to ten 24-hour samples at least once per season at each site. Approximately 100 organic molecular markers were screened in the organic complex mixtures extracted from the fine particle filter composites using Gas Chromatography/Mass Spectrometry chemical analysis.

Distributions of some key groups of molecular markers produced unexpected findings. For example, the spatial and seasonal distributions of C10 to C20 *n*-alkanoic acids in the metropolitan NYC area demonstrated the influence of local sources, such as commercial cooking oils, lards, fats, and greases for deep-fat frying, as contributors to PM_{2.5} mass. In addition, the seasonal and spatial ambient mass concentrations of levoglucosan, a molecular marker for fuels composed of cellulose (e.g., wood, cardboard, paper), showed an unexpected pattern. The Queens, NYC receptor site had the highest concentrations throughout the 2002-2003 annual cycle, compared to Chester, NJ, Elizabeth, NJ and Westport, CT. Unknown local emissions sources affected the Queens location and could likely have been generated from refuse burning, home heating, commercial kitchens, and street vendors.

The results of the SOAP 2002-2003 field campaign provide new evidence for further development of emission inventories for the metropolitan New York area. The SOAP project provides information that contributes to improving and validating NY State emission inventories and to controlling fine particle concentrations from energy production and use in local and regional NY State airsheds.

ASSESSMENT OF CARBONACEOUS PM_{2.5} FOR NEW YORK STATE AND THE REGION

John Graham, Project Manager
Northeast States for Coordinated Air Use Management

This presentation draws on information from a comprehensive assessment report of the carbonaceous fraction of ambient fine particulate matter (PM_{2.5}) in New York State. The report was developed around the central science/policy questions of the session to assess the importance of carbonaceous PM_{2.5} to ambient PM and public health, and to delineate available strategies for emission reductions. It is structured in three chapters: 1) atmospheric science and emission sources; 2) human health effects; and 3) control technologies and strategies.

Analyses of ambient data collected in New York State show the carbonaceous components of fine particulate matter (PM_{2.5}) comprise a significant fraction of measured mass and much of that aerosol comes from in-state sources. There are appreciable spatial and temporal variations in measured carbon aerosols. On an annual basis, organic carbon (OC) constitutes between a fourth and a third of the ambient PM_{2.5} mass, with elemental carbon (EC) contributing as much as 8% of total PM_{2.5} at urban sites. Seasonally, contributions range a bit wider, while individual 24-hour measurements can be nearly all carbonaceous. OC levels peak in summertime across the State, driven by increased photochemical activity that also results in increased ozone levels, while EC levels tend to be flat with some evidence of wintertime increases at urban sites with abundant local motor vehicle sources.

On average, urban areas measure higher levels of carbon aerosols than more remote regions. For both OC and EC, significant gradients exist across the metropolitan areas. Comparing OC measurements across New York City, the maximum seasonally averaged OC concentration can be 50% greater than the minimum measured levels. Seasonally averaged EC concentrations at the site with maximum levels can be nearly twice as high as at the site with the minimum. These intra-urban differences offer a lower-bound estimate of highly-local impacts of carbon aerosol emissions. Local EC contributions reach as high as 85% of monitored EC in urban areas. Local urban OC contributions generally do not exceed two-thirds of the ambient urban OC levels. The more-regional nature of OC may be due, in part, to the fact that it is both a primary pollutant (e.g., directly emitted) and a secondary pollutant (one formed in the atmosphere), as well as the large diversity of contributing source categories. Uncertainties associated with the relative importance of primary and secondary contributions to OC complicate researchers' ability to accurately attribute the contribution of sources to ambient OC.

CARBONACEOUS MATTER IN AIR QUALITY MODEL APPLICATIONS

Gopal Sistla, Prakash Doraiswamy*, Kevin Civerolo, Christian Hogrefe, and Winston Hao
New York State Department of Environmental Conservation

Ambient measurements of fine particulate matter (PM_{2.5}) speciation data over New York State indicate that sulfate, nitrate, and metals make up between 40 and 70% of the measured mass, with the remainder mainly comprised of organic and elemental carbon. Emission sources and chemical and physical processes that contribute to the formation of sulfate and nitrate are reasonably well known; hence, efforts to mitigate their effects have been underway for decades. Such is not the case with PM_{2.5} carbon, whose sources are far more varied, and composition far more complex. In this presentation, we discuss some of the gaps in our understanding of PM_{2.5} carbon from a modeling perspective. We compare CMAQ-based estimates of carbon concentrations to those measured at two locations in New York State, and discuss the limitations of such a comparison and issues associated with its mitigation.

