Improving Estimates of Air Pollutant Emissions in the Northeast and Mid-Atlantic States: A Workshop Report and Summary

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Workshop Sponsors

NARSTO co-sponsored this workshop to help bring a regional focus to recommendations made in the 2005 NARSTO report *Improving Emission Inventories for Effective Air Quality Management Across North America*. NARSTO is a public-private partnership dedicated to improving management of air quality in North America. It was established on February 13, 1995 when representatives of Canada, the United States, and Mexico signed the NARSTO Charter in a ceremony at the White House.

Workshop co-sponsors were three NARSTO members: the New York State Energy Research and Development Authority (NYSERDA), the Mid-Atlantic Regional Air Management Association (MARAMA), and the Northeast States for Coordinated Air Use Management (NESCAUM).

NYSERDA’s Environmental Monitoring, Evaluation, and Protection (EMAP) Program provides policy-relevant research aimed at enhancing the understanding of electrical energy-related pollution and its impacts on the environment and human health, characterizing relative impacts of electrical energy production sources, and evaluating ways to mitigate the impacts of electrical energy use and production.

MARAMA members represent seven Mid-Atlantic states, two local areas, and the District of Columbia. MARAMA provides training and technical support and encourages regional approaches to improve air quality in the region. MARAMA also provides support for the Mid-Atlantic Diesel Collaborative.

NESCAUM’s purpose is to provide scientific, technical, analytical, and policy support to the air quality and climate programs of the eight Northeast states. NESCAUM also provides forums for public education, promotes research initiatives such as the Northeast Center for Atmospheric Science and Policy (NCASP) and the Northeast Diesel Collaborative (NEDC), and hosts the Clean Air Academy, which provides advanced air quality training for state officials.

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Table of Contents

1 Summary and Recommendations ................................................................. 1
   Introduction........................................................................................................ 1
   Improving Estimates of On-road Mobile Source Emissions............................... 4
   Improving Estimates of Emissions from Non-road Mobile Sources.................. 5
   Improving Estimates of Emissions on High Electricity Demand Days................ 6
   Improving Estimates of Emissions from Space Heating with Liquid Fuels.......... 8
   Improving Estimates of Emissions from Space Heating with Biomass............... 9
   Improving Estimates of Agricultural Ammonia Emissions............................... 12
   Key Recommendations for Short-Term Improvements in Emissions Estimates for the Region........................................................................................................ 15

2 Preface ............................................................................................................. 17
   Background.......................................................................................................... 17
   Workshop Planning............................................................................................... 17
   Workshop Objectives and Focus.......................................................................... 18

3 Plenary Presentations ......................................................................................... 21
   Emissions Inventories: Why We Need a Regional Approach............................ 21
   Regional Air Quality and Emissions Overview.................................................. 22
   Emission Estimates Needed for the Next Round of Modeling............................ 26
   Intra-urban Pollution Gradients and Public Health Impacts.............................. 27
   Emerging Trends in Energy Technology and Fuels and Potential Environmental Implications........................................................................................................ 29
   Updating the National Emissions Inventory....................................................... 31
   Mobile Source Developments and Issues (MOVES Update)................................ 34
   Role of Ammonia, Status of Ammonia Emissions Estimates, and Prospects for Improvements........................................................................................................ 37
4 **Improving Estimates of Emissions from On-road Mobile Sources** ........ 39  
   Uncertainties in On-road Emission Estimates.................................................................40  
   Additional Challenges and Considerations.................................................................41  
   Summary of the On-road Breakout Session Discussion...............................................45  
5 **Improving Estimates of Emissions from Non-road Mobile Sources** ....... 53  
   Generating Non-road Emissions Estimates.................................................................55  
   Summary of the Non-road Breakout Session Discussion...............................................57  
   Non-road Breakout Group Participants........................................................................65  
6 **Improving Estimates of Emissions on High Electricity Demand Days** .... 67  
   Issue..................................................................................................................................67  
   Discussion Topics............................................................................................................68  
   Workshop Discussions..................................................................................................68  
   Current Emissions Estimates and Data Gaps...............................................................69  
   Needs for Emissions Estimates in Key Areas...............................................................70  
   Tools and Techniques for Improving Emissions Estimates........................................70  
   Specific Studies or Actions to Improve Emission Estimates..........................................71  
7 **Improving Estimates of Emissions from Space Heating Using** 
   **Liquid Fuels**.............................................................................................................73  
   Issues and Concerns Raised in Breakout Session Presentations...............................73  
   Breakout Session Findings and Recommendations...................................................75  
8 **Improving Estimates of Emissions from Space Heating with Biomass** .... 81  
   Statement of the Problem..............................................................................................81  
   What emission information gaps need to be filled?.....................................................84  
   Data Needs Created by Changes in Fuels, Technologies, and Use Patterns................88  
   Tools and Techniques to Improve Emissions Estimates.............................................93  
   Collaboration Opportunities for the Region...............................................................93  
   Biomass Heating Work Group Participants..............................................................95  
   References......................................................................................................................95
9 Improving Estimates of Emissions from Agricultural Ammonia Sources 97

The Problem..................................................................................................................................................97

Improvement and Evaluation of Current Ammonia Estimates....................................................101

Breakout Session Recommendations for Improving Ammonia Emission Estimates 104

References.....................................................................................................................................................106

Appendix A: Workshop Organizers and Advisory Committee ......................... 109

Appendix B: Agenda....................................................................................................................................... 111

Appendix C: Session Leaders and Contributing Authors ............................................. 115

Appendix D: Workshop Participants.................................................................................................117

Appendix E: Workshop Evaluation by Participants ......................................................... 125
List of Figures

Figure 1  Summer 2007 Daily NOx Emissions from Electricity Generating Units in NYC and NJ .............. 7
Figure 2  Spatial US Variability of Ni Concentrations (Based on PM$_{2.5}$ Speciation Data) ......................... 8
Figure 3  Total 2002 New York State Primary PM$_{2.5}$ and Sources of Carbonaceous PM$_{2.5}$ ..................... 10
Figure 4  Density Map of 1988 Ammonia Emissions by County ................................................................. 13
Figure 5  Spatial US Variability of Ni Concentrations (Based on PM$_{2.5}$ Speciation Data) .................... 74
Figure 6  Total New York State Primary PM$_{2.5}$ and Carbonaceous Detail in 2002 ............................... 82
Figure 7  Comparison of Emission Limits for Small Solid Fuel Boilers .................................................. 83
Figure 8  Winter Diurnal Profiles of Estimated Wood Smoke in Four New England Communities ....... 86
Figure 9  Average Number of Hogs per Farm (Iowa & U.S., 1974-2002) ................................................. 98
Figure 10 MANE VU Ammonia Emissions Projections ............................................................................ 99
Figure 11 MANE VU 2002 V3 Emissions Inventory – Top Ammonia Sources ............................................... 100
Figure 12 Density Map of 1998 Nitrogen Oxides Emissions by County .................................................. 102
Figure 13 Density Map of 1998 Sulfur Dioxide Emissions by County .................................................... 103
Figure 14 Density Map of 1998 Ammonia Emissions by County ........................................................... 103

List of Tables

Table 1  Comparison of Emission rates from Small Boilers across Four Fuel Types .................................. 88
Table 2  Comparison of Performance Levels among Small Commercial/Institutional Wood Boilers ........... 90
Table 3  Comparison of Feasible Control Devices for Wood Boilers ....................................................... 91
Table 4. National Emissions Estimates (fires and dust excluded) for Common Pollutants and their Precursors .................................................................................................................. 99
1 Summary and Recommendations

Introduction

A Workshop on Improving Northeast and Mid-Atlantic Regional Emissions Estimates was held in Albany, NY, November 12-13, 2008. The Workshop identified ways to improve current estimates of air pollutant emissions, addressing six issues important to the Northeast and Mid-Atlantic region of the US. NARSTO’s Improving Emission Inventories for Effective Air Quality Management Across North America (2005) laid the foundation for this workshop by identifying strengths and weaknesses in emissions estimates in Canada, Mexico, and the U.S.

Opening the workshop, Jared Snyder, Assistant Commissioner of New York’s Department of Environmental Conservation, said, “We need to understand the sources of pollution in order to effectively reduce air pollution. It becomes much more important when we have multiple states and regions involved. It’s so much easier to reach agreement when the underlying data is sound.”

Workshop organizers are all members of NARSTO, a tri-national North American air quality research group. In addition to NARSTO itself, organizers included New York State’s Energy Research and Development Authority (NYSERDA) and two regional associations of air pollution control agencies—the Mid-Atlantic Regional Air Management Association (MARAMA), and the Northeast States for Coordinated Air Use Management (NESCAUM).

NARSTO’s Emissions Inventory Assessment noted that inventories of air pollutant emissions are better now than ever before, but continued improvement is needed in order to reflect the changing nature of emissions sources as well as respond to new ways to use emissions estimates. The Assessment recommended that efforts to reduce uncertainty in the emissions inventory focus on source categories whose control will be most effective in reducing pollution.

Focus of the Workshop

The Workshop organizers formed an advisory committee to consider how to address NARSTO’S recommendations and improve emissions estimates for the Northeast and Mid-Atlantic Region. The advisory committee included technical experts from air quality agencies, health departments, universities, and private industry. (Members are listed in Appendix A.) The advisors recommended addressing the following emissions sectors:

- On-road mobile sources,
- Off-road mobile sources,
• Electricity generation on days with high electricity demand,
• Space heating with liquid fuels,
• Space heating with biomass, and
• Agricultural activities that emit ammonia.

For each of these six sectors, workshop participants were asked to address four questions: a) What are the gaps in current emissions estimates? b) What future trends will influence emissions? c) What tools exist to improve emissions estimates? and d) What specific studies or actions should be taken to improve emissions estimates?

Before the workshop, organizers recruited experts to prepare “white papers” summarizing the status of emissions estimates for each of the six sectors and providing background to inform participants. Invitations were sent to a range of potential participants in order to achieve a mix of scientists, regulators, private industry experts, and public interest groups. Those who agreed to attend were asked to read the white papers in advance and come prepared to address the issues posed for discussion. Information included in the white papers is reflected in Sections 4 through 9 of this report, along with a summary of work group discussions.

**Plenary Sessions**

The workshop opened with eight plenary presentations. (See Section 2 of this report.) Three of the presentations provided motivation for improving regional emissions estimates:

- “Emissions Inventories: Why We Need a Regional Approach,” by Jared Snyder, Assistant Commissioner, New York State Department of Environmental Conservation,
- “Regional Air Quality and Emissions Overview,” by Susan Wierman, Executive Director, MARAMA, and
- “Emission Estimates Needed for the Next Round of Modeling,” by Tad Aburn, Chair, MARAMA, Director, Maryland Department of the Environment, Air and Radiation Management Administration

Another plenary presentation emphasized the need to consider local variations in emissions and their impacts on public health:

- “Intra-urban Pollution Gradients and Public Health Impacts, by Thomas Matte, Director of Environmental Research, Bureau of Environmental Surveillance and Policy, New York City Department of Health and Mental Hygiene.

A fifth plenary presentation introduced anticipated technological developments and changes in fuels used that are expected to lead to changes in emissions:

- “Emerging Trends in Energy Technology and Fuels and Potential Environmental Implications,” by Janet Joseph, Program Director, Clean Energy Research and Market Development, NYSERDA.

Two presentations by representatives of the U.S. Environmental Protection Agency (EPA) explained improvements planned nationally:
• “Updating the National Emissions Inventory,” by Doug Solomon, EIAG Group Leader, EPA OAQPS, and
• “Mobile Source Developments and Issues (MOVES Update),” by Gene Tierney, Environmental Scientist, EPA OTAQ.

A final plenary presentation provided background on ammonia emissions, one of the topics to be addressed at the conference:

• “Role of Ammonia, Status of Ammonia Emissions Estimates and Prospects for Improvements,” by Praveen Amar, Director, Science and Policy, NESCAUM.

**Trends Influencing Emissions**

Trends that will influence future emissions were identified by participants in each of the six sector-specific break-out groups. Many of the trends identified will influence emissions in more than one sector. Trends identified included:

• The economic downturn that began in 2007 has led to reduced vehicle miles traveled and has reduced energy demand and generation.
• Changes in the comparative costs of fuels (natural gas, oil, coal, wood, etc.) cause shifts in consumption, which result in changes in emissions.
• There is an increasing emphasis on the use of alternative fuels and on finding ways to increase energy efficiency.
• New emissions standards are resulting in emissions reductions from both stationary and mobile sources, new fuel standards for motor vehicle fuels are reducing emissions, and new equipment and vehicles have lower emission rates.
• State and local agencies are implementing programs to reduce vehicle idling and to encourage diesel retrofits, repowering, and replacement.
• Some areas are providing incentives for replacing old wood stoves with newer models.
• Power transmission system upgrades are planned for parts of the region. This may change the pattern of electricity generation and the nature and location of emissions.
• Programs to track and reduce greenhouse gas emissions will influence emissions of other air pollutants.
• Variations in the weather influence emissions. Hot, dry years tend to experience more violations of the ozone standard, for example. Cold winters lead to increased wood combustion.

Given these trends, participants discussed gaps in current emissions estimates and tools available to improve the estimates, and each break-out group recommended actions to improve regional emissions estimates. Brief summaries addressing each of the sectors discussed by participants follow.
Improving Estimates of On-road Mobile Source Emissions

Motivation

On-road mobile sources of air pollutants include light and heavy duty vehicles that burn gasoline, diesel, and other fuels. One of the most important sources of air pollution in the region, on-road mobile sources are responsible for a large percentage of regional emissions of nitrogen oxides (NOx), which contributes to the formation of ozone. Unhealthy levels of ozone pollution are among the most persistent and widespread air pollution problems in the region. On-road mobile sources are also responsible for a large percent of greenhouse gas emissions.

Recent research has shown that concentrations of pollutants caused by on-road mobile sources are much higher near major roadways, and that this can create unhealthy conditions for nearby residential areas. Ultra-fine particles and toxics are of concern, in addition to NOx and fine particles.

Emissions from this source sector are estimated using an emissions model. As described in the plenary presentation by Gene Tierney of EPA, the MOVES model was under development by EPA. MOVES replaced the MOBILE6 model in early 2010. Both models were developed by EPA, and state, local, and regional agencies are required to use the most up-to-date EPA-approved model to estimate on-road emissions.

Gaps in Emissions Estimates for On-Road Mobile Sources

Participants were concerned that while the MOBILE and MOVES models would provide reasonable estimates for national studies, the level of detail needed for project-level analyses was difficult to obtain. Participants also identified a need for emissions modeling tools to allow quick screening evaluations of scenarios for reducing mobile source emissions.

A small percentage of vehicles are responsible for most emissions from this sector, but it is difficult to model the impact of these high emitters and to predict the impact of control programs. Estimates of emissions from light duty vehicles were considered more reliable than estimates of emissions from heavy duty vehicles, because there is less information about in-use emissions from heavy duty vehicles. Participants also identified gaps in data on condensable particle emissions and ultra-fine particle emissions as well as emissions of toxic air pollutants from on-road motor vehicles.

Tools to Improve Estimates of Emissions from On-road Mobile Sources

Participants looked forward to the release of the new MOVES model, which was developed to provide better estimates of emissions from on-road mobile sources. In addition, participants noted the existence of portable emissions measurement systems (PEMS), which enable measurement of emissions while a vehicle is being driven.

Participants also recommended investigation of non-traditional data sources to get better information on actual traffic patterns. This might include data from toll systems, traffic management systems, and information from fleet operators.
Studies or Actions Needed to Improve On-road Mobile Source Emissions Estimates

The work group addressed three categories of improvements: vehicle activity data, emissions profiles, and data on ultra-fine particles and toxic air pollutants.

To improve vehicle activity data, the participants recommended 1) developing regional and local data to replace national default data in the MOVES model, 2) exploring previously-unused sources of information such as those identified in the previous section, and 3) comparing data gathered for different purposes and scales as a means to assess the reasonableness of MOVES estimates.