**On assignment to NYSDEC from ASRC, University at Albany*

SEMIVOLATILE EMISSIONS AND PHOTOCHEMICAL AGING: IMPLICATIONS FOR HUMAN EXPOSURE AND CONTROL STRATEGIES

Allen L. Robinson, Center for Atmospheric Particle Studies, Carnegie Mellon University

Organic aerosols constitute a major component of fine particle mass ($PM_{2.5}$), but current regulatory strategies focus on the inorganic components of $PM_{2.5}$ because of uncertainty in the sources of the organic fraction. Organic aerosols are either directly emitted by sources (primary organic aerosol) or formed in the atmosphere from low volatility reaction products of gas-phase compounds (secondary organic aerosol). One prevailing conceptual model is that primary emissions from anthropogenic sources such as motor vehicles, wood combustion, and cooking dominate the organic aerosol budget in urban areas. However, field evidence indicates that organic aerosol concentrations are dominated by oxygenated organics that are thought to be associated with secondary production. The source of these oxygenated organic aerosols is not well understood.

This presentation discusses recent field, laboratory, and modeling results to illustrate the effects of semi-volatile emissions on the organic aerosol budget. The results reveal a dynamic picture in which low-volatility organics emitted by combustion systems evaporate, oxidize, and re-condense as they are transported away from the source. Accounting for these processes in a chemical transport model dramatically alters the predicted primary-secondary split and brings the model results into agreement with the field measurements of oxidized organic aerosols. The presentation concludes with a discussion of the implications of these recent findings on human exposures and the design of regulations to control organic aerosols.

HEALTH EFFECTS AND EXPOSURE RISK OF WOOD SMOKE

Philip R. S. Johnson, Yale University

Exposure to residential wood combustion (RWC) emissions presents an ongoing public health concern because of the known toxicity of wood smoke, a source rich in carbonaceous fine particulate matter ($PM_{2.5}$) and gaseous compounds. Across the U.S., upwards of 80% of the current woodstove fleet was manufactured without efficient combustion designs or particulate controls required in devices built since 1990. In large part because of this slow turnover rate, aggregate emissions from RWC represent one of the largest current sources of ambient $PM_{2.5}$ in North America. Moreover, the growing use of outdoor wood boilers presents a new threat to public health because these devices, exempt from federal wood stove PM emission standards, burn year round and have low stacks and primitive emissions controls.

Residents of the Northeast Census Region (including New England, NJ, NY, and PA) could experience elevated wood smoke exposures because of the region's heavy wood burning use and terrain and demographic features. The 9-state region consumes over twice the number total cords of wood in woodstoves per year than the Midwest, South, or West, while New England has the highest per capita indoor woodstove ownership in the country. Rooted in a colonial economy based on mechanical water power, much of the rural Northeast today consists of densely populated hamlets and towns whose residents live in river valleys and drainage corridors conducive to the formation of inversions that trap wood smoke.

The non-urban mid-Atlantic and Northeastern region is likely home to numerous hotspots. Drainage basins and mountainous areas with population centers are dominant in many parts of the

region. It is possible these areas experience frequent diurnal inversion events in wintertime and early spring when wood stove burning is common. During an inversion, a small number of woodstoves can exert a disproportionate effect on local air quality compared to other PM_{2.5} sources. This effect has been observed across a wide range of non-urban population centers, from sparsely populated hamlets to densely populated small cities.

A preliminary approximation of the magnitude of exposure to RWC emissions across a prescribed area (e.g., state or region) could be conducted by compiling and analyzing existing datasets. Such a study would first identify areas where RWC emissions occur and where hotspot areas are located. Useful datasets include activity use information (demographic, complaint, and emissions inventory) and physical information (topographic, meteorological, source apportionment, emissions measurement). This information would then position the subsequent use of modeling to estimate wood smoke emissions in selected areas, with the option of applying targeted pollution measurements. The integrated analysis of these different indicators of RWC could present a more complete picture to assess the potential for exposure across a large area.

COMPARING THE ACUTE RESPIRATORY EFFECTS OF PM_{2.5} COMPONENTS: RECENT RESULTS FOR NYC

Patrick Kinney
Mailman School of Public Health, Columbia University

The objective of the study was to compare associations between different components of ambient fine particulate matter (PM_{2.5}) and respiratory symptoms and emergency visits for asthma. Since traffic emissions are a local driver of PM_{2.5} in cities, black carbon (BC, a measure of traffic-related particles) may be an important driver of respiratory effects in urban settings. Further, because 90% of particles are ultrafine particles (UFP, <0.1 mm diameter), it is critical to test the relative impacts of UFP on respiratory responses.

Over three weeks, symptom diaries were completed by 58 students attending an urban high school located 34 meters from a major trucking thoroughfare in NYC. Outdoor PM_{2.5} mass concentration was monitored using a beta attenuation monitor. BC mass was monitored using an aethalometer. UFP numbers were monitored using a scanning mobility particle sizer. In a separate study, daily emergency room visits in the Bronx and Manhattan were analyzed in relation to PM_{2.5} and BC concentrations over a two-year period.

Temporal changes in BC were significantly correlated with PM_{2.5} ($r = 0.81$, $p < 0.0001$) and UFP ($r = 0.69$, $p = 0.0007$). UFP and PM_{2.5} were not significantly correlated. Among a majority of subjects, average PM_{2.5}, BC, and UFP were higher on days when wheeze was reported, compared with days when wheeze was not reported. In repeated measures analyses, there was a higher association between BC and wheeze, cough, shortness of breath, and chest tightness, relative to PM_{2.5} and UFP numbers. The odds ratio (OR) (95% CI), which describes the association between a 1 µg/m³-increase in the daily average BC and wheeze was 1.05 (0.93, 1.19). The OR for a 1 µg/m³-increase in PM_{2.5} was 1.00 (0.99, 1.03) and 1.01 (0.97, 1.05) for 10,000 particle/cm³ increase in UFP. By contrast, emergency room visits were more strongly associated with PM_{2.5} concentrations than with BC.

The symptom results suggest that particles from traffic may be a more relevant indicator of acute respiratory symptoms than PM_{2.5}. Results for emergency room visits, on the other hand, showed stronger effects for PM_{2.5}. Possible reasons for this discrepancy are discussed in the presentation.

**NYSERDA'S CLEAN DIESEL TECHNOLOGY FIELD TESTING PROGRAM:
EVALUATION OF NOVEL PM AND NOX CONTROL TECHNOLOGIES
ON DIESEL CONSTRUCTION EQUIPMENT**

Tim Hansen, William Crews, Staci Haggis, and Kevin Hicks, The Southern Research Institute
Barry Liebowitz, NYSERDA
Thomas Lanni, NYSDEC, Bureau of Mobile Sources and Technology Development

Non-road diesel equipment is the single largest contributor of mobile source-based diesel particulate matter in New York City. To address this, NYSERDA has sponsored several development and demonstration programs targeting clean diesel technologies focused on particulate and NO_x reductions for priority equipment types and geographic areas in NYS. NYSERDA's Clean Diesel Technology Field Demonstration Program was implemented to identify target non-road equipment types, evaluate the feasibility of PM and NO_x emission control strategies, and demonstrate and test the performance of a variety of control strategies under real-world operating scenarios.

An inventory of non-road diesel emissions for NYS and the New York City Metropolitan Area (NYMCA) was developed and refined based on survey data obtained from equipment owners and operators. Results of the non-road inventory indicate that 54% of NYS non-road diesel PM emissions originate in the NYCMA, and that construction and mining equipment is responsible for 62% of the non-road diesel PM emissions in the NYCMA. The inventory results were utilized to prioritize the demonstration program, focusing on 4-5 diesel-construction equipment types operated in the NYCMA.