Emissions profiles are descriptions of the quantities and types of pollutants emitted under various ambient temperatures and in various operating conditions, such as cold starts, acceleration, and at various speeds. For light duty vehicles, participants recommended gathering or using available data to improve model estimates of the deterioration of cold start emissions as the vehicle ages, increases in PM emissions with temperature, and the impacts of the use of alternative fuels. For heavy duty vehicles, participants recommended measuring in-use vehicle emissions.

Two additional recommendations with respect to emissions profiles were to address the relationship between energy consumption and emissions of greenhouse gases and criteria pollutants, and to validate MOVES estimates of emissions.

Participants made five major recommendations with respect to improving on-road mobile source emissions of ultra-fine particles and toxics. Standardized test methods for ultra-fine particles and toxics are needed. Studies of the relationship between ambient concentrations emissions were recommended.

Participants also recommended adapting regional-scale emissions models for use in near-roadway and other small-scale studies. Fostering collaboration among various groups working with mobile source emissions was also recommended.

It was emphasized that fine particles are emitted not only from vehicle engines but also by tire wear, break wear, and road dust.

Improving Estimates of Emissions from Non-road Mobile Sources

Motivation

Non-road mobile sources of air pollutant emissions include a wide variety of equipment, including ships, boats, planes, ground service equipment used at air, ground, and sea ports, farm equipment, construction equipment, lawn mowers, etc. This wide variety of small and large equipment is difficult to characterize in terms of emission rates, location, and hours of operation. This source sector, however, is estimated to be responsible for a relatively large portion of NOx emissions and VOC emissions, both of which contribute to ozone formation. Non-road equipment is also an important source of fine particle emissions and hazardous air pollutants.
Gaps in Estimates of Emissions from Non-road Sources

Estimates of emissions from many types of non-road mobile sources are developed using EPA's NONROAD model. General estimates for national analysis may be reasonably accurate, but regional and project-scale data is difficult to verify. Furthermore, there is a lack of information about hazardous air pollutant emissions, emissions of greenhouse gasses, and PM size fractions.

Tools to Improve Estimates of Emissions from Non-road Sources

Little information was available on new sources of information to improve estimates of emissions of non-road equipment. In the future, EPA plans to incorporate an updated version of the NONROAD model into the MOVES modeling system for on-road vehicles. Some information is available concerning projects underway to reduce diesel emissions.

Studies or Actions Needed to Improve Estimates of Emissions from Non-road Sources

Workshop participants recommended that states work with EPA to provide information for updating the NONROAD model. Participants suggested creating a regional database of fleets and other vehicles that have been repowered or had diesel emissions controls installed. In addition, participants recommended that EPA standardize techniques and guidance for estimating emissions from marine vessels. (EPA was working on an updated estimate of marine vessel emissions.) The group also recommended that a study be initiated in a representative urban area that would provide data that could be extrapolated to other similar areas. Finally, it was recommended that EPA refine methods to measure emissions from non-road vehicles and to assess their contribution to ambient air pollutant concentrations.

Improving Estimates of Emissions on High Electricity Demand Days

Motivation

High electricity demand days are days when electricity generating units are called on to produce more electric energy than usual, and peak energy use days in this region generally are hot summer days when a lot of people are using air conditioning. As shown in Figure 1, in 2007 base load EGUs in the New York metropolitan region are coal-fired units. As demand increases, residual oil-fired units are used more, producing more emissions. Natural gas units provided increasing amounts of energy and generated increased emissions on higher demand days. Finally, as demand reached peak levels, increasing amounts of diesel- or other oil-fired units were used.
To better understand ozone production on hot summer days, it is important to use a more realistic estimate of EGU emissions variability during the year. Using meteorological data and emissions data from the same year can help better predict ozone production.

**Gaps in Estimates of Emissions**

Past air quality modeling for the region used emissions estimated for typical summer days rather than for these peak demand days. It is likely that this underestimated emissions from electricity generating units on peak days.

Furthermore, there is little data on the small generators that are used for “peak shaving” on high demand days. Distributed generation, a demand response technique, is being used more widely, and air quality agencies lack data on the location, size, emissions rate, and use patterns of these units.

**Tools to Improve Estimates of Emissions**

First, it is important to utilize continuous emissions monitoring data for sources where it is available. System operators or companies that aggregate small units to facilitate selling power to electric companies may also be willing to share data. Most importantly, collaboration with public service commissions and other state and local agencies should be emphasized.

**Studies or Actions Needed to Improve Estimates**

Obtaining and quality assuring data from continuous emissions units should be a high priority. States and localities should identify local sources of information on emergency or other small generators. It may be appropriate to conduct a survey.
It will be important to develop appropriate methods to project future peak emissions. Finally, to raise awareness of this issue, it will be important to identify the health consequences of the combination of temperature stress and poor air quality.

**Improving Estimates of Emissions from Space Heating with Liquid Fuels**

**Motivation**

Emissions due to the combustion of liquid fuels for space heating contribute to regional air pollution. Levels of fine particles, ozone and trace metals in the atmosphere are significantly affected by emissions from this source category.

Dr. Morton Lippmann of NYU reported that epidemiology studies regressing PM components on daily mortality data from the NMMAPS study showed significant associations with Nickel and Vanadium, which are trace metals discharged from oil-fired boilers. Data from PM speciation monitors and IMPROVE monitors indicates that Nickel and Vanadium have substantially higher concentrations in New York City than in any other US city. (See Figure 2.)

![Figure 2 SPATIAL US VARIABILITY OF NI CONCENTRATIONS (BASED ON PM2.5 SPECIATION DATA) MAP PREPARED BY ZEV ROSS, SPATIAL ANALYSIS, ITHACA NY](image)

One of the largest users of residual oil in the City is the public school system. Cleaner burning heating fuel is one of the initiatives being pursued under PlaNYC’s goal of having the cleanest air quality of any big city in America.

8
**Gaps in Estimates of Emissions due to Liquid Fuel Combustion**

Emissions estimates for boilers and other equipment burning fuel oil rely on data concerning the amount of fuel burned, the sulfur content of the fuel, and emissions factors based on tests of similar equipment. For large sources that are required to obtain permits from air quality agencies, fuel use data is typically reported annually. For other, smaller units, estimates are generally made by subtracting the fuel used by large units from state-wide totals, and then allocating the remaining fuel to counties on the basis of population.

Researchers studying health effects would like to have more detailed estimates of the emissions at a sub-county level and broken down with more detail by equipment type. Current emissions information is not sufficient to estimate how much oil is burned in New York City compared to New York State. Lack of source information not only makes it difficult to assess the effects of space heating on human health, but it also makes it difficult to construct an accurate greenhouse gas (GHG) inventory for the City.

Emissions from liquid-fired furnaces will be changing due to adoption of new technologies and changes in fuels. Information will be needed on the age and replacement rate of equipment in order to accurately characterize emissions.

**Tools to Improve Estimates of Emissions from Liquid Fuel Combustion**

Both NESCAUM and NYSERDA have conducted studies that will help improve estimates of emissions from burning liquid fuels. NESCAUM conducted a survey sampling trace metals in fuel oil. NYSERDA studied emissions from various biodiesel blends. NYSERDA also compiled information on emergency generators. Workshop participants also suggested that emission inventory developers use information from air quality permits for large sources burning oil to estimate the fuel sulfur content in an area. Collaborating with agencies developing greenhouse gas emissions inventories may also provide more information.

**Studies or Actions Needed to Improve Estimates of emissions from Burning Liquid Fuels**

Improvements in three areas were discussed by workshop participants: spatial allocation of emissions, temporal allocation of emissions, and emission factors. To improve spatial allocation, participants recommended investigating the allocation of emissions between urban and rural areas. Sales tax information was suggested as helpful in this process. To improve temporal allocation, participants suggested using heating degree days rather than just splitting the annual total among four seasons. Finally, to improve emissions factors, the participants suggested analyzing fuel sulfur content reported by large sources with Title V permits, and including information from NESCAUM and NYSERDA studies, particularly to improve information about nickel and vanadium emissions.

**Improving Estimates of Emissions from Space Heating with Biomass**

**Motivation**

Biomass combustion (e.g., wood) can be a low cost home heating energy source, particularly in non-urban areas of the Northeast with ready access to sufficient wood supplies.
However, wood burning emits significant quantities of known health-damaging pollutants, including several carcinogenic compounds. The close proximity of high-emitting wood burning devices that fail to adequately disperse emissions in residential neighborhoods is an increasing concern facing state health and environmental agencies. Poorly designed or older wood burning equipment can be a significant source of fine particulate matter (PM$_{2.5}$) and air toxics at local and regional levels, posing a serious public health threat if not properly managed. Topography and weather can lead to significant PM$_{2.5}$ spatial variability, adding local pollution to regional PM$_{2.5}$ contributions – creating evening “hotspots” in valleys, for example.

Figure 3 TOTAL 2002 NEW YORK STATE PRIMARY PM2.5 AND SOURCES OF CARBONACEOUS PM2.5 (NYSERDA, 2008)

The recommended method for developing an inventory of emissions from biomass burning is to conduct a survey, and some states in the region have done this. In addition, the U.S. Census of Housing provides information for many areas concerning the nature of woodburning equipment.

The Northeast Census Region (New England, NJ, NY, and PA) consumes over twice the number of total cords of wood in woodstoves per year than the Midwest, South, or West. Upwards of 80 percent of the woodstoves currently in use were manufactured without efficient combustion designs or pollution control devices, which have been required since 1988. Moreover, the growing use of outdoor wood boilers, pellet stoves, and fireplaces has presented regulators with an added air quality problem.

Numerous biomass fuels other than wood are emerging as well. Sometimes they are mixed with sawdust for improved binding in pellet form, sometimes they are not. The agricultural sector is pursuing pellet production from various grasses such as Switch Grass and Reed Canary Grass. There is also interest to use hay that is off-specification for animal feed and dried corn kernels have been used as pellet fuel for some time. Due to the higher ash content in
these feedstocks, equipment burning grass pellets typically requires a different design (including mechanical ash removal) compared to wood combustion units. The higher ash content of these feedstocks makes it important to perform careful emissions tests for them.

**Gaps in Estimates of Emissions from Biomass Burning**
Participants in the workshop identified improvements needed in the estimates of emissions from biomass burning. Certain types of equipment were not yet included in the regional emissions inventory, there was a lack of information about emissions rates from certain equipment, information on the location of wood burning equipment was inadequate, diurnal patterns of burning needed to be incorporated into the data, and variations in the type of wood or other biomass fuel were uncertain. The urban vs. rural allocation of emissions was of concern, and more information was needed on the number of new wood burning appliances that met EPA certification guidelines and therefore had lower emissions.

Participants noted the importance of characterizing small commercial units, in the 1 to 10 MMBTU size range. A number of states, the U.S. Forest Service, and the U.S. Department of Agriculture are promoting commercial scale wood combustion. Numerous northern states have implemented “Fuels for Schools” programs in which they provide financial incentives for schools to convert their existing heating systems to wood-chip-fired systems. While these systems may provide significant economic savings, there is little data on the emissions or energy performance of these commercial wood-fired systems. Characterizing emissions from these units should be a priority.

**Tools to Improve Estimates of Emissions from Biomass Burning**
NESCAUM measured in-use emissions from outdoor wood-fired boilers to estimate how emissions in the field may vary from those obtained in the laboratory test.

A $2.3 million research, development, and deployment effort by NYSERDA and partners\(^1\) was underway to characterize the energy and environmental performance of biomass technologies, support technology development with manufacturing partners, and demonstrate advanced biomass technologies at the small commercial scale. Projects included:

- For residential scale technologies, EPA’s Office of Research and Development was evaluating a wide range of boilers including an outdoor wood-fired boiler, a recent model dual-fuel outdoor boiler, a high-efficiency split-wood boiler, and a state-of-the-art pellet boiler imported from Europe. A duty-cycle was to be developed based on the “call for heat” demand of a home in the Northeast.

- Evaluations of small commercial-scale biomass boilers were to be conducted by NESCAUM, Vermont’s Department of Environmental Conservation, and Clarkson University for conventional and high-efficiency units respectively.

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\(^1\) Partners include NESCAUM, EPA’s Office of Research and Development, Brookhaven National Laboratory, Clarkson University, Cornell University, the State University of New York at Canton, Alternative Fuel Boilers, and Advanced Climate Technologies.
• A wood smoke field study with a GIS model was being conducted by NESCAUM and researchers from the University of British Columbia to improve spatial and diurnal wood smoke information in northern New York State.

• Advanced biomass boiler technologies under development were expected to displace current oil-fired systems. Alternative Fuel Boilers and Advanced Climate Technologies, two New York State based companies were manufacturing 2-stage gasification combustion units with thermal efficiencies of 87 and 90% respectively. The companies are working with NYSERDA to evaluate and demonstrate these technologies.

Workshop participants suggested that estimates of the numbers of units as well as the spatial distribution of biomass-fired units could be improved by using trade association data for national sales. Participants indicated to do so might require an EPA order under Section 114 of the Clean Air Act to manufacturers to provide information on how many units have been sold and in which states.

Participants stressed the importance of sharing information among various levels of government and the private sector regarding initiatives to promote the use of biomass, replace old equipment, or estimate emissions.

**Studies or Actions Needed to Improve Estimates of Emissions from Biomass Burning**

To better estimate emissions from biomass heating equipment in residential and small/medium commercial applications, improvement is needed in estimating the number and type of wood-burning appliances in use, their general locations, and the amount of fuel burned; characterization of various feedstocks; and the emissions profile for each appliance. Additionally, realistic duty cycles need to be developed for technology evaluations.

EPA had begun work to improve information about biomass burning and to improve emission factors. EPA planned to add outdoor hydronic heaters commonly called outdoor wood boilers, wax logs, and indoor wood furnaces to the national emissions inventory (NEI) and update emission factors for all residential wood burning devices for the 2008 NEI.

**Improving Estimates of Agricultural Ammonia Emissions**

**Motivation**

Like SO$_2$ and NOx, ammonia is important to the atmospheric chemistry of fine particles, and is a local and regional pollutant that reacts and is transported in the atmosphere (as ammonium sulfate and ammonium nitrate). Current ammonia emissions estimates are highly uncertain. Most ammonia emissions are difficult to quantify, as they come primarily from livestock management and fertilizer application for production of food. EPA’s 2002 National Emission Inventory (NEI) indicated that these agricultural sources accounted for approximately 86% of the estimated U.S. total ammonia emissions.

Because it is a key pollutant in the formation of secondary ambient PM, accurate estimates of ammonia emissions are crucial to obtaining realistic air quality modeling results.
and in developing effective strategies to reduce regional haze and particle pollution. Additional important impacts of ammonia include:

- soil and freshwater acidification,
- eutrophication of ecosystems with consequent species loss,
- modification of the transport and deposition patterns of SO₂ and NOx, and
- aerosol production affecting radiative-forcing (the “greenhouse effect”).

A recent evaluation of the USEPA Concentrated Animal Feeding Operations (CAFOs) study by the United States Government Accountability Office stated that ammonia emissions from CAFOs are on the rise. The study estimated that the number of CAFOs increased from 3600 in 1982 to 12,000 in 2002, an increase of over 230%. For animal production, this change has meant a movement to significantly larger operations that can house as many as 2 million chickens or 800,000 hogs at one facility (GAO, 2008). It should be noted that according to the 2002 animal census, the average number of hogs per facility is 800 nationwide and 1,500 in Iowa.

EPA estimated ammonia emissions in the US to be about 4 million tons per year in 2002, and the trend for ammonia emissions is most probably increasing in the absence of any strategies to control ammonia emissions. By comparison, 17 million tons per year of NOx and 13 million tons per year for SO₂ were emitted in 2007 and the trend for these pollutants is downward.

Ammonia emissions from agricultural operations are estimated using data on the number of animals present by county and the application of emissions factors based on available information about average rates of emissions. In general, county-wide estimates are not disaggregated to a finer geographical distribution.