A summary of available technologies for diesel emissions control was developed, with the feasibility of application to non-road, diesel-construction equipment evaluated via analysis of the emission reduction performance, economics, operational impacts, installation and maintenance requirements, and other factors. Based on this analysis, six different classes of control strategies were selected for implementation in 27 different installations. Currently, nine technologies have been tested with an additional six scheduled evaluations in November 2007. Tests have been completed on five different equipment types, including front-end loaders, articulated dump trucks, and skid steer loaders. Control technologies evaluated include passive or active diesel particulate filters, flow-through diesel particulate filters, diesel oxidation catalysts, and biodiesel.

Control strategies were evaluated for relative reductions of CO, CO₂, NO_x, THC and PM emissions. In addition, elemental and organic carbon, NO, and NO₂ were evaluated. Engine parameters were recorded to document in-use test-cycle characteristics and evaluate cycle-to-cycle repeatability and consistency. The economic, installation, and operating requirements were also evaluated and documented for each strategy. These requirements varied widely depending on technology type and equipment application. Ultimately, a variety of feasible strategies, in terms of performance and economics, were demonstrated. Testing programs were conducted utilizing the *Generic In-Use Emission Testing Protocol for Off-Road Equipment* developed by Southern with input from industry and government experts.

RECENT TRENDS IN ATMOSPHERIC DEPOSITION IN NEW YORK

Doug Burns, Director National Acid Deposition Assessment Program, USGS
Thomas J. Butler, Institute of Ecosystem Studies and Cornell University

Data from precipitation sampling sites in New York indicate that the acidity of precipitation peaked in the late 1970s and has been declining since that time. Most of the decrease from the late 1970s through the late 1990s was driven by decreases in sulfuric acid concentrations in precipitation. As of the late 1990s, nitrate concentrations had not decreased significantly at precipitation sites across New York. Since 2002, however, nitrate concentrations have decreased markedly at these sites. As of 2006, the acidity of precipitation was less than half of the peak values in the late 1970s. These changes in precipitation chemistry are closely related to decreases in SO₂ and NO_x emissions from stationary sources located upwind, primarily in the Ohio River Valley. Decreases in these stationary source emissions were mandated first by the original Clean Air Act of 1970, and additional decreases of emissions have resulted from Title IV of the Clean Air Act Amendments of 1990. Emissions of SO₂ and NO_x are expected to continue to decrease in the future as mandated by the Clean Air Interstate Rule, which should result in continued decreases in precipitation acidity in coming years.

CHANGES IN WATER CHEMISTRY OF LAKES IN THE ADIRONDACK REGION OF NYS

K.M.Roy, New York State Department of Environmental Conservation
C.T.Driscoll, Syracuse University
K.M. Driscoll, Syracuse University
J. Dukett, Adirondacks Lake Survey Corporation

Long-term changes in the chemistry of wet deposition and lake water were investigated in the Adirondack region by the Adirondack Long-Term Monitoring (ALTM) program. Marked decreases in concentrations of SO₄²⁻ and H⁺ have occurred in wet deposition since the late 1970s. These decreases are consistent with long-term declines in emissions of SO₂ in the eastern US. Changes in wet NO₃⁻ deposition and NO_x emissions have been minor over the same interval. Virtually all Adirondack lakes have exhibited large decreases in concentrations of SO₄²⁻, which coincide with decrease in atmospheric S deposition. Since 1992, concentrations of NO₃⁻ have also decreased in many (27 of 48) Adirondack lakes. As atmospheric N deposition has not changed appreciably over this period (1992-2004), the mechanism contributing to this apparent increase in lake/watershed N retention is not evident. The Decrease in concentrations of SO₄²⁻ + NO₃⁻ have resulted in increases in acid neutralizing capacity (ANC; 37 of 48 lakes), and decreases in concentrations of inorganic monomeric Al, particularly in acid-sensitive lakes. Concentrations of dissolved organic C (DOC) have also increased in some (15 of 48) lakes coinciding with decreases in acid deposition. Examination of changes in lake chemistry by hydrologic classes revealed that drainage lakes in watersheds with thin deposits of glacial till, and mounded seepage lakes, have generally been the most responsive to decreases in acidic deposition.