Gaps in Estimates of Emissions of Ammonia from Agricultural Sources

Although they are important in the formation of fine particles and other pollutants, ammonia emissions are not estimated with as much precision as emissions of other pollutants, such as sulfur dioxide and nitrogen oxides. Information about the geographic and temporal
distribution of emissions should be improved, and emission factors should be improved to better reflect variations in agricultural operations. Soil emissions may be high, and more information is needed on emissions rates and factors influencing emissions from soils.

Tools to Improve Estimates of Emissions of Ammonia from Agricultural Sources

A US Census of Agriculture was conducted in 2007, and data is now available to improve the estimates of the number of animals by county. Furthermore, a National Pollution Discharge Elimination System (NPDES) permit is required for CAFOs that discharge wastewater into federal waters. These permits include many details about the farms, including their locations, size and manure storage and application characteristics.

EPA and agricultural associations have initiated a “National Air Emissions Monitoring Study” to develop protocols for measuring and quantifying air emissions (including ammonia) from animal feeding operations. This universities-led research effort started in 2007, and it was scheduled to be completed in 2009. However, the Government Accounting Office had raised concerns that the study might not represent a statistically valid sample of all CAFOs, and might not collect enough information necessary for EPA to develop planned protocols (GAO 2008).

The 2003 report of the National Academy of Sciences (NAS, 2003) recommended developing a process-based model to improve livestock ammonia emissions estimates. Such a modeling approach would allow a more dynamic estimate of emissions of ammonia and related species from such sources. The University of California at Davis is developing process-based models for various agricultural sectors, but the models require very detailed input data and are complex to use. The Midwest Regional Planning Organization is investigating methods to simplify the use of these models for certain agricultural operations.

Studies or Actions Needed to Improve Estimates of Ammonia Emissions from Agricultural Sources

Because of ammonia’s importance in particle formation, ammonia emissions need to be characterized to the same level of accuracy, reliability, and spatial and temporal resolution as NOx and SO₂ emissions. Given these requirements, the ammonia emissions breakout session returned the following four priority recommendations:

1. Treat the largest CAFOs as point sources for air quality modeling.

   Emissions from the largest CAFOs may be quite large. One task is to explore the possibility of treating the largest CAFOs as point sources in the inventory and to calculate their emissions based on specific characteristics of the facility. Information necessary to do this may be available in NPDES permits. If treated as a point source, their specific characteristics and locations should be determined and mapped on a GIS system.
2. Assemble and review current scientific information about ammonia emissions and atmospheric behavior.

Participants recommended developing a report on recent research at universities and agencies with a particular focus on how this information could be used to improve ammonia emissions estimates.

3. Obtain Information about farms and trends in the region.

Participants emphasized the importance of using the 2007 Census of Animals. Data from the census should be compared to the previous (1997) census. In addition to gathering information from NPDES permits, participants recommended looking into anticipated modifications in requirements for these permits.

Participants encouraged contacting other agencies and groups who might have information about CAFOs and other agricultural operations, including state agricultural agencies and university extension services, EPA, the University of California at Davis, LADCO, and the Chesapeake Bay Foundation. Agricultural extension personnel in each state should be identified and contacted to determine if databases are available that could be used to characterize farms and ammonia emissions in the area.

To evaluate the new generation of process-based models when they become available, 2008 farm population data should be collected. State-specific farm characteristics should be utilized, where available, or reasonable default values developed. Farm-specific data should also be collected, or develop reasonable default values. The model should then be run to estimate emissions with better time resolution and with the use of local data. An up-scaling of these results should be done to generate state, regional, and national ammonia emission estimates. The model should then be evaluated using the baseline real farm data to increase confidence in the process-based model.

4. Confirm ammonia emissions estimates by comparison with ambient measurements and the use of inverse modeling.

Workshop participants recommended evaluating ammonia emissions estimates by using “inverse modeling,” a technique for comparing air quality model results to measurements of ammonia concentrations in ambient air. EPA has done this for previous versions of the emissions inventory and has found it to be a useful technique.

Key Recommendations for Short-Term Improvements in Emissions Estimates for the Region

Three general recommendations consistently emerged from each of the six topical discussions at this workshop, namely 1) explore previously unused sources of information, 2) compare data gathered for different purposes and at different scales to assess the uncertainty and reasonableness of emissions estimates, and 3) collaborate with other agencies. Additional specific recommendations for each of the six sectors included the following key points:
On-road mobile sources: Develop specific input data for the new MOVES model to improve emissions estimates for this sector, and then evaluate the results.

Non-road mobile sources: Create a clearinghouse of information about emissions reduction projects, and use updated methods as they become available.

High electric demand days: Use continuous emissions monitoring data to better reflect the variability of emissions from large sources on days with high electrical demand, and work with other agencies and organizations to develop better data on smaller sources used on peak days. Use fuels tax data and heating degree days to improve the spatial and temporal allocation of emissions.

Space heating with liquid fuels: Use nontraditional data sources to improve the spatial and temporal resolution of emissions estimates for this sector. For example, review Title V permits to assess fuel sulfur content.

Space heating with biomass: Improve equipment and fuel use data and develop better emissions profiles for biomass burning. Update emissions factors and information on activity levels.

Ammonia: Use the 2007 Census of Agriculture to improve emissions estimates, and investigate the potential use of data on large animal feeding operations gathered in the water quality permitting process. Treat large operations as point sources.
2 Preface

Background

According to a major international assessment of the state of emissions inventories in Canada, the United States, and Mexico, “...emission inventories in all three countries of North America have significant weaknesses or shortcomings that will become increasingly important for future air quality management problems.” (NARSTO, 2005) In the assessment, entitled Improving Emission Inventories for Effective Air Quality Management Across North America, NARSTO recommended eight principal actions to improve emissions information in the three countries:

1. Reduce uncertainties for key under-characterized sources.
2. Improve speciation estimates.
3. Improve emission inventory development tools.
4. Quantify and report uncertainty.
5. Increase inventory compatibility and comparability, especially across international borders.
6. Improve use accessibility.
7. Improve timeliness.
8. Assess and improve emission projections.

NARSTO recognized that specific actions and priorities would vary not only between countries but also between regions and subregions within countries. Thus, NARSTO envisioned that implementation of their recommendations might require a series of workshops or regional studies to further refine and prioritize actions for improving emissions information on these finer scales.

This report summarizes the findings and recommendations of a regional workshops held November 12-13, 2008 in Albany, New York. The goals of the workshop were to assess priorities and make recommendations for improving information about air pollutant emissions in the northeastern United States.

Workshop Planning

In the spring of 2007, the New York State Energy Research and Development Administration (NYSERDA), the Mid-Atlantic Air Management Association (MARAMA), the Northeast States for Coordinated Air Use Management (NESCAUM), and NARSTO agreed to organize a workshop to assess the priority needs for improving emissions information in the region encompassed by the NESCAUM and MARAMA organizations. To identify these priority needs and develop plans for the workshop, the organizers invited a group of U.S., Canadian, and regional experts to meet January 9, 2008 at NYSERDA’s offices in New York City. The
Workshop Advisory Committee’s guidance was instrumental in shaping the topics addressed and speakers included in the workshop. National and regional experts were invited to attend the workshop. ¹

**Workshop Objectives and Focus**

After considering the specific needs of the Northeast region the Workshop Advisory Committee and organizers agreed to focus on the following emissions information issues:

1. On-road mobile source emissions,
2. Non-road mobile source emissions,
3. Emissions on high electricity demand days,
4. Emissions from space heating with liquid fuels,
5. Emissions from space heating with biomass/wood, and
6. Emissions from agricultural ammonia sources.

Through discussion with the Advisory Committee and subsequent iterations among the workshop organizers, the purpose and objectives of the workshop were defined to be:

- Characterize current emissions estimates of several high-priority source categories and identify current data gaps such as emissions profiles (including speciation), spatial distribution, activity patterns, among others;
- Identify changes in fuels, technologies, and use patterns that are anticipated in the short (3-5 years) and long term (7 or more years) and the data needs they will create;
- Identify tools that could be applied to improve emissions estimates; and
- Explore potential opportunities for collaboration among the state, regional, and federal players in the Northeast region.

The workshop agenda is reproduced in Appendix B. The workshop was kicked off by a series of topical presentations designed to set the stage for in-depth discussion in breakout sessions of the six emissions information issues listed above. Each workshop attendee was assigned to a breakout session and provided in advance with a short “white paper” that summarized the current state of knowledge regarding the issue in question and offered a few suggested improvements. After preliminary remarks by the breakout session chairs and some additional presentations, session participants were asked to collaborate in

- Identifying the needs that existing emissions estimates fail to meet in this category.
- Characterizing current emissions estimates and identify current data gaps such as emissions profiles (including speciation), spatial distribution, activity patterns and others.

¹ Names and affiliations of the conference organizers and Workshop Advisory Committee are provided in Appendix A. Participants are listed in Appendix D.
- Identifying changes in fuels, technologies and use patterns that are anticipated in the short- (3-5 years) and long-term (7 years or more) and the data needs they will create.
- Identifying the tools and techniques available to help improve the emissions estimates.
- Identifying specific studies or actions that should be undertaken to improve the emissions estimates for the northeast and mid-Atlantic region.

After completing their work, each breakout group reported its conclusions and recommendations to the full workshop.

Sections 3 of this report summarizes the plenary presentations, and Sections 4 through 9 incorporate information from the white papers and the work groups’ discussions and recommendations concerning each of the six topics listed above. Appendix C identifies session leaders and the contributing authors who developed Sections 4 through 9 of this report.
3 Plenary Presentations

Setting the stage for the workshop deliberations, eight plenary presentations reviewed the need for regional emission inventories, the status of information about air pollutant emissions, and emerging issues requiring attention. Each of the eight presentations is summarized below.

Emissions Inventories: Why We Need a Regional Approach

*Summary of remarks by Jared Snyder, Assistant Commissioner, New York State Department of Environmental Conservation*

Sound information is the foundation of sound policy, and emissions information is certainly the foundation for good air quality management policy. In fact, it is relatively easy to cite examples of air quality management initiatives being weakened or crumbling on the basis of a less than adequate understanding of emissions. One example is the European Union’s attempt at establishing a CO₂ cap-and-trade system, and the subsequent collapse of the price of CO₂ emission permits, before there was a solid understanding of the CO₂ emissions inventory. Another example might be the initial failure of EPA’s Clean Air Interstate Rule (CAIR), which the court apparently believed did not conform to the available information.

Another argument in favor of establishing policy development on a firm foundation of data is that it makes it easier for policy makers to decide on what needs to be done. Cooperation among groups is much easier to achieve when we have a common understanding of the underlying facts. This observation is true for climate change as well as for interstate programs for controlling air pollution. Policy-making is easier when the disputes are not about the data.

The spatial scale of concern in questions surrounding interstate air pollution control has grown over time. Twenty years ago, interstate air pollution control efforts focused on airsheds, such as areas adjacent to the New York, New Jersey, and Connecticut border. But by 1990, science had established that problems such as acid deposition, ozone, and subsequently particulate matter, had to be addressed on a regional basis. This understanding led to the 1990 Clean Air Act Amendments and the establishment of the acid rain control program and the Ozone Transport Commission. Within a few years, the Ozone Transport Assessment Group (OTAG) recognized that ozone control in the eastern United States would entail a much larger regional effort. Data gathering in support of this effort, which indicated the need for region-wide reductions in NOx emissions, led to the NOx SIP Call.¹

¹ The NOx SIP Call was an EPA mandate that State Implementation Plans (SIPs) be revised to reduce NOx emissions in the eastern US to reduce interstate transport contributing to ozone pollution.
Since then, Regional Planning Organization (RPO) work has been the focus of coordination and has included emissions inventory development. Inter-regional coordination is essential for broad agreement. Agreement on the nature of the air quality problem is an essential prerequisite to inter-regional agreements. We need to rely on consistent inventories.

The organizers of this workshop have identified six cases in which improved emissions information is needed:

- On-road mobile sources
- Non-road mobile sources
- High electricity demand days
- Space heating using liquid fuels
- Spacing heating using biomass
- Agricultural ammonia sources

Data relating to the power sector is very well developed, but emissions estimates on high electricity demand days may not be. As standards are tightened, we must consider more off-normal events and look at a greater diversity of sources. For example, space heating suffers from a lack of good information on fuels and emissions factors (e.g., in the case of space heating with biomass, how much and what kind of wood is used). Non-road mobile sources are also becoming a larger and larger part of the inventory, and electricity production on high demand days relies increasingly on nontraditional sources of electric generation. To characterize emissions on high demand days, we must have a good understanding of the generators—Where are they? When do they run? How much do they emit?—We will need information from the ISOs (Independent System Operators) and the aggregators to gather these data. Projection of future emissions from EGUs is also an issue. In the case of ammonia, emissions are not well understood. Ammonium sulfate and nitrate are the majority of PM, but the formation and transport of these pollutants is not well understood.

The first need in air quality planning is a high quality emissions inventory. We need to understand the sources of pollution in order to effectively reduce it. This understanding becomes much more important when multiple states and regions are involved. It’s so much easier to reach agreement if the underlying data is sound.

In closing, the work you’re doing is vitally important. Keep up the good work. We look to you to develop the data needed.

Regional Air Quality and Emissions Overview
Summary of remarks by Susan Wierman, Executive Director, MARAMA

Meeting air quality standards in the northeastern United States remains an ongoing problem, and none of the states in this region can address the problem on their own. Although exposure to air pollutants may be dominated in some cases by nearby emission sources, the air quality of this region is governed by emission on scales from the neighborhood to regional or
larger, and by the transport and processing of these emissions on all scales. This discussion provides an overview of the problem from an Atlantic seaboard perspective, covering:

- The principal air pollution challenges facing the Mid-Atlantic and Northeast Regions;
- The effects of transport and air stagnation conditions on local air quality;
- The principal sources of poor air quality in the region; and
- The strengths and weaknesses of emissions inventories as they affect air quality management of the region.

**Challenges**

The principal regional-scale air pollution problems facing the northeast corridor remain ozone and particulate matter (PM), with a broad swath of the area from northern Virginia to Maine in nonattainment for one or both of these criteria pollutants. Ozone is a widespread summer pollution problem, while PM is an urban and regional problem year round. The current National Ambient Air Quality Standards (NAAQS) for these pollutants are given below:

<table>
<thead>
<tr>
<th>Ozone</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.075 ppm (8-hour)</td>
<td>15 µg/m³ (annual)</td>
</tr>
<tr>
<td></td>
<td>35 µg/m³ (daily)</td>
</tr>
</tbody>
</table>

Peak ozone concentrations have been declining over the past decade throughout the region; however many areas from Washington, DC to Boston, around Pittsburgh, and along the great lakes exceed the eight-hour standard. Ozone is formed in the atmosphere downwind from sources of nitrogen oxides and volatile organic compounds.

Atmospheric particles span a wide spectrum of sizes, and are complex mixtures of sulfates, nitrates, ammonium, a multitude of organic compounds, and elemental carbon. Ambient concentrations of PM can vary significantly from day to day depending upon a variety of factors, including long-range transport. In rural areas of the Northeast, PM concentrations tend to be higher in summer than winter, and the dominant chemical component tends to be sulfate. In urban areas, high concentrations of ambient PM can occur any time of year. Urban PM also has higher concentrations of nitrate in addition to sulfate.

Particles in the air absorb and scatter light, thus impairing visibility. In the Northeast, ammonium sulfate is the principal chemical component of regional-scale PM pollution. Ammonium sulfate is hygroscopic. The source of the sulfate in ambient PM is emissions of SO₂, which is formed during combustion of fuels containing trace amounts of sulfur. In the atmosphere, SO₂ is oxidized by various gas-phase or aqueous-phase reactions to sulfuric acid or bisulfite and then reacts with atmospheric ammonia to form ammonium compounds.

We know quite a bit about the sources of SO₂ emissions. We have much less quantitative information about the sources of ammonia. The principal sources of atmospheric ammonia are primarily emissions from livestock operations. These sources are difficult to quantify. (This problem is discussed in more detail in Section 2.6, below.)
### Meteorological Effects

Air pollution events in the Northeast are modulated by local to regional scale meteorological conditions and by the transport of pollutants and pollutant precursors into the area. Air pollution events in the winter are characterized by high levels of particulate matter and are usually associated with air stagnation conditions, which can last for several days. Summertime transport brings ozone and PM and their precursor pollutants from one urban area to another within the region and into the region from large air pollution sources in the Ohio River valley and other areas outside the region. Transport makes attainment of air quality standards in the Northeast a multi-state problem – a fact that has been known for some time.

### Sources Affecting Air Quality in the Northeast

As is well known, ozone is a “secondary” air pollutant that is formed in the atmosphere via a complex set of coupled chemical reactions involving volatile organic compounds (VOCs) and nitrogen oxides that are emitted by an array of natural and anthropogenic sources. The sources of particulate matter, on the other hand, include both direct emissions of particles (i.e., primary particulate emissions) and secondary formation via atmospheric reactions involving primarily SO₂, NOx, VOCs and semivolatile organic compounds, and ammonia. These principle sources are summarized in the following table:

<table>
<thead>
<tr>
<th>Ozone</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Oxides</td>
<td>Primary Particles</td>
</tr>
<tr>
<td>On-road vehicles</td>
<td>Wood combustion</td>
</tr>
<tr>
<td>Off-road equipment and vehicles</td>
<td>Wildfires</td>
</tr>
<tr>
<td>Combustion</td>
<td>Dust</td>
</tr>
<tr>
<td>Volatile Organics</td>
<td>Sulfur Dioxide</td>
</tr>
<tr>
<td>Natural emissions from vegetation</td>
<td>Fossil fuel combustion</td>
</tr>
<tr>
<td>On-road vehicles</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td>Agricultural sources</td>
</tr>
<tr>
<td></td>
<td>VOCs and NOx</td>
</tr>
<tr>
<td></td>
<td>Same as for ozone</td>
</tr>
</tbody>
</table>

### Strengths and Weaknesses of Existing Inventories

In 2005, NARSTO published an assessment of emissions inventories in the three countries of North America. The assessment characterized the strengths and weaknesses of current inventories, and it proposed eight general recommendations for improving them. In summary, the strengths and weaknesses of inventories in the United States are as follows.
Strengths of the regional emissions inventory include:
- Emissions of criteria pollutants and their precursors from major point sources are well characterized.
- Quantitative estimates of emissions are available at the county level and up.
- The importance of natural biogenic emissions has been recognized and this knowledge has affected the design of air quality management strategies in areas where they are important.

Weaknesses of the regional emissions inventory include:
- Emissions from area sources, smaller point sources, and mobile sources are much more uncertain than emissions from large point sources equipped with continuous emissions monitoring systems.
- Emissions estimates are often based on a few measurements.
- There is inadequate information on the chemical composition of emissions from many important sources.
- Temporal and spatial variations in emissions are not well characterized.
- Emissions inventories are not developed and updated in a timely manner.
- Projections of future emissions are highly uncertain.

In brief, NARSTO’s eight recommendations for addressing these weaknesses were
1. Reduce uncertainties, focusing on the most important source categories.
2. Improve speciation estimates for PM, VOCs, and toxic air pollutants.
3. Develop new and improve existing emissions measurement methods.
4. Quantify uncertainty and report it.
5. Define and implement standards to increase inventory compatibility and comparability.
6. Improve access, via the internet, to emissions data, documentation, and calculation methods.
8. Assess past methods and improve projections of future emissions.

In order to address these recommendations and improve the emissions inventory for the Eastern U.S., an ad hoc committee of professionals from state and local air quality agencies and EPA called the Eastern Regional Technical Advisory Committee (ERTAC) pursued the following activities
- A review of methods for calculating emissions from key area source categories for consistency;
- Coordination of a 2005 modeling inventory; and
- Organization of a meeting with the Ontario Ministry of Environment to promote coordination with that province.

In addition to these activities, many states are beginning to build greenhouse gas inventories. Another inter-regional project is underway to improve estimates of organic carbon
emissions from light duty vehicles, and efforts are being undertaken to improve estimates of condensable PM emissions from electric generating units.

In summary, improving emissions estimates is an ongoing process. Perfection is not attainable, but continuous improvement is. The key to progress is to focus on those areas where improvements can make a difference in our quest for better air quality. For this workshop we have identified six priority areas where improvements would enhance the effectiveness of air quality management:

- On-road mobile sources,
- Non-road mobile sources,
- High electricity demand days,
- Space heating (liquid fuels),
- Space heating (biomass and wood), and
- Agriculture and ammonia sources.

The conference organizers believe that the recommendations regarding improving emissions estimates made at this conference will influence how funds are spent on emissions inventory improvement.

**Emission Estimates Needed for the Next Round of Modeling**

*Summary of remarks by Tad Aburn, Chair, MARAMA, and Director, Air and Radiation Management Administration, Maryland Department of the Environment*

Emissions inventories provide the basis for decision-making. Inventories define where we are starting from in dealing with an air pollution issue. They help us understand the sources of problems, and they are the critical input to the models that predict whether actions taken to reduce emissions will achieve the desired outcomes. From this presenter’s perspective, the principle inventory issues are speed, support for weight-of-evidence demonstrations, and emissions growth.

**Speed in Preparing Emissions Inventories**

The policy process continues to become more dynamic. Answers are needed in days and weeks, not months and years. The emissions inventory community needs to come to terms with this fact. Many times we need models, and the emissions information to support these models, that can be used quickly for screening and “what if” scenarios. This process is iterative, and it needs to be able to characterize uncertainty in a way that is meaningful to the policy issue under consideration.

**Dealing with Weight-of-evidence and Uncertainty**

More stringent standards make simple “bright line” demonstrations of attainment more difficult. In fact, given inherent uncertainties, is a bright line test for attainment even realistic? The weight-of-evidence approach is more beneficial in that it recognizes the uncertainty in model results. Although the weight-of-evidence approach makes it more difficult for EPA to decide whether or not attainment has been demonstrated, it is a better way to use model
results. Modeling results should be accompanied by other analyses. However, EPA guidance for weight-of-evidence demonstrations focuses mostly on modeling.

Ozone and PM standards are going to be difficult to meet in Maryland. Ozone concentrations in the air that comes into Maryland, for example, frequently exceed the standard.

**Forecasting Growth in Emissions**

Emissions growth is one of the key inventory and policy issues facing the state of Maryland. It may be time to consider several growth scenarios when projecting future emissions. The principal justification for modeling is predicting the future. The question becomes how do you capture the air quality effects of nontraditional emissions reduction programs (e.g., greenhouse gas reduction measures or environmental education initiatives)? Some greenhouse gas reduction initiatives, such as cap-and-trade, give us a different version of how emissions will grow in the future due to lower energy consumption, for example, or changes in driving habits. The bottom line is that we should be using a range of emissions growth scenarios in our preparation of State Implementation Plans (SIPs). Recognition of the uncertainties in emissions growth makes bright line attainment demonstrations even more problematic.

Speciation, transport of pollutants and precursors, and spatial and temporal variations in emissions are all factors that affect model performance. But the emissions inventory does not have to be perfect: just good enough. The question to ask is just how good this has to be.

**Importance of Coordination**

Coordination and collaboration among states and regions is of increasing importance, and inter-regional communication and collaboration should be ongoing. Because of pollutant transport, states care as much about the quality of the emissions inventory upwind as they do about their own inventory.

Resources are limited. We always need to consider whether we can get a better product if we work together regionally and leverage our resources and efforts. We have a history of doing this. We need to build on it.

**Intra-urban Pollution Gradients and Public Health Impacts**

*Summary of remarks by Thomas Matte, Director of Environmental Research, Bureau of Environmental Surveillance and Policy, New York City Department of Health and Mental Hygiene*

Serious examination of the relationships between air quality and health in New York City (NYC) began in the 1930s. During the depression era, the City Health Department partnered with the Air Pollution Survey of NYC to examine the problem. As an estimate of exposure, dustfall was measured in tin cans on rooftops around the city. Researchers concluded that the slum areas had the worst air quality, while private residential sections had the best. The study
surveyed all combustion equipment in Manhattan by equipment type and fuel burned. The study employed hundreds of people through the Works Progress Administration.

During the 1950s and 60s it was assumed that air quality within a metropolitan area could be tracked using limited number of sample sites and that these data could be linked to health data for assessment purposes. Using a limited number of sites it is possible to track day-to-day variations in pollutant concentrations and to study variations in these concentrations between cities. With these data, time series studies can be conducted to compare air quality data and health effects data. Such studies allow scientists to estimate the links between chronic exposure and health effects, but they are not intended to track exposure to emissions from nearby sources.

There is increasing concern about pollution gradients within cities. Environmental justice issues resulting from the higher pollution exposures found in poorer neighborhoods drive some of this concern. Research on the health effects of air pollution is, therefore, placing greater emphasis on understanding intra-city differences. This concern has fueled a tremendous increase in the number of studies that focus on land use differences and near-road exposures. These studies try to look at differences in exposure through measurement, interpolation between monitors, source proximity, modeling, or hybrid approaches. Spatially resolved emissions estimates, especially using traffic counts, can help improve the scientific understanding of air pollution and its effects on human health. As the health of people within New York City varies considerably, several questions arise: How much does air pollution contribute to these health disparities? How much is due to differences in exposure? How much is due to differences in vulnerability? How much is due to differences in both or to interactions among pollutants?

Asthma prevalence varies considerably within New York City, with the highest incidences in poorer neighborhoods. Other chronic diseases vary in the same way—diabetes, obesity, and age-adjusted cardiovascular disease. Even if air quality were uniform there would be differences due to vulnerability. For example, the number of seniors without air conditioning varies across the city. This difference alone can affect population response to both heat and air pollution. Other vulnerabilities that may vary across the City include pre-existing health conditions that would predispose one to health effects due to air pollution, access to health care, treatment of asthma, etc. People whose asthma is not as well managed, for example, are more vulnerable to air pollution.

Have improvements in air quality led to improvements in health within New York City? This connection has not been shown directly, but the same comment could be made about studies linking tobacco use to cancer. There are studies in particular locales, such as the 6-city studies, that have shown a relationship between air quality and public health. This information allows us to project the health benefits from air quality improvements.

To begin assessing variations in pollutant concentrations in New York City, Ross et al (2007) created a map of estimated PM$_{2.5}$ variation across the City using available monitoring data, land use information, and traffic data. But we really don’t know how these variations contribute to health disparities. The New York City community air survey is an effort to measure street level air quality at a large number of sites and get a better understanding of
intra-city variations in air quality and the sources of these variations. The design for the survey is based on similar studies in other cities. In order to document within-city variations, measurements are made at 150 locations for one two-week period each season (spring, summer, fall, winter). Additional “reference sites” are located at the New York Department of Environmental Conservation and at parks, and samples are made at the reference sites every two weeks during the year. Average seasonal air quality is calculated and adjusted for temperature. Queens College conducts the monitoring. PM mass, Elemental Carbon, metals, NO, NO₂, NOₓ, ozone, and SO₂ are measured at all 150 locations using samplers mounted on light poles at about 10-12 feet high. At the time of this conference, reference sites had been established, and the project was to begin December 1, 2008. The sites are intended to document variations in pollutant concentrations and not for judging compliance with the National Ambient Air Quality Standards. The sites do not meet the criteria for official monitoring sites. As these data are being collected, discussions are underway with other researchers who are conducting paired indoor and outdoor measurements.

Emerging Trends in Energy Technology and Fuels and Potential Environmental Implications

Summary of remarks by Janet Joseph, Program Director, Clean Energy Research and Market Development, NYSERDA

The New York State Energy Research and Development Administration (NYSERDA) focuses on the development and deployment of energy efficient technology. It works at the intersection of energy, environment, economic development, and education. NYSERDA’s environmental research program (the Environmental Monitoring, Evaluation, and Protection program, or EMEP) supports policy-relevant research to enhance the understanding of energy-related environmental issues as they affect New York State.

NYSERDA is currently supporting several technology-forcing energy and environmental policies. These include:

- The Regional Greenhouse Gas Initiative (RGGI), a regional cap and trade program intended to stabilize greenhouse gas emissions from electric generation in the Northeast,
- An energy efficiency portfolio standard for New York, similar to programs in other states,
- A New York State renewable portfolio standard, analogous to renewable standards in 25 other states,
- Work anticipating how federal diesel technology and fuel rules will change the emissions profiles, and
- Research on how proposed national climate legislation might fundamentally change the energy landscape.
These policies are changing the way we generate electricity. New renewable power facilities are coming on line, and these changes will affect the future emissions profile of the electric power sector.

Socolow and Pacala’s 2006 article in *Scientific American* popularized the concept of reducing greenhouse gas emissions by implementing a large number of emissions-reducing technologies and policies, which they termed stabilization wedges. The purpose was to show that significant emissions reductions could be obtained by implementing a large number of existing technologies. Examples of these stabilization wedges that are being investigated by NYSERDA are given below.

There are a number of emerging technologies in the building sector that promise significant energy savings. These technologies include solid-state lighting, on-site electricity production, combined heat and power generation, and space and hot water heating using renewable resources. For example, efficiencies of 65-75 percent (about double the typical power plant) are achievable through combined heat and power generation. This technology also changes the type and location of pollution emissions as well as the height of release.

Increased use of solar hot water heating would reduce demand for other fuels and would reduce pollutant emissions. Likewise, reducing sulfur content in conventional heating fuel would have a big impact on emissions. With respect to other renewables, there is increased interest in the use of biodiesel for water and space heating. Using biodiesel in boilers and furnaces would be an environmental win. Although using biofuels in boilers and furnaces does not reduce NOx emissions, it does decrease green house gas (GHG) emissions. In compression engines, the effect is different, as pointed out below.

In recent years, there has been a proliferation of low efficiency high emissions wood boilers in more rural portions of the Northeast. However, there is new technology, already in widespread use in Europe, which can burn wood or pellets much more efficiently and cleanly. Policies that encourage the use of this technology can raise the floor in terms of performance and stimulate a new industry. In addition, two-stage or gasification technology can significantly reduce emissions.

Wind, gasification (biomass, coal, and municipal solid waste), biofuels, and kinetic hydro are also technologies of interest to NYSERDA. At this time there is insufficient information on emissions from some gasification operations for them to be included in inventories. On the other hand, there are reasons to believe that blending biofuels with traditional fuels can reduce GHG emissions.

Emerging vehicle technologies – clean diesel, hybrid vehicles, biofuels, plug-in electrics, fuel cells, etc – will change vehicle emissions. In internal combustion engines, blending biodiesel into traditional fuels at low concentrations can reduce CO2 without increasing NOx. The use of ethanol in spark-ignition engines would change the chemical composition of engine emissions, which raises air quality questions.

Changes in agricultural practices need to be captured in our emissions inventory. We have inadequate data, and our inventory needs improvement. The break-out session on
agricultural and ammonia emissions planned for this Workshop will be very helpful in this regard.

In conclusion, the energy landscape is changing, and we need to ensure that these changes are consistent both with our energy and environmental goals. We need to embrace an energy efficiency and multi-pollutant approach to these challenges. Emissions standards that are output-based and reward high efficiency can be technology-forcing. The vast majority of environmental improvements we have seen have resulted from technology-forcing rules. Even renewable sources must be optimized to maximize energy efficiency and emissions performance. Although nuclear power has not been discussed in this presentation, it is part of the state energy planning process. It may need to be one of the options for the future.

**Updating the National Emissions Inventory**

*Summary of remarks by Doug Solomon, Emissions Inventory and Analysis Group Leader, Office of Air Quality Planning and Standards, US Environmental Protection Agency (EPA)*

The National Emissions Inventory (NEI) is EPA’s estimate of the emissions of criteria pollutants, precursors that contribute to criteria pollutants, and hazardous air pollutants. It is developed in partnership with the states, local air pollution agencies, and tribal governments. The inventory includes estimates of emissions from point sources, area sources on a county level, and mobile sources (road and non-road). At the current time it is updated every three years.

The NEI is used to assess the effect of proposed legislation and regulations on national, regional, and local air quality; and it is the basis for the development of air quality management actions needed to meet national air quality standards. The NEI is also a source of public information on emissions of pollutants, including hazardous air pollutants, and it is the data source for international emissions reporting.