TRENDS IN STREAMS AND SOILS OF THE ADIRONDACK REGION

G.B. Lawrence, United States Geological Survey
K.M. Roy, New York State Department of Environmental Conservation
B.P. Baldigo, United States Geological Survey
H.A. Simonin, New York State Department of Environmental Conservation
S.B. Capone, Adirondack Lakes Survey Cooperation
J.W. Sutherland, Nantucket, MA
S.A. Nierzwicki-Bauer, Rensselaer Polytechnic Institute
C.W. Boylen, Rensselaer Polytechnic Institute

Evaluation of trends is an essential component of environmental assessment programs. These types of data are necessary for the development and verification of predictive models, and ultimately provide the information needed to evaluate the effectiveness of environmental policies. Although a large-scale program for monitoring Adirondack lake chemistry has provided valuable data since 1982, no such program exists for streams or soils. Nevertheless, streams are more prone than lakes to acidification from acidic deposition, and the base status of soils is a key factor in the recovery of surface waters, as well as in the long-term health of forests. Some information on stream chemistry is available from re-sampling of streams in 2003-2005 that had been previously sampled in the early 1980's. Acid-neutralizing capacity by Gran titration (ANC_G) and pH tended to be higher in the samples from 2003-2005 than in the samples from the early 1980's, but the difference was difficult to quantify because other factors that can affect stream chemistry, such as flow, could not be fully controlled in the comparison. Monitoring of ANC_G and pH in two western Adirondack streams from 1991-2001 showed increasing trends in Bald Mountain Brook, but no trends in Buck Creek. More recent stream monitoring at Buck Creek from 1998-2007 showed no trends in the base cation surplus, ANC_G or NO_3^- concentrations.

The only study to re-sample Adirondack soils to assess long-term changes found a decrease in exchangeable Ca concentrations in Oa horizons from 1930 to 1984. Samples with an original pH > 4.0 also had a lower pH in 1984 than in 1930. Relationships between high-flow stream chemistry and exchangeable soil chemistry provide further evidence that changes in base status have occurred in Adirondack soils. Neutralization of acidity in stream water during high flows was found to be more closely linked to the Oa horizon than the B horizon, despite the fact that parent material in the B horizon is considered to be the primary source of base cations. This result, coupled with much lower base saturation values throughout the B horizon than in the Oa horizon, suggests that the B horizon has become Ca depleted. Furthermore, inorganic Al concentrations in stream water were found to be related to exchangeable Al concentrations in the Oa horizon, but unrelated to exchangeable Al concentrations in the B horizon, where exchangeable Al concentrations are highest. Depletion of Ca in the B horizon may have led to upward movement of Al within the soil profile, thereby causing some degree of Ca depletion in the Oa horizon as well.

BIOLOGICAL AND FOREST HEALTH TRENDS

Myron J. Mitchell
State University of New York, College of Environmental Science and Forestry

The presentation provides a review of how sulfur and nitrogen deposition affects biotic responses, with particular emphasis on forested ecosystems and their associated surface waters in New York State. In evaluating the effects of acidic deposition on forest ecosystems, the role of mobile

anions (sulfate and nitrate) in depleting soils of base cations will be outlined. The depletion of these nutrient cations, particularly calcium, has been linked to the decline of important tree species, including sugar maple. Throughout the region, the effects of acidic deposition have been influenced by interactions among geology, soil, and vegetation. The role of these interactions in affecting spatial patterns in biotic responses to acidic deposition is discussed. For aquatic systems in the Adirondack Mountains, evidence will be provided which shows that chemical recovery has been followed by biological recovery. This biological recovery has included changes in various aquatic assemblages including fish. The evaluation of biological trends associated with the deposition of nitrogen and sulfur is complicated by other factors that are currently affecting ecosystems of the region, including climate change, herbivory, the introduction of exotic species and land use practices. The importance of including these additional factors, when ascertaining long-term trends in biological processes and forest health, will be emphasized.