In recent years a number of critiques of the current NEI process have appeared from both external (CAAAC, NARSTO, and the NAS) and internal EPA sources. These critiques have emphasized the need for improvements in emissions data that are being driven by new demands on this data source, for a less cumbersome process for generating emissions estimates, for increased transparency in the process used to generate these estimates, and for improved quality control.

In order to implement the recommendations of these critiques, EPA is reengineering the NEI development process. The goals of this reengineering are to:

- Improve the quality of emissions measurements and estimates,
- Obtain greater stakeholder collaboration (from both the suppliers of emissions information and the users of this information), and

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2CAAAC is EPA’s Clean Air Act Advisory Council. NAS refers to the US National Academy of Sciences.
• Develop improved tools that would reduce the time required to develop emissions inventories, improve the quality of these inventories, and provide better access to the data and greater transparency in the development of these data.

A critical component of the reengineering effort is the development of an Emissions Inventory System (EIS). The EIS will be the tool for developing the National Emissions Inventory. It will consist of four components:

• The EIS gateway,
• A means for submitting emissions data through EPA’s Central Data Exchange (CDX) Node,
• A portal for public access to the data, and
• Tools and resources for facilitating the development of emissions information.

The principal benefits of the EIS will be to a) reduce the time required to produce the NEI; b) make the development process more transparent; c) build quality assurance steps into the NEI development process; d) provide state, local, and tribal access to the data; and e) enable public and industry access to current and historical emissions information data.

Stakeholder collaboration in the development of the EIS is being achieved through two working groups: an NEI taskforce composed of state, local, tribal, and RPO representatives; and the NACAA Emissions and Modeling Committee, which is composed of a larger group of state and local agency staff. Short-term milestones for the development effort at the time of this conference were to complete development of the EIS at EPA’s National Computer Center (NCC), obtain approval of the EIS security plan, obtain system certification and accreditation, and launch the EIS gateway by October 2009. Longer-term goals for the project were to provide access to historical emissions data through the EIS by January 2009, provide emissions access through the CDX node by July 2009, provide public access to these data by December 2009, and complete the 2008 NEI cycle by December 2010. Eventually, the goal will be to complete compilation of new annual emissions inventories within one year.

The following table summarizes the comparative features of the current NEI development procedure and the new NEI/EIS process.
<table>
<thead>
<tr>
<th>Old Process</th>
<th>New Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Access to the database</strong></td>
<td>Stakeholders will have direct online access to the EIS database throughout the development process, including access to their data one business day after submittal.</td>
</tr>
<tr>
<td>No direct access.</td>
<td></td>
</tr>
<tr>
<td><strong>Loading emissions inventory data</strong></td>
<td>Data automatically loaded into the EIS database at the time of successful submission.</td>
</tr>
<tr>
<td>Submitted data are sent to and loaded in several EPA contractor databases.</td>
<td></td>
</tr>
<tr>
<td>Data are not loaded onto EPA servers until after creation of the final inventory. This can be several months after data submission.</td>
<td></td>
</tr>
<tr>
<td><strong>Linking to other EPA data systems</strong></td>
<td>As the EIS will be housed at the NCC, it will be linked to other EPA data systems, e.g., TRI, CAMID, and FRS.</td>
</tr>
<tr>
<td>Database not linked to any other EPA data system.</td>
<td></td>
</tr>
<tr>
<td>Other sources of data must be converted and loaded manually into the database.</td>
<td></td>
</tr>
<tr>
<td><strong>Tracking changes to the data</strong></td>
<td>Changes to the data will require the submittor to document the reasons for the change. This documentation will become part of the record.</td>
</tr>
<tr>
<td>Changes to the data are inconsistent and not generally documented.</td>
<td></td>
</tr>
<tr>
<td><strong>Old Process</strong></td>
<td><strong>New Process</strong></td>
</tr>
<tr>
<td>----------------</td>
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</tr>
<tr>
<td><strong>Correcting emissions inventory data</strong></td>
<td>Stakeholders will have web access to the EIS database and can make corrections to the data online.</td>
</tr>
<tr>
<td>Air agencies make corrections by submitting a new emissions inventory, phoning-in the corrections, or sending the corrections via e-mail.</td>
<td></td>
</tr>
<tr>
<td>Actual changes to the database are made by an EPA contractor.</td>
<td></td>
</tr>
<tr>
<td><strong>Quality assurance</strong></td>
<td></td>
</tr>
<tr>
<td>The process relies on several EPA-supplied tools.</td>
<td>The EIS will use centralized quality assurance procedures that apply to all data.</td>
</tr>
<tr>
<td>Not all data are quality-assured before being loaded into the database,</td>
<td>The EIS will contain a QA environment in which all data can be quality assured prior to submission.</td>
</tr>
<tr>
<td>Much of the quality assurance was performed manually.</td>
<td>All quality assurance will be performed by the system.</td>
</tr>
<tr>
<td><strong>Facility inventory process</strong></td>
<td></td>
</tr>
<tr>
<td>Point source facility descriptive information must be submitted with every inventory, regardless of whether or not the data have changed.</td>
<td>Point source facility descriptive information need not be repeated with every inventory.</td>
</tr>
<tr>
<td>EPA expends considerable resources quality-assuring these data.</td>
<td>The automated QA environment and online access to the data will be used to quality-assure facility descriptive information efficiently.</td>
</tr>
<tr>
<td><strong>Creating the NEI</strong></td>
<td></td>
</tr>
<tr>
<td>State, local, and tribal agencies have 17 months from the end of the inventory year to submit their data.</td>
<td>EPA has proposed a regulatory change that shortens the submission period to 12 months.</td>
</tr>
<tr>
<td>After submission, it takes EPA 19 months to create the NEI.</td>
<td>EPA proposes to create the NEI within 6 months after data submission.</td>
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</table>
Mobile Source Developments and Issues (MOVES Update)

Summary of remarks by Gene Tierney, Environmental Scientist, Office of Transportation and Air Quality, US EPA

Emissions from mobile sources must be estimated using models that have inherent strengths as well as weaknesses. These models do a good job in estimating emissions on the regional and larger scales and for common, well-studied sources such as light duty gasoline-fueled vehicles (LDGV). Emissions estimates are most reliable for gaseous criteria pollutants (e.g., hydrocarbons, CO, and NOx), and for vehicles that run on common fuels (gasoline and diesel) and are operated close to standard operating modes. Mobile source emissions are less reliable for:

- County or smaller scales (such as estimating emissions for “hot spots” or for estimating emissions associated with specific projects),
- Less common equipment (such as large trucks, construction equipment, or aviation and marine engines),
- PM and non-criteria pollutants including greenhouse gases and most air toxics,
- Unusual and less-studied operating modes (such as cold-start, extended idling, high speed, and most non-road cycles),
- Alternative and less-common fuels (such as ethanol, biodiesel, and aviation fuels), and
- The newest engine technologies.

Improvement in these categories will require additional research and development. The key opportunities for making improvements include better fleet information (e.g., age distributions and population data), better activity information (when where and how mobile sources operate – vehicle miles traveled, hours of operation, number of starts, and the number of hours in specific operation modes), and information on how usage patterns change with vehicle age. Finally, there is continuing need for better emission factors and better models.

Improved activity information could be achieved through the deployment of portable emission measurement systems (PEMS) on on-road vehicles and non-road equipment and by using aerial and satellite data for obtaining real-world speed and acceleration data. Another pressing need is improved allocation of vehicle miles traveled (VMT) from the state to county level. The current method uses road-length and population data for this purpose. Other allocation methods could employ population density, transportation usage and census data. Finally it is important to maintain and expand US Census collection of data relevant to this problem.

To improve emissions estimates, better information is needed for less common operating modes (starts and extended idle) and for cold starts when catalysts are not functioning. Emissions information is especially needed for species that have been poorly measured in the past. These species include PM, N2O, CH4, NH3, air toxics, metals, and so forth. Finally better information is needed on how emissions change for all technologies as these technologies age. This information could be obtained through the deployment of improved PEMS on in-use vehicles. Consequently, it is important to develop new PEMS technologies that are capable of measuring the key species mentioned above. For species that cannot be measured by PEMS, emission factors would have to be estimated via dynamometer
Additional longitudinal studies will be required for developing information on emissions from in-use vehicles or equipment change with age.

It is important to recognize that emissions models are improving. The MOVES model is the latest step in this process. In developing MOVES, EPA analyzed data from nearly 70,000 vehicles from various states across the country in order to establish emission rates. These data came from dynamometer tests, emissions measurements derived from inspection and maintenance (I/M) programs, and from other vehicle emissions sampling experiments. One of the significant findings was that although vehicle emissions increase with age, these increases flatten out in jurisdictions with I/M programs. This flattening in fleet deterioration indicates that I/M actually works. However, not all high emitters are scrapped. Some may be exported to areas without I/M programs and some may be re-registered in jurisdictions just outside the I/M area and driven back into it.

Another insight gained during the development of MOVES was that the Tier 2 assumptions in MOBILE6 regarding deterioration of emission controls are conservative. In contrast, it was found that on-board diagnostics (OBD) and enhanced evaporative emission controls continue to work, even in areas without I/M programs. The principal source of evaporative emissions appears to be vapor and fuel leaks. Current testing will help quantify the magnitude and prevalence of such leaks.

Other differences in emissions estimates for light duty vehicles in MOVES as compared to the previous MOBILE model are summarized in the following table. Differences for heavy duty vehicles were still being analyzed at the time of the presentation.

<table>
<thead>
<tr>
<th></th>
<th>Tier 1</th>
<th>Tier 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>Up</td>
<td>Down</td>
</tr>
<tr>
<td>Exhaust HC</td>
<td>Down</td>
<td>Down</td>
</tr>
<tr>
<td>Evaporative HC</td>
<td>Down</td>
<td>Down</td>
</tr>
<tr>
<td>PM</td>
<td>Up</td>
<td>Up</td>
</tr>
</tbody>
</table>

MOVES will facilitate analysis at different levels of detail – national, regional, and local. Data importation software was being developed to simplify data input, and EPA was preparing guidance documents and planning for outreach and training. MOVES is designed for application at the macro, meso, and micro scales. This scalability translates into different geographical domains. At the national scale, MOVES provides scale-appropriate default data, allocated to the county level. These defaults are appropriate for broad national analyses, but they are not appropriate for use in SIPs or conformity analyses. Application at the nonattainment or county-level requires local environmental, fleet, and activity data, as previously used in MOBILE. Output from MOVES is at the county level by road type. Project-level data are input as links.

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3 A draft version of the MOVES model was released for comment in early 2009. The official version became available in early 2010. EPA began to share results with stakeholders in the fall of 2008. A workgroup met to review the model in October 2008. Next, EPA began to work with the National Association of Clean Air Agencies and the US Department of Transportation to train users.
Fleet and activity data are entered as individual links. It is possible to enter detailed driving behavior (including idle and start) by link, and multiple links can be modeled in a single run.

MOVES is an emissions model. It is designed to estimate total emissions by road and vehicle type at a range of scales: national, attainment area, and project. Optional look-up table output produces emissions estimates in grams per mile for other applications. EPA was also considering developing grams per hour output for non-running emissions, and for sources such as construction equipment and other non-road sources.

Moves will have interfaces that can be used to create alternative databases, tables, and data records for a range of applications. The MOVES team developed data import software to simplify creation of local input files. These features will enable creation of custom input data without the need for specialized knowledge of database commands and syntax. These importers help ensure that updates are only made to the appropriate tables, and they will assist the user in making sure that data entries are complete and contain no gaps. The importers can include some error checks, and they can be designed to import data from MOBILE6 to MOVES.

Several guidance documents were to be released shortly after the conference:

- Technical guidance for SIPs and conformity,
- Project-level conformity guidance for PM, and
- SIP and conformity policy guidance.

EPA developed and implemented a joint training plan with the Federal Highway Administration.

EPA plans to incorporate NONROAD into MOVES in 2011. In the interim, NONROAD will continue to be used.

**Role of Ammonia, Status of Ammonia Emissions Estimates, and Prospects for Improvements**

*Summary of remarks by Praveen Amar, Director, Science and Policy, NESCAUM*

Ammonia sources are indeed different. The most important anthropogenic sources result from animal waste associated with animal husbandry. Sources are varied and dispersed, and estimating the emissions is not simple. Ammonia is an important component of total reactive nitrogen in the atmosphere, and it reacts with the inorganic acids created by the oxidation of SO₂ and NOx emissions to form ammonium bisulfate/sulfate and nitrate, which are principal components of atmospheric PM. Ammonia is not measured routinely in any national network, but it may constitute more than eighty percent of the reduced nitrogen deposition at some locations. In addition to being a substantial component of PM, ammonia or ammonium deposition contributes to the acidification of terrestrial and aquatic ecosystems and to the nitrogen enrichment of ecosystems and the eutrophication of aquatic systems.

Ammonia emissions are increasing. For example, MANE-VU projected net ammonia emissions would grow from a little over 300,000 tons/year in 2002 to about 380,000 ton/year in
The largest sources of ammonia emissions are agricultural operations and gasoline-fueled vehicles. Fuel combustion and waste treatment are also among the top ten source categories, but seven of the top ten categories are agriculture-related. Because of the dominance of agriculture-related emissions, the geographical distribution of ammonia sources differs from that of SO\(_2\) and NO\(_x\) emissions sources. Emissions density correlates strongly with those parts of the country that are predominately agricultural. However, the principal areas of emissions growth are changing. For the period 1989 to 1999, emissions in parts of the Midwest appeared to be decreasing, while there was a rather large growth in emissions in eastern North Carolina.

Ammonia is both a local- and a regional-scale pollutant. There is some evidence that the deposition velocity for ammonia has been overestimated in atmospheric transport and chemistry models, implying that these models have overestimated the fraction of ammonia emissions that are deposited locally. The “range of influence” of an ammonia “hot spot” is probably 300 km or more. Thus on a regional basis, about 50% of the ammonia is removed by wet deposition, about 25% by dry deposition, with the remainder transported out of the region.

Current work to improve estimates of ammonia emissions includes both model development and field studies. The EPA has funded major field experiments around concentrated animal feeding operations (CAFOs) in order to characterize emissions from these activities. This work has been supplemented by university-led studies funded by the states and by the private sector. There is also a major study underway at the University of California Davis to develop a detailed, process-based model of CAFOs that would result in more accurate emissions estimates. Other research suggests that soil emissions could be a large and highly uncertain component of total ammonia emissions. There is also evidence that emissions from gasoline engine exhaust catalysts could account for as much as 10-20 percent of total ammonia emissions.

Future work should build upon recent advances in understanding ammonia emissions:

- Enable estimates of ammonia emissions at the same spatial and temporal scales as SO\(_2\) and NO\(_x\) (12-36 km and hourly),
- Understand, coordinate, and integrate the work of universities and public agencies; make it useful to air quality managers,
- Use USDA 2009 animal census data,
- Calibrate the UC Davis/LADCO process-based emissions model for MANE-VU sources and apply to the eastern U.S.,
- Improve spatial and temporal profiles of fertilizer applications from the 2001 CMI/NESCAUM/MARAMA work,
- If not already done, locate CAFOs on a GIS,
- Perform additional field studies of emissions from CAFOs to corroborate emissions models, and
- Investigate the use of inverse modeling techniques to corroborate emissions estimates.