CRITICAL DEPOSITION LOADS: INFORMING ENVIRONMENTAL PROTECTION STRATEGIES

Timothy J. Sullivan, E&S Environmental Chemistry, Inc.
Bernard J. Cosby, University of Virginia

Atmospheric sulfur and nitrogen deposition are decreasing throughout much of the eastern United States. Some damaged resources are showing signs of recovery from past acidification. Key questions now facing scientists and policy makers concern the prognosis for future change in soil and water chemistry and the extent to which emissions and deposition might need to be further reduced to allow full ecosystem recovery and prevent further damage. To aid in addressing these questions, model-based critical loads can be calculated for acid-sensitive resources, assuming chemical/ biological dose-response relationships. The critical load is defined as the deposition load below which harmful effects do not occur to sensitive elements of the environment according to present knowledge. Because different species respond at varying chemical levels, multiple critical loads can be calculated or applied to a given resource. Land managers are now beginning to use model-based critical load calculations to set resource protection and restoration goals for public lands.

Model calculations of critical loads are sensitive to scientific and policy judgments concerning the level of resource protection desired, over what time-period. Higher deposition loads can often be tolerated if one only wishes to protect sensitive resources in the near term, as compared with more stringent deposition reductions required to extend resource protection for a longer period. Steady-state model estimates of critical load differ from dynamic model estimates. Steady-state approaches estimate loads that will accomplish permanent protection; however, it may take centuries to attain the steady state condition, in some cases resulting in over- or under-protection in the decadal timeframe. Higher loads are allowable, for example, if one wishes to prevent water acidification to ANC = 0 (chronic acidification) as compared with a more restrictive approach designed to protect against ANC below 50 $\mu\text{eq/L}$ (likely episodic acidification in the northeast). The presentation explores aspects of applying the critical load concept to natural resource management. Examples are provided of model-based critical load calculations. We discuss ways in which these results can help to bridge the gap between science and policy.

**Session C: Science and Policy Issues Related to Mercury in the Environment:
10:30am-12:30pm**

CLEAN AIR MERCURY RULE UPDATE

Sam Napolitano
Clean Air Markets Division, Office of Air and Radiation, USEPA

This presentation provides an overview of the Clean Air Mercury Rule (CAMR) program and describes the status of EPA's implementation of the program. EPA designed the CAMR program for implementation by the states and is now reviewing state plans for the program. Additionally, EPA is finalizing a "backstop" Federal Plan to go into effect if states do not provide an approvable plan to EPA by the spring of 2008, and is developing a national mercury-monitoring network. These efforts, and other program aspects, are covered in detail in the presentation.

NYS MERCURY REDUCTION INITIATIVES

David J. Shaw
Director, Division of Air Resources, NYS Department of Environmental Conservation

WET DEPOSITION MERCURY TRENDS IN NORTH AMERICA

David A. Gay, University of Illinois & National Atmospheric Deposition Program
Eric Prestbo, Tekran Instruments Corporation

One of the most critical measurements needed to understand the biogeochemical cycle of mercury, and to verify emission-source attribution models, is the rate of atmospheric deposition. The Mercury Deposition Network (MDN), part of the National Atmospheric Deposition Program (NADP), operates sites across North America to monitor total mercury in wet deposition. MDN's primary goal is to provide both spatial and temporal trends in mercury wet-deposition fluxes to support analysis by scientists, modelers, and policy makers.

Annual summaries from weekly data collected at 100 locations are reported for the years 1996-2005. Volume-weighted total mercury concentrations are lowest at remote sites in northern California/Oregon and the Canadian Maritime Provinces (4 to 6 ng/L), with the highest concentrations in Florida, Minnesota, and several Southwest locations (10 to 16 ng/L). Wet deposition of mercury depends on both the concentration in the rain and the total rainfall amount. Wet deposition of mercury ranges from over 25 mđg/m² yr in south Florida to less than 3 mđg/m² yr in northern California. Mercury deposition is strongly seasonal in eastern North America, with summer concentrations about double that found in the winter, and average summer wet deposition more than three times higher in summer than in winter. Significant decreasing concentration trends were noted at about half of sites, particularly across Pennsylvania through the Northeast. Seven primarily Atlantic coast sites had depositional decreases, with several sites showing increases.