\(^4\) MANE-VU is the Mid-Atlantic/Northeast Visibility Union, and its geographic area includes the states from Maine through the District of Columbia.
4 Improving Estimates of Emissions from On-road Mobile Sources

The users of emissions information represent a spectrum of objectives and needs. Some users require a relatively crude aggregate emissions assessment to inform a “build-no-build” or “adopt or not to adopt” type of decision. These users may only need basic “thumbs up/thumbs down” decisions so they can move ahead with plans and actions already in motion. In some cases, emissions data are only used to determine a correct direction, not a quantitative result. For other users, it is critical that all the inter-connections and details of the emissions information development process accurately reflect the root causes that lead to a specific emission result. In such applications, it is important to not only have the emissions estimation process arrive at a correct result, but that the result is based on correct technical attribution. Some of these users will be basing programmatic decisions on specific portions of the broader emissions information development process, such as the emissions benefits/detriments of using an alternative fuel in a fleet. Still other users need inventories for emissions that have direct public health impacts, such as toxics and ultra-fine particles. As the health research in these areas is dynamic, and these emissions are often associated with high-resolution issues such as “hot-spots” or “near-roadway” concerns, current tools for estimating emissions do not serve this need. For instance, the emissions information tool kit is inadequate for providing decision-making information on ultra-fine particles vs. more traditional mass-based “particulate matter” (PM) and its toxic impacts. In these areas, direct ambient measurement may be required in order to “calibrate” the emissions estimation tool provide this kind of information.

Current emissions estimation tools are most attuned to the development of State Implementation Plans (SIPs). The official mobile source emissions model approved by the US Environmental Protection Agency (EPA) must be used for any SIP or other legally mandated air quality management exercise, whether for an intersection, a region, or a specific control program. Most state efforts for improving mobile emissions estimates have focused on discussions with EPA concerning modifications or improvements of subsequent versions of the MOBILE model, rather than undertaking direct testing work and building state-specific datasets. States have few resources to make or populate their own models. How easy it may be to replace national and regional defaults with state-specific emissions data in EPA’s new MOVES model remains to be seen. The MOVES model, which allows for local and regional inputs, may be a great departure from previous models, with significant program and policy benefits. However, the states will still be responsible for either collecting large amounts of new data or using the model defaults. Few states or localities will have the research resources to gather and manipulate the needed data; thus, most are likely to rely largely on the default values.
Uncertainties in On-road Emission Estimates

The most uncertain point in the emissions estimation process may vary with each type of application. Of necessity, the same emissions estimation tools are used for a wide range of tasks, often beyond the scope contemplated when a particular model was built. Thus, assumptions that are appropriate for regional SIP development may not be acceptable for other applications, such as microenvironment analysis. In each of these cases, the suitability of an emissions estimate for a particular application rests upon the professional judgment of the emissions modeler.

Clearly, it is not reasonable to use the same emissions estimation tool kit for all users and for all temporal and spatial scales of interest. Thus, a variety of tools may be needed to meet the varied requirements for accuracy, spatial and temporal resolution, and uncertainty estimation of each user of mobile source emissions estimates.

Activity data, usually based on a limited sample of data on vehicle miles traveled (VMT) from travel demand models, contain too many assumptions (e.g., fleet mix, fleet age distribution, speed distribution of VMT), to be used in a model to project activities for all vehicles. This nexus between the travel demand model and the emission factor model could be the “weakest link” in getting to the final emissions estimate; but one might never know this, as these modeled activity factors serve only as inputs to the next model (i.e., MOVES and/or MOBILE). For example, activity models are built on the assumption that for large aggregates of vehicles, averages over many types of driving patterns will provide a reasonable estimate of emissions at the aggregate level. This may work at the macroscale. But if the problem is estimating the air quality benefits of a specific intersection, using a model developed to provide an estimate of the emissions for a fleet of millions of vehicles is questionable. Appropriate cautions must be appended to extrapolations into regions where the model may fail, even if the model may be the only emissions estimation tool available for the task at hand.

The following is an illustrative list of possible emission estimation applications:

- Regional estimates of emissions for ozone air quality models;
- Hot spot and on-road estimates for PM and toxics;
- Near-roadway estimates for assessing direct traffic exposure;
- SIP NAAQS attainment demonstrations;\(^1\)
- Conformity budgets and project conformity determinations;\(^2\)
- Alternative fuel and technology project scenarios.

For each application, the emissions analyst must ask the following questions: What are the weak links in the application? What are the requirements for spatial and temporal resolution? How sensitive could the outcome be to uncertainties in the emissions estimates?

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\(^1\) A SIP NAAQS attainment demonstration is a demonstration using modeling and other analyses that the emissions controls in the State Implementation Plan (SIP) will result in air quality improvements sufficient to comply with the National Ambient Air Quality Standards (NAAQS).

\(^2\) “Conformity” refers to the requirement that transportation plans conform to air quality plans. Emissions from projects included in the transportation plan must not exceed emissions from mobile sources included in the SIP.
Although this list of questions is incomplete, it serves to illustrate that the critical weakness of the emissions estimation process may well be different for each application.

Next, the emissions analyst must ask if he or she can “spin straw into gold” by taking sparse or weak VMT and activity data and classifying them into the bins or categories used by the model to create an emissions estimate seemingly more valid that the underlying data would support. Can one mathematically take sparse data and build a better model than the original data would justify? The answer may be a qualified “yes,” by using re-sampling methods, and by relying also on the power of very large samples. A systematic critical examination of where weaknesses in the emissions model come into play may be needed as a “carry-along” metric that is a routine part of the emissions estimation process.

Additional Challenges and Considerations

**Skewed Emissions Distributions (Gross Emitters)**

It has been known for many years that a very few vehicles in the total on-road fleet are responsible for the bulk of total emissions. This may become increasingly true as the large majority of vehicles (cars, trucks, buses, etc.) become cleaner, leaving a few “rotten apples” to dominate net emissions. Accounting for this aspect of the vehicle population within emissions estimation tools has great impact on the interpretation of emissions modeling results, and must be kept in mind at all times when conducting research, estimating impacts and benefits of programs, and setting up policy options.

Obtaining better information on the tails in the emissions probability distribution function by documenting emissions from high emitters in the on-road vehicle fleet was in large part the basis for the continued interest in the use of remote-sensing devices (RSD) for drive-by pollution measurement, or in vehicle emissions testing programs that require only dirty vehicles to come in for testing rather than forcing acceptably clean vehicles to also be subjected to testing.

The highly skewed nature of emissions from the on-road fleet leads to many complications for emissions-reduction programs, such as “junker-scrapper,” or RSD programs to find high-emitters, and in the heavy duty diesel (HDD) case, where 30-year-old trucks that drive only a few miles dominate the inventory compared to clean vehicles driving many more miles.

Emissions estimation models tend to underestimate the contributions of high emitters, leading to errors in emissions estimates in the aggregate. If a fuel parameter is changed in the emissions estimation effort (e.g. sulfur or ethanol), one can be reasonably confident that all vehicles will be affected and the result (however controversial) will be broadly spread across the fleet. However, if the analyst is running an emissions estimation model to assess the benefits of an Inspection/Maintenance program focused on reducing emissions from high-emitters, the actual number of high-emitting vehicles affected needs to be known in order to complete the benefits calculation.
When high-emitting vehicles tend to be found on certain roadways, the near-roadway impacts will be inordinately larger than might be derived from an emissions model designed for generating regional-scale estimates. For example, dirty heavy duty diesel (HDD) trucks and buses might be concentrated in urban areas while clean HDD vehicles may be concentrated on long-haul routes. Consequently, emission estimates based on national default values, that may be accurate on the regional scale, would not be appropriate for the urban setting. In this case, how should we account for and adjust the emissions estimate of the few high-emitters that dominate the actual total emissions? Unless we recognize these kinds of problems, we can easily fall into the program and policy trap of correctly estimating emissions at a large scale (and concluding that there are no emission problems) but overlooking that there could be significant problems at much smaller scales.

The impacts of skewed fleet emission distributions are a basic fact of life for emissions estimation. It is an almost impossible task to project the population of high-emitters for future technologies and fuels that have not yet been placed in large-scale service. One hopes that these vehicles will be inherently low-emission, but this assumption needs to be tested over the full life cycle of the proposed technology/fuel so that continuous improvement and improved accuracy of the emissions estimation tools used by states are assured.

**Activity Data for MOBILE and MOVES**

While the new MOVES model is a major step in the direction of linking vehicle emissions estimation with improved vehicle use and activity inputs, it is important to understand both the importance of activity data to the overall emissions estimate and the difficulty of obtaining this information. A major study conducted in 1994 by the National Cooperative Highway Research Program examined how the many sources of data are all used to give an emissions estimate. Without looking in great detail at the myriad components of the estimate, one can conclude that variability in the inputs to the MOBILE (or MOVES) models may be a source of uncertainty in the overall emissions estimation process. For example, data on highway speeds, traffic volumes, etc., are collected a few times per year on selected roadways. These data are then used as inputs to the MOBILE or MOVES models and are assumed to be representative of other roadways.

Other uncertainties arise from the age distribution of the vehicle fleet. We know that newer vehicles are driven more miles per year during their early years than older vehicles of the same class. It is also plausible to assume that the newer vehicles are driven at higher speeds and on major roads, while the older portion of the fleet may more likely operate on secondary roads and streets. If the skewed distribution of emission-emitter categories were combined with a thoroughfare-specific vehicle type and age mix, the resulting emissions estimate for specific local streets might be significantly different from an estimate based on a regional-scale estimate modified by a factor designed to account for the emissions from this same class of vehicles. In other words, how can we expect emissions estimates based on inputs appropriate for a larger scale to provide valid road-specific estimates for hotspot and urban-canyon toxic and PM emissions?
The next generation of activity models needs to be able to support high-resolution emissions estimates, which is the goal of the MOVES model. Modern VMT tracking, electronic vehicle tracking, and similar approaches may be able to supply this information, but the large volumes of data generated may also overwhelm the few staff available to process the data. Electronic surveillance of cars as part of regional traffic control is already in place in a number of cities around the word (e.g., Singapore, London, and others), but these systems may not be suitable for generating the activity data needed for MOVES. In the future, emissions estimation models will use this kind of data.

An example of how vehicle-tracking data could improve emissions estimates might be found by looking at the problem of estimating Heavy-Duty Vehicle fleet emissions for an area such as NYC-Manhattan. While the Metropolitan Transit Authority’s bus fleet has been dramatically cleaned up through the use of alternative fuels, hybrid drive systems, and the installation of continuously regenerated trap filter systems on most buses, a significant portion of the bus fleet on the streets of NYC comes from outside the metropolitan area. These vehicles are often older and dirtier. When the only activity metric is the VMT for all buses, accounting for this vehicle mix may not be possible. Could data collected for other programs, such as Intelligent Transportation Systems, be mined for improving activity data and, therefore, emissions estimates?

In summary, it can be argued that the sheer size of the vehicle fleet will serve to “average out” the variability and give the correct net estimate of the regional emission inventory even if the activity data are poorly represented, distributed incorrectly between bins, or inaccurate to begin with. However, when one tries to do specific project analysis, or near-roadway impacts assessments, the actual activity data might give significantly different estimation results than when looking at the millions of vehicles as a single statistical mix.

**Development of Particle Number/Size Metrics for Emissions Estimation Use**

Concerns about the health effects of particulate matter are increasingly focused on the ultra-fine size fraction, but in this area, the emissions estimation toolbox is essentially empty for the program and project analyst. We do not have accepted standardized laboratory testing methods, or the ability to distinguish between different fuels, technologies, and engine characteristics (e.g., high emitters versus clean vehicles) with respect to emission of ultra-fines. Constructing a practical emissions model capable of giving guidance to program and project managers on options for reducing ultra-fine PM emissions will not be simple. Identifying options for dealing with gaps in the emissions estimation process for ultra-fine PM was one of the questions discussed at this conference. If methods for estimating near-roadway ultra-fine emissions are not available, air program managers will be forced to address public health concerns regarding this issue on the basis of little or inaccurate information. European researchers have conducted a number of health-based studies demonstrating the negative health impacts of living near roadways, and California has enacted a rule limiting the building of schools within a given distance of roadways. This emerging information, and some of the reactions to it, raise a number questions:
• How will other states deal with mounting pressure to “do something” in this area as increasing health studies have reported that ultra-fine PM can move directly into the brain?

• What research agenda is needed in order to establish a building-block approach to link the emerging public health research findings with experimental testing of different vehicle combustion technologies, emission control systems, fuels, operating modes, lifecycle deterioration (high emitter), and other factors that are needed to guide and monitor policy and program choices?

• How can long-term ambient monitoring of ultra-fines be used to test for impacts flowing from policy and program choices that are already coming but not yet documented (e.g. installation of filters on HDV, use of alternative fuels, elimination of high-emitters)?

• What fundamental combustion research is warranted in order to seek methods for upstream control and reduction of ultra-fines in the combustion and exhaust processes?

**Projecting Emissions Impacts of Emerging Technologies**

Changes in vehicle and fuel technology can have large effects on emissions. The implementation of EPA’s 2007 PM and NOx motor vehicle emissions standards is already included in the various emissions estimation models, but some impacts (such as impacts of ultra-fine PM in combination with filters on HDD) may not be well characterized. The effects of these standards probably deserve a long-term near-roadway monitoring effort, as the impact of these standards could have significant environmental implications in areas that are greatly affected by large numbers of diesels.

The long-hoped-for electric car in the form of plug-in hybrid-electric vehicles (PHEVs) may be on the verge of mass production (e.g., Chevy Volt and several other offerings from other major manufacturers). Combined with economic shifts in car-buying habits and possible government incentives, we might see a long-term fundamental shift in emission factors from the broad fleet of vehicles. Are current emissions estimation tools configured to deal with these possibilities? Finally, there is broad agreement on the need for alternative fuels and advanced technologies in order to reduce greenhouse gas emissions and to deal with other air quality issues. We are also likely to see major funding initiatives to develop and deploy these technologies. Will these innovations lead to significant changes in emissions, or will their deployment take so long that they can be ignored for many years?

**Projecting Emissions Changes Resulting from Changes in Economic Conditions**

Changes in economic activity as well as the price of fuels can have significant effects on emissions. Projecting how these changes affect emissions is important for understanding past trends in ambient air quality and for projecting future emissions growth. The past year (2008) saw significant increases in fuel costs (as well as their collapse) and the beginning of a possibly long and deep recession. We may be in the first stage of an economic re-ordering that will have impacts on emissions for years to come. People are already driving less. The price of fuel is subject to great swings, and driving habits have changed and will change quickly. Past trends will likely not be a good basis for future projections. Different types of vehicles will increasingly
populate the roadways. The fleet age and characteristics may take a dramatic departure from current data used for emissions estimation activities. How, and at what pace, can the emissions estimation process adapt to any of these new realities?

**Climate Change Goals, and Emission Factors for Greenhouse House Gases and Fuel/Energy Consumption**

In the near future, the emissions estimation process must include projections of energy consumption. We understand that MOVES is already configured to do these estimates. Emissions analysts will need to look at the macro-scale to provide policy makers “big picture” impacts of differing public investment choices with respect to greenhouse gas (GHG) and fuel use linked to things like land-use policy decisions. Also, there may be a number of small-scale projects proposed to reduce green house gas (GHG) emissions and to promote reductions in fuel consumption, such as use of HOV lanes, TOT lanes, signal improvements, and many other proposals we may have not yet seen. These projects will need to be analyzed on the more micro-scale, as states try to track the GHG and fuel-use benefits associated with all projects. There will be a de facto “SIP” for GHG, and all sorts of proposals will come forward seeking “credit” from state authorities to justify CMAQ funding and other government incentives and requirements. The emissions estimation tools for these project-specific analyses must be sufficiently accurate so that proper determinations can be made that each can stand up to critical scrutiny.

**Looking for Program Concepts by Running the Emissions Estimation Process in Reverse**

Generating emissions estimates is usually thought of as a sequential process by which data obtained by the emissions analyst are input to a model, which provides the emissions estimate. Perhaps that is the way it should be. However, an alternative might be to run the emissions estimation tools in reverse, and see what emerges as a source for new program options. Certainly one cannot and should not do this blindly. The analyst needs to come to the emissions estimation tool kit with some ideas to test and evaluate, but the process may well be an iterative one in which the model can teach the analyst and modify the proposal under consideration. This use of emissions models as testing grounds is common, and it can be most valuable when the inner workings of the emissions estimation tool kit are properly established and can be trusted to be realistic. This approach to emissions program analysis will become increasingly important in the future for dealing with energy consumption and GHG emissions issues.