The presentation will also provide an update about a newly developing NADP network, which has the following objectives: 1) determining the status and trends in concentrations of

atmospheric mercury fractions (reactive gaseous, particulate-bound, and elemental) in select locations; 2) offering high-quality measurement data to estimate dry and total deposition of atmospheric mercury to aquatic ecosystems and other locations influenced by emissions and transport on the local, regional, and global scale; and 3) offering high-quality data necessary for atmospheric mercury model evaluation and development.

ECOLOGICAL EFFECTS OF MERCURY DEPOSITION IN THE ADIRONDACK REGION OF NEW YORK: CRITICAL ISSUES FOR RECOVERY

Charles T. Driscoll, Jason Dittman, Pranesh Selvendiran, and Ryan Adams, Syracuse University
Jason Demers, Cornell University
Hyun-Deok Choi and Thomas M. Holsen, Clarkson University
Joseph T. Bushey, University of Connecticut
David Evers, BioDiversity Research Institute

The presentation will provide a synthesis of multi-disciplinary research on atmosphere-forest Hg dynamics and the effects on ecosystems in the Adirondack region of New York, including factors regulating recovery following emission controls. The Adirondacks have exhibited marked changes in net Hg deposition since about 1900, including decreases since the 1970s. Recent analysis shows that the western/central Adirondacks is a biological Hg hotspot due to the shallow soil within the forested landscape, abundant wetlands, and unproductive lakes. Litterfall is the dominant influx pathway of Hg ($\sim 17 \mu\text{g}/\text{m}^2\text{-yr}$) to the Adirondacks, with throughfall nearly balanced by soil evasion losses, including the major loss via soil accumulation ($\sim 15 \mu\text{g}/\text{m}^2\text{-yr}$). Limited drainage losses of ionic Hg are converted to methyl Hg largely in wetlands, particularly during the summer growing season, which supplies downstream surface waters. But a question remains as to how Adirondack watersheds have responded to recent decreases in atmospheric Hg deposition, and how will they respond to anticipated future decreases. A recent resurvey of 25 Adirondack lakes shows the water columns have largely exhibited decreases in total and methyl Hg concentrations, while changes in the Hg content of yellow perch have been mixed. These changes appear linked to changes in the DOC concentrations and the acid-base status among the lakes. Critical issues for the recovery of Adirondack ecosystems are the effects of changes in atmospheric Hg, SO_4^{2-} and NO_3^- deposition, changes in DOC and its influence of Hg bioavailability, and the legacy of Hg accumulated in soils.

INVERTIVORE METHYLMERCURY EXPOSURE AND SENSITIVITY: PAST ASSUMPTIONS, CURRENT FINDINGS

David C. Evers, Melissa Duron, Dave Yates and Oksana Lane, BioDiversity Research Institute
Daniel A. Cristol, College of William and Mary
John Schmerfeld, U.S. Fish and Wildlife Service
Bart Hoskins, U.S. Environmental Protection Agency
Robert J. Taylor, Texas A&M University

Past assumptions of methylmercury exposure and sensitivity in birds and mammals are overly simplistic. Recent efforts to dispel assumptions stem from empirical laboratory and *in situ* findings. Risk of methylmercury exposure is generally considered greatest in piscivorous taxa, particularly those that are long lived. While biomagnification and bioaccumulation of methylmercury is well documented in piscivores, it has not been well-established in invertivores. Our findings demonstrate that many avian and mammalian invertivores can regularly equal or

exceed methylmercury body burdens in associated piscivores. Forage guild also plays an important role in a bird's sensitivity to methylmercury. Species that have coexisted with elevated levels of methylmercury (e.g., marine piscivores) likely have a greater tolerance than those with historically minimal interactions (e.g., terrestrial invertivores). Recent anthropogenic changes in the rate and distribution of mercury emissions and deposition could place many species at greater risk than realized. Many invertivores, such as wetland songbirds and aquatic-foraging bats, represent taxa groups that may be both at an increased risk and increasingly sensitive to methylmercury exposure than piscivores. Therefore, federal environmental programs assessing mercury risk and injury need to better incorporate bird and bat species that reflect the greatest potential risk of methylmercury exposure.

**Environmental Issues Related to Alternative Energy and Emerging Technologies
(continued from Day 1): 1:45-3:30pm**

**SMALL AND MEDIUM SCALE BIOMASS COMBUSTION: POLLUTANT
FORMATION, POLLUTANT REDUCTION, AND APPLICATIONS FOR
RESIDENTIAL HEATING AND DISTRICT HEATING**

Thomas Nussbaumer
University of Applied Sciences Lucerne, Switzerland

Biomass combustion is widely applied for residential heating in stoves and boilers, district heating in automatic combustion plants, and combined heat and power production in industrial scale boilers. For small-scale applications, fuelwood is currently the principal source of biomass today, with an increasing interest in wood pellets. For medium-scale applications, wood chips are the most common fuel source. The technologies of current combustion systems are presented and their relevance to pollutant emissions are discussed. For this purpose, the characteristics of wood as a fuel and the reactions during wood combustion are presented. It is shown that biomass combustion is related to relatively high pollutant formation due to two reasons, discussed below.

First, an incomplete combustion can lead to high emissions of unburnt pollutants, i.e., CO, VOC, PAH, soot, and condensable organic matter. A significant reduction of unburnt pollutants can be achieved through a two-stage combustion, with a gasification of the wood with primary air, and a subsequent gas-phase oxidation with secondary air. This technology is being applied to modern boilers, while only limited improvements have been achieved for wood stoves so far. Further, the type of operation of manually-operated wood combustion strongly influences the emissions in practice.

Second, inorganic particles and NO_x are formed as a result of fuel constituents (N, K, Cl, Ca, Na, Mg, S and others). Hence, biomass combustion exhibits relatively high emissions of particles and NO_x. Air staging and fuel staging offer a limited potential to reduce NO_x, while staged combustion by low excess air and reduced temperatures in the primary zone can result in a reduction of inorganic particles. Furthermore, additional options, such as particle separation and selective NO_x reduction, are available as secondary measures.

An investigation of the toxicology of different combustion particles revealed that particles from the incomplete combustion of wood exhibit a far-higher health relevance than Diesel soot, while inorganic particles from the near-complete combustion of wood exhibit a significantly lower toxicity than Diesel soot.

BIOPOWER – TECHNOLOGY AND POLICY CHALLENGES

Edward E. Gray
Antares Group Incorporated

Biomass resources are diverse, as are the technologies that can be employed for energy conversion. Although biomass feedstocks can be used to provide a range of different products such as heat, electricity, fuels, and chemicals, the focus of this presentation is biopower technologies. This presentation will look at some of the key environmental issues related to biopower: greenhouse gas potential, criteria pollutant emissions and sustainable biomass production and use. It will also examine the environmental benefits and challenges particular to bioenergy development and use, and the implications for policy decisions.

ETHANOL/BIODIESEL: CHALLENGES AND OPPORTUNITIES

Carl J. Mas, New York State Research and Development Authority
James J. Winebrake, Dept. of STS/Public Policy, Rochester Institute of Technology

The ethanol and biodiesel industries have seen unprecedented growth over the past ten years, fueled in part by State and National initiatives and growing public concern over energy security and climate change. This presentation discusses recent work sponsored by the New York State Energy Research and Development Authority (NYSERDA) aimed at better understanding the energy and environmental impacts associated with the use of these fuels. In particular, we present the preliminary results of a literature review conducted by the Pace Energy Project that examines total fuel cycle analyses for each fuel, focusing on: net-energy-ratio, greenhouse gas emissions, air pollutants, and land-use impacts. We also present the results from the recently developed New York Greenhouse gases, Regulated Emissions, and Energy use in Transportation (NY-GREET) model. This model allows users to evaluate total fuel cycle energy use and emissions of various alternative fuels in a New York State context.

BIOGAS: ENVIRONMENTAL PERFORMANCE OF BIOGAS SYSTEMS

Kurt Roos
United States Environmental Protection Agency