**Summary of the On-road Breakout Session Discussion**

The On-Road Emissions Estimate Work Group was divided into four small groups to develop specific project proposals along the themes of:

1. Policy and Program Assessments
2. Vehicle Activity Data
3. Emission Profiles
4. Ultra-fine PM and Toxics

Results of each of these discussions are summarized below.

**Policy and Program Assessments**

Policy makers and program directors often require fast turn-around decision-making tools. These tools could be, and perhaps should be, distinct from tools and models used for research and final SIP planning. Some current regional emission models require time-consuming computer runs, which limit the number of policy scenarios that can be examined. Initial policy-screening models are needed to provide relative comparisons among program options. Once examined, the most attractive policy options can be assessed by more complex and detailed emissions projections.

SIP planning and regional air quality projections using general vehicle class activity data inputs, which are needed to drive MOBILE or MOVES, may not result in policy comparisons of the type needed by program directors. Such comparisons might, for example, be driven by questions such as “What will be the specific emissions benefit if we retro-fit the entire fleet of garbage trucks?” or “If we have a given amount of money to spend on clean up of trucks in a certain weight class, which options will give the most reductions for the money spent?” Screening tools for addressing such questions do exist, but there is no central clearinghouse for identifying them, documenting their capabilities or making them available to a broad set of users. Examples of some of the uses for screening tools include 1) cost/benefit analysis, 2) analysis of the benefits of alternative fuels, 3) assessments of the effects of advanced vehicle technologies, 4) analysis of tax policies aimed at changing purchase and use habits, and 5) assessment of local targets of opportunity for reducing fuel consumption and greenhouse gas emissions.

Near-roadway exposure to PM and air toxics is another issue of concern to policy analysts. Although additional research on this problem is needed, there is already public concern regarding near-roadway exposure, and program and policy analysts are being asked to make recommendations for mitigating it. In order to make sensible proposals, analysts need screening tools that can deal specifically with the age of the vehicles on the roadway, the type of vehicle mix, and the occurrence of high-emitters. Such models need to be flexible and easily programmable so that rapid turn-around scenario testing can be conducted and can provide decision-making guidance that is correct in a relative sense.

Historically, EPA and other organizations have provided excellent training on the use of MOBILE6, and EPA has begun providing similar training for MOVES. Beyond the training that is being offered by EPA for MOVES, there may also be a need for regional-level training to facilitate regional consistency in the generation of activity patterns and in the use of MOVES for the many estimation tasks that span boundaries. Activities from broad-scale regional SIPS to micro-hot spot analyses for PM and toxics could all benefit from consistent regional training. This training should also include any tools for fast survey analyses for scenario testing at the
policy and program level. Collaboration with EPA’s diesel retrofit groups is suggested as part of this effort.

In summary, policy and program emissions analysis tools should include:

• Screening tools for addressing:
  – Relative benefits from control options to bridge huge gap between policy maker decisions and needs of cutting edge research
  – Cost/Benefit
  – Preliminary regional-scale decisions
  – Scenario testing of strategies, e.g., emission reductions for project specific tasks or technology or fuel options

• Training for MOVES

• Analysis tools that quickly reflect inter-related dynamics of the economy, e.g., vehicle sales, fleet age, changes in fleet mix, VMT, fuel costs

• Strategies for reaching out to and collaborating with partners beyond traditional environmental stakeholders, as the policy impacts of long-term decisions affect other stakeholders and environmental concerns are only one element of final decision matrix

As discussed above, some of the pieces for doing this are available; they simply need to be integrated. Also, screening analysis must be distinguished from final assessment. The former requires quick-turnaround models that can deliver the “30,000 ft.” perspective in a timely fashion.

**Vehicle Activity Data**

Activity pattern input files are a necessary prerequisite to running emission models such as MOBILE or MOVES. The activity inputs needed are themselves the result of traffic data counts used in preliminary models to provide broad-scale estimates of vehicle mixes [LDV, HDV types and populations], vehicle speeds and accelerations, and many more factors for each roadway type. It is often possible that the underlying “activity data” are the weakest link in the chain of models needed to accurately estimate emissions. It is extremely difficult to identify the level of uncertainty and the sources of error in the final emission estimates. Depending upon the needs of the users of emission estimates, the same vehicle activity data set may be acceptable or not. Generally, large regional SIP planning that uses broad vehicle activity data is considered to be acceptable, even though improvements, albeit of lower priority, may be advisable. However, when the same set of activity data are used for project-level assessments, such as hot-spot PM/toxic analyses, the data may be misleading.

Various new sources of vehicle operation data may be useful, such as electronic data from an E-Z Pass sort of source, truck operation data monitoring, traffic management surveillance, and others not known to this workgroup. These data might be “mined” for significant improvements in assessing numbers of vehicles on specific roads by class, speed, emissions category level, acceleration, vehicle load (trucks), day of week, time of day, and more. If these non-traditional data sources could be mined and joined with appropriate
emission models such as MOVES, a significant improvement in overall accuracy and use of the emission estimate effort could be achieved with little or no new actual measurement of vehicle emissions.

Special studies with portable emissions measurement systems (PEMS), which are very low cost and provide telemetered data from the above metrics of activity, could be used in a few representative vehicles to improve the estimation of activity patterns for the on-road fleet as a whole.

Exploration of these novel sources of vehicle activity data and testing tools, including PEMs is a major project recommendation of the working group. Suggestions for improving vehicle activity data are:

- Explore data mining from existing unused sources (ITS data from TMC, ITS World Congress, Electronic traffic surveillance data, private data bases from truck/taxi fleet monitoring).
- Improve activity by vehicle class, speed, acceleration, facility type, day of week, and time of day. Detailed data are needed for specific fleets such as garbage trucks, buses, taxis, school buses, and refrigeration units on moving and parked trucks.
- Develop regional (multi-state) and local [hot spot] scale activity inputs sufficient to populate MOVES (regionally/locally representative driving cycles, spatial/temporal resolution, ensure statistical representation for inference at each scale application).
- Develop a roadmap to guide use of all activity tools and data sources starting with the needs of the user, determining the level of complexity needed for specific analysis tasks. Track how different applications have different requirements for activity projections.
- Invent ways to translate data collected for other needs to help estimate vehicle activity (fuel use, tax data, and Landsat satellite records might be examples).
- Explore the use of road-grade data to improve MOVES results, and use advanced GPS data for road-grade data inputs. Conduct assessment to determine importance of road-grade on emissions estimates.
- Design selected in-field measurement projects using low-cost in-vehicle monitors (PEMS) to obtain a few representative activity files that might be used as surrogates for the entire on-road fleet and to check inputs used in MOVES. Explore use of “Smart Cones” for collecting on-road activity data from direct drive-by monitors.
- Different models should be developed for different scales. Results should be calibrated against each other.
- Seek data sources for HDD vehicle fuel use that could be incorporated into the MOVES estimation of CO₂ emissions. Many local projects are based on goals of reducing fuel use from the HDV segment, but the data on fuel use is sparse. Measuring HDV tare loading by surrogate means may be significant in both fuel use and emissions.
Emission Profiles

There are several areas where additional light duty vehicle (LDV) testing is warranted in order to improve the current estimates carried in MOVES. These areas include 1) the deterioration of cold-start emissions control, 2) increases in PM emissions from Tier II vehicles, and 3) the impacts of alternative fuels.

The current emission factors contained in both MOVES and MOBILE are derived from a large number of dynamometer tests on a wide range of cars and light-duty trucks. Additional LDV vehicle testing to improve regulated emissions databases in the models should be of low priority. However, as new vehicle and fuel technologies emerge in a rapidly changing world of vehicle technology, continued testing will be needed even on small numbers of candidate “beta site” vehicle fleets to provide life-cycle emission projections for newer vehicles such as hybrid electric vehicles (HEVs) and plug-in HEVs (PHEVs). It is difficult to project, with any degree of certainty, the future in-use emissions evolution for a new fuel/technology. Studies of the rate of emissions deterioration could be part of technology rollout evaluations and offer new avenues for collaboration among stakeholders interested in emissions and those advocating the new technologies and fuels.

In comparison to light-duty vehicles, little is known about in-use emissions from the existing fleet of HDD truck emissions, because truck engines are tested and certified as bare engines not as completed vehicles. Also, truck and HDV emissions control technology is undergoing a large-scale turnover as totally new control systems such as diesel particulate filters, NOx controls, selective catalytic reduction (SCR), NOx traps, electronic engine controls schemes, and a myriad of exhaust after-treatment concepts are introduced. As the emerging HDD fleet undergoes this technology changeover, extensive emissions monitoring will be needed to insure that the reductions planned and demonstrated in certification testing of engines are delivered for the on-road fleet. The HDV fleet, and the emerging controls technologies being applied to that fleet, require a major new initiative in emissions measurement, both in terms of PEMs and for whole-vehicle dynamometer studies.

The development of software “data converters” that could join disparate data sources into improved emissions profiles is also a worthy topic for additional study. This effort could be joined with others to seek new data sources for activity patterns.

Gaps to be filled concerning vehicle emission profiles:

• Conduct Selected LDV Testing for key issues (e.g., emission factors for Hybrid-Electric Vehicles)

• Explore new data sources for:
  – Deterioration of emissions control during cold starts,
  – Monitor emission impacts from vehicles certified on gasoline but now operated with other fuels such as bio-fuels.

• Continuing HDV emission factor measurements in order that MOVES will accurately reflect existing fleet as well as expected fleet technology turnover effects.
• Conduct both on-road (PEMs) and laboratory testing to track new fuel/engine/retrofit technologies for HDVs.

• Establish emission factors and deterioration projections for new and emerging technologies and fuels that are not available, are subject to poor estimation, and must be backed-up by long-term in-use data measurement. Rapid age/mileage accumulation fleet studies are a first step, to be followed by testing in-use vehicles characterized by a wider range of maintenance.

• Determine which GHG emissions and fuel consumption data are needed to allow MOVES to be used dependably for policy decision at the project level.

• Examine the use of advanced laboratory testing tools as part of all emissions measurement studies to provide real-time speciation of VOC/toxic emissions. These data are needed in conjunction with real-time measurement of PM size and character in order to develop models for near-roadway exposure to a range of particles and toxics of interest in health effects studies that are finding effects on health but do not have answers regarding what is causing the observed impacts.

• Conduct selected emission testing to validate use of “data converters” which create emissions data inputs to MOVES from other sources.

Ultra-fine PM and Toxics

The emission of ultra-fine, combustion-generated particles has been known and studied by academic researchers for decades. Health-effects studies have increasingly implicated these “nano PARTICLES” as key contributors to observed health impact end-points, especially near roadways.

The dynamic nature of how these particles agglomerate to change size distribution, are affected by dilution mixing upon leaving the vehicle exhaust, and are affected by mixing with organic and inorganic emissions has impeded the development of generally accepted test methods that could be used across vehicle, combustion type, fuels, and potential control technologies. The Swiss have adopted a testing approach that “bakes off” the volatile portion of any particles so that just the hard-particle core of the net emission is counted as a way to move forward with a standardized emissions test.

The exhaust emissions of particles and condensable organics are joined by other vehicular sources such as brake wear, tire wear, and re-entrainment from highway matter. The present lack of any sort of standardized test method also affects this area.

A major project recommendation is that test method developments are needed to allow systematic vehicle testing to differentiate among fuels, technologies, combustion types, and control approaches to minimize emissions of nano-particles and associated organic toxics. This is a major undertaking that will require extensive collaboration and support as it reaches beyond what any one organization or research team can accomplish.

The implications of health studies that link ultra-fine PM emissions to health impacts have led some areas to ban the construction of schools near roadways. It is not clear at this
time if all vehicles (gasoline and diesel, new and old, clean and high emitter) are equal contributors to traffic related pollution, or if there might be test methods that would identify the real culprits without thwarting the use of fuels and technologies that do less health damage or are relatively harmless.

Ultra-fine PM and toxic species—test method, emissions, and model projection needs:

• Link ambient measurements to tailpipe measurements:
  – Determine the relevant measurements needed to link tailpipe and ambient measurements.
  – Conduct ambient measurements with spatial resolution aimed at assessing vehicle impacts.
  – Determine physical/organic chemical emissions protocols. (What real-time measurements, including nano-PM measurements, are needed?)
  – Link direct tailpipe measurements to ambient measurements in order to provide information needed by new models of exposure.

• NYSERDA should foster collaboration among groups:
  – For example, the Health Effects Institute (HEI), EPA, the California Air Resources Board (CARB), researchers with air monitoring supersites, the Coordinating Research Council (CRC), European researchers and regulators, etc.
  – Encourage a consortium approach.
  – Stakeholders must see that lack of test method leads to poor decisions.

• Study the mix of sources of ultrafine PM, including tire wear, brake wear, and road dust, from a variety of vehicles with different emissions signatures.

• As near-road exposure becomes a dominant policy driver we need:
  – spatial/temporal projections based on data,
  – adaption of regional-scale emissions estimation tools for micro-scale issues,
  – data evaluating assumptions that PM/toxics/ultra-fines are distributed in proportion to traditional certification measured emissions, and
  – projection methods to account for highly skewed vehicle emission profiles (gross emitter impacts) adapted to micro-scale toxic and PM emissions estimates. Each roadway segment may have different numbers of vehicles in discreet categories.
5 Improving Estimates of Emissions from Non-road Mobile Sources

While emissions from large stationary power generators are measured using continuous emission monitors (CEMs), emissions from transportation systems (i.e., mobile sources including the on-road and non-road sectors) are not routinely monitored due to the large number of individual sources and engines involved and the mobility of these sources. On-road sources include passenger vehicles and trucks of all types registered for on-road use. Non-road sources include equipment used in a wide range of applications including agriculture, forestry, construction and mining, airport ground operations, industrial operations, as well as rail and marine applications. Although localized or site-specific measurements of mobile source emissions are occasionally performed, along with laboratory dynamometer tests on selected mobile source types for generating emissions information, our ability to estimate local, state, regional, and national mobile source emissions depends largely upon modeling. Mobile source emission models combine information in a number of data categories and return estimates of net vehicle emissions. The data categories used to calculate mobile source emissions include:

- Type of emission process (fuel evaporation, combustion),
- Population and size distribution (number of vehicles and size of engines),
- Geographic distribution,
- Usage or activity (e.g., vehicles mile traveled or hours of use),
- Operating states (e.g., load fraction, idle, start-up),
- Emission rates,
- Energy efficiency,
- Fuel composition and characteristics (oxygen composition, chemistry, vapor pressure), and
- Environmental factors (e.g., temperature, humidity, and atmospheric pressure).

The accuracy and certainty of emissions model estimates is a composite reflection of the accuracy and certainty of individual data categories. Developments and improvements within each of these categories can significantly affect the development of more accurate and, therefore, more useful mobile source emissions inventories.

The users of transportation-related emissions information cover a wide spectrum of interests and needs. They include:

- Air quality managers responsible for developing state implementation plans (SIPs) to meet National Ambient Air Quality Standards (NAAQS);
- Transportation planners needing to assess effects of changes in transportation infrastructure on degrading or improving air quality or to demonstrate conformity with air quality plans;
Health officials interested in assessing the impact of vehicle emissions on public health;
Fuel manufacturers and energy policy analysts who want to determine the effect on emissions due to changes in fuel use and composition;
Environmental advocates interested in mitigating the impacts on groups living near traffic congested roadways, industries, and construction sites;
And more recently, corporate, municipal, and other entities committing to reducing carbon emissions and develop voluntary sustainable and carbon neutral policies.

The emissions information needs of each of these users are ever-changing due to impacts of new regulatory programs (e.g., non-road engine emission certification levels), economic drivers (e.g., changes in economic activity related to the business cycle), and other factors. Consequently, source data for inventories needs to be regularly checked and updated to insure inventory accuracy and relevance.

Within the Northeast and Mid-Atlantic States\(^1\), the transportation sector (on-road plus non-road) accounted for about 30 percent of total energy consumption in 2006\(^2\). In New York State, the transportation sector was responsible for about 28 percent of total energy consumption in 2006. Although non-road equipment was responsible for about 11 percent of net transportation-sector energy consumption in 2002 in New York State,\(^3\) non-road vehicles were responsible for 2.5 to 14 times more emissions than on-road vehicles on a unit energy basis depending on the parameter. Based on 2002 emissions inventory data for New York State, the percentage contributions of non-road equipment to the total transportation sector emissions of priority pollutants are as follows: 24% of Carbon Monoxide (CO); 28% of oxides of nitrogen (NO\(_x\)); 31% of Volatile Organic Carbon and hydrocarbons (VOC, HC); 58% of sulfur oxides (SO\(_x\)); 58% of particulate matter greater than 10 micron aerodynamic diameter (PM\(_{10}\)); and 66% of PM\(_{2.5}\).\(^4\) In addition to criteria pollutants, the non-road sector is also a source of toxic air pollutants. Therefore, the effect of non-road sector emissions on ambient air quality substantially exceeds its contribution based on net energy consumption. Moreover, emissions from these sources are released near the ground, increasing human exposure to direct emissions.

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\(^4\) Based on analysis of emission inventory data provided by NYSDEC.
Generating Non-road Emissions Estimates

Non-road sources conventionally include about 300 equipment types used in mining, agriculture, logging, construction, airport ground operations, commercial operations, industrial operations, lawn and garden care, and recreational vehicles as well as pleasure craft. NONROAD2005 is the current U.S. model for allocating total emissions of non-road equipment in these categories on the regional, state, and county scale. Aircraft, rail transport, and commercial marine vessels are also non-road sources, but they are typically accounted for separately. NONROAD does not cover emissions from locomotives, aircraft and commercial marine vessels. Hence, several inventories are needed to account for the non-road sector as a whole. At the time of this workshop, EPA was developing the Motor Vehicle Emission Simulator (MOVES) model, which eventually will have the capability to model both on-road and off-road emission sources including all off-road sectors.

NONROAD estimates exhaust, crankcase, and evaporative emissions for HC, CO, NOx, PM, SO2 and CO2. The model addresses spark- and compression-ignition engines, it accounts for engine type (e.g., two-stroke or four-stroke), as well as for different types of fuel (gasoline, diesel, compressed natural gas, and liquefied petroleum are currently treated). The model generates emission estimates both spatially (e.g., nationally, regionally, or by state and county) and temporally (e.g., annually, monthly, seasonally, or daily accounting for weekday and weekend periods). The model can be used with model data to generate past, present, and future emission estimates (i.e., accounting for equipment population growth and scrappage rates).

NONROAD incorporates data files that specify the equipment population for a base year distributed by age, power, fuel type, and applications. Equipment are ascribed an average load factor, activity (hours of operation annually), and parameter specific emission factors that reflect engine deterioration (i.e., “brand new” emission factors are used as a starting point), the introduction of new standards, and differing performance factors depending on usage (e.g., differences due to transient behavior). In addition, provision is made to address fuel characteristics (e.g., Reid vapor pressure, oxygen and sulfur content) as well as seasonal temperature variation and atmospheric pressure.

The model allows geographic allocation of emissions to counties. The non-road construction equipment population is apportioned to counties by a weighted formula based on the dollars spent in four categories of construction: single and two-family housing; other building construction; road and bridge construction; and public works related construction. This formula has been modified to address differences in construction costs nationally. Corrections to load factors and the median-life of compression-ignition engines used in earlier versions of NONROAD have led to reductions in the emission inventory. The resulting revisions

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5 http://www.epa.gov/otaq/models/moves/index.htm
made to estimated equipment population have contributed to reducing the overall NONROAD-calculated emission inventory by 25 percent on an annual basis.

The MOVES model will significantly change the way emission estimates are generated when it is fully developed for the non-road sector. MOVES characterizes vehicle performance as a function of processes: e.g., running, moving, start-up, and idle. It will account for the energy consumption and emissions associated with obtaining fuel (from the source to the pump), and it will account for energy consumption and emissions associated with manufacturing the vehicle and its disposal or scrappage. The energy consumption and emissions of fuel-to-pump and manufacture/disposal will be based on the Greenhouse gases, Regulated Emissions and Energy use in Transportation (GREET) model.

The energy use and emissions rates for equipment while “running” will be characterized as a function of activity using a “binning” approach rather than using correction factors (e.g., for transient behavior). MOVES for on-road has created 17 bins of vehicle or engine specific power and speed classifications including both braking and idle bins\(^6\). The energy use and emission rate data will be based on collecting second-by-second data by bin class. In general, knowing the pattern of an activity (percentage time spent in a given bin) of a vehicle or piece of off-road equipment and the emission factors (mg/sec per pollutant per bin) one can calculate the aggregate emission rate.

Following this paradigm, an array of look-up bin tables will need to be generated that classify emission and energy use factors as a function of duty cycle. Engine specific power and vehicle speed may not be applicable to many non-road pieces of equipment given the range of work duties performed.

### Data Needs and Gaps

Additional data on emissions rates from non-road vehicles will be needed for development of the MOVES non-road model. The scope of MOVES when fully implemented will cover a full range of emission parameters. Beyond criteria pollutants already mentioned, this will include: hydrocarbons (e.g., Total Hydrocarbons - THC, Non-Methane HC, Volatile Organic Compounds - VOC, Total Organic Gases – OG, and Non-Methane OG); particulate matter (sulfate, organic carbon, elemental carbon, total carbon, lead, sulfur dioxide, ammonia, brake wear particles, and tire wear particles); air toxics (Benzene, 1,3-Butadiene, Formaldehyde, Acetylaldehyde, and Acrolein); and Carbon Dioxide. Hence, bin specific emission rates will need to be developed for each of these emission types.

Currently, the Non-Road Pilot Program in EPA Region 7 with the Coordinating Research Council (CRC Project E-70) has deployed portable emissions measurement systems and portable activity monitoring systems (PEMS/PAMS) to characterize gaseous and particulate emissions from non-road construction equipment. In addition to better characterizing the population of construction equipment in Region 7 (Nebraska, Iowa, Missouri, and Kansas), the program will

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determine activity (on/off, date/time, and engine speed), and operating parameters (if available, computer area network data), as well as measure fuel properties such as specific gravity, total aromatics, polynuclear aromatics, cetane number, flashpoint, viscosity, sulfur, and metals in oil. In addition, an equipment survey will be conducted, which may serve as a basis for verifying population estimates made by NONROAD or MOVES. In total, 33 pieces of equipment will be monitored for activity and gaseous and PM emissions. This study is a model for future research that will be needed to provide more realistic data for MOVES databases.

The EPA/CRC pilot program represents a significant advance in improving emissions information for non-road equipment, but continuing work will be needed to keep emissions estimates current. For example, while gaseous- and PM-PEMS have matured over the last ten years, more reliable indirect techniques may need to be validated due to the complexity of direct measurements of PM-mass as provided by quartz crystal microbalance techniques as embodied in Sensors Inc., Semtech PPMD.\(^7\) In addition, engine and emission control technologies will develop further over time, reducing and changing the profile of emissions in non-road equipment. The use of engine controls and aftertreatment (such as diesel oxidation catalyst, active and passive particle filters, and selective catalytic reduction for NOx control) will change the emissions inventory over time. Moreover, the changing composition of fuels and fuel mixtures will require adjustments to energy efficiency and emission profiles for all of these many equipment types. Uses of biodiesel blends, for example, are expected to change the composition of diesel emissions with higher percentage blends significantly reducing particulate matter, but increasing oxides of nitrogen. The lower energy content of biofuels needs to be considered. The tradeoff between efficiency gains and emission changes will need to be assessed.

Another continuing problem is determining just what kinds and numbers of non-road equipment are out there. Without registration of non-road equipment, planners and modelers rely on model estimates. Efforts to validate non-road population estimates (type, number, size distribution, and age) may be required to validate model estimates.

Finally, the end use of the inventory plays a role in defining the needs and gaps in the current inventories. Inventories may be needed and utilized on a regional, state, local, project-specific, or even smaller scale. Data needs and data gaps, and, ultimately, inventory accuracy may be defined by the end use of the inventory data.

**Summary of the Non-road Breakout Session Discussion**

As stated in Section 2 of this report, each breakout session was asked to address the following five topics:

- Identify needs that existing emission estimates fail to meet.

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\(^7\) [http://www.sensors-inc.com/Semtech_PPMD.htm](http://www.sensors-inc.com/Semtech_PPMD.htm)
• Characterize current emission estimates and identify current data gaps such as emission profiles (including speciation), spatial distribution, activity patterns, and others.
• Identify changes in fuels, technologies, and use patterns anticipated in the short run (3-5yr) and long term (7+ yr).
• Identify the tools and techniques available to help improve the emissions estimates.
• Identify specific studies or actions that should be undertaken to improve the emission estimates for northeast and mid-Atlantic region.

The session was initiated by asking participants to share what they hoped to gain from the discussion or their problems with emission estimates. Some comments and interests included:

• What steps do other air quality planners take in assessing the impact of airport expansion projects on air quality?
• How have localities structured local law to improve the environmental performance of diesel powered non-road equipment?
• How does one go about customizing NONROAD based on independent data sources?

Session facilitators, Tim Hansen and Barry Liebowitz, summarized some ongoing work, sponsored by NYSERDA, including emissions inventory development (locomotive and construction equipment in the NYC metro area), the evaluation of retrofitted diesel emission control devices on non-road construction equipment through in-use testing, and assessing the precision and accuracy of PEMS portable emissions monitoring technology for particulate matter used for in-use testing.

Participant discussions generated the observations and recommendations described below.

**Remedy shortcomings of current non-road emissions estimates.**

Generally, the group recognized the value of the U.S. EPA’s efforts to develop an activity-based model to estimate emissions from the non-road sector that would be based on the Motor Vehicle Emission Simulator (MOVES) model, and they recognized the continuing utility of the existing NONROAD model. However, the participants specified several areas needing additional work:

• **NONROAD model accuracy at the regional, local, and project levels:** While the NONROAD model may provide a reasonable estimate on the national scale, the level of accuracy cannot be adequately gauged. The group did not have confidence in the ability of NONROAD to provide accurate emission estimates at the regional, local, and project scale for state implementation planning and policy analysis. There are many instances where the potential impacts of local regulatory/voluntary programs (e.g. NYC local law 77 and the NYS Diesel Emission Reduction Act) cannot be easily assessed with any degree of certainty or accuracy, because retrofit and other types of programs are not accounted for by the model. Analyses used to
address the effect of regulatory or technology “what-if” scenarios affecting segments of the non-road sector cannot be readily preformed for environmental justice and other evaluations with existing models. Environmental justice, projectspecific and corporate voluntary programs (e.g., Environmental Performance Commitments) need to be addressed by micro-inventory or specific engineering studies to assess project impacts on neighborhoods. Current models do not do this well.

- **Applicability of MOVES emissions estimates to non-road equipment:** While MOVES promises to provide the capability to analyze regional, local, and project-specific on-road impacts, this capability may be problematic for the non-road sector. For example, construction equipment does not travel in predefined pathways or stay in one location, and the types of equipment used in any one place will change over time.

- **Lack of specific estimates of hazardous air pollutants, greenhouse gases, and PM metrics:** The difficulty in using the NONROAD model to estimate criteria pollutants with some degree of accuracy or certainty also applies to hazardous air pollutants, greenhouse gases, and speciated, size-fractionated particulate matter (i.e., filterable and condensable PM). Currently, NONROAD does not include emission factors for these pollutants (aside from CO2). Although there are several hypotheses regarding the effect of ambient aerosols, there is limited information on the emission characteristics of non-road equipment regarding the characteristics of PM from the perspective of evaluating impacts on air quality.

- **Lack of consistency in methodologies for those sectors not modeled by the NONROAD model:** NONROAD does not estimate emissions for rail, marine, or aviation sources, all of which are included in the non-road sector. Aside from aviation, there is no consistent guideline or procedure for calculating emission estimates from each of these sub-sectors. Each regional or local emission estimate may be carried out as the inventory developer sees fit. Therefore, consistency among local and regional inventories is missing.

Locomotives emissions should be amenable to improvement as a generalized model, as track-usage can be geographically resolved. The problem is gaining up-to-date information on equipment populations and usage. The NYS locomotive survey provided a more accurate estimate of this sector, but should the states be required to do this work? Regulations or a database requiring locomotive stock characteristics, usage, and fuel consumption would be helpful. Engine certification emissions levels are typically used for emission factors. However, the emissions from aged, in-use locomotives should also be evaluated to better estimate actual emissions. The Eastern Regional Technical Advisory Committee is engaged in developing rail inventory for 2008 for the northeast and mid-Atlantic states. This may provide a uniform process for generating a railroad emission estimate that could be more widely adopted.
Improving the marine equipment and port emissions inventory has been the focus of a number of studies across the country (West Coast and Great Lakes as well as the Eastern region). Several recommendations for improving marine port emissions estimates can be found, e.g., “Current Methodologies and Best Practices in Preparing Port Emission Inventories,” prepared by ICF for the U.S. EPA. In all cases, typical equipment, activity, and emission factor data must be assembled and calculations made to geographically resolve emission contributions from the sector. Comprehensive approaches that address on-land, in-port, and off-shore transit and port operations need to be taken into account. Much data on ship characteristics and activity (e.g., cruise speeds, locations and duration, reduced speed operation, maneuvering, and “hoteling”) must be assembled and factored in to better develop and geographically resolve emission contributions. For the national emission inventory, EPA estimates marine vessel emissions based on marine bunker fuel sales in the U.S., and then assumes that fuel is combusted in marine activities. Although this may provide a decent estimate for the national inventory, on the local and regional scale, methods described above (based on activity, equipment/vessel types, duty cycles, etc.) would provide more accurate estimates of emissions. A consistent methodology would be beneficial when building regional estimates from local estimates.

The emissions from ground support equipment at airports are estimated by NONROAD as well as by the Airport Emissions Development Model (EDMS) based on landing and take-off activity. EDMS has a methodology to calculate aircraft emissions for priority and hazardous air pollutants. There is lack of a consensus, however, on appropriate upper level boundary limits using EDMS for apportioning emissions for air quality modeling. Few air quality planners are equipped to run EDMS. Discrepancies between NONROAD and EDMS methods may result in inconsistencies in inventories across a region.

State and regional air quality planners have little access to military marine and aircraft activity and emission factor data to include these sources in an emissions estimate. EPA should take the lead to address this inventory gap and provide apportioned emissions estimates to states and localities with active military installations (ships, port facilities and airfields).

- **Lack of guidance on how to use existing project, local, state, and regional data to develop more accurate, consistent, and improved inventories at national, regional, state, and fleet scales:** Participants in the breakout session observed that there are several individual emission estimates being developed at project, entity, local, and state scales. These data could be used to improve the emission estimates for the region and nation. However, guidance is lacking on how to go about customizing data files for use in the existing NONROAD and other non-road sector models, e.g., there is not an easy way to introduce individual inventory data. While some felt that

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8 [http://www.epa.gov/ttn/chief/conference/ei15/session1/browning.pdf](http://www.epa.gov/ttn/chief/conference/ei15/session1/browning.pdf)

state air quality planners could provide alternate data to use in modeling, there was a lack of guidance on requirements for acceptance of alternate emission estimates into the national inventory. Some participants referred to inconsistent specifications and requirements for reporting estimates, which stymie state and local initiatives to improve inventories.

**Improve activity information, equipment population estimates, and speciation estimates.**

Several suggestions were made for improving the characterization of current emission estimates and for filling current data gaps such as emission profiles (including speciation), spatial distribution, activity patterns, and others.

- **Non-Road Equipment Activity Information:** The participants of the breakout session noted that non-road equipment emissions are duty cycle dependent. This is especially important for large non-road contributors such as construction equipment, locomotives, and marine equipment. While traffic information is available for on-road equipment, no such continuous counting and activity data is available for non-road equipment. More detailed emission factor information based on activity patterns would improve the accuracy of emission estimates in the non-road sector. Data users should bear in mind that duty cycle information and activity for one type of equipment may also vary significantly by region or location.

- **Non-Road Equipment Population Data:** The problems of using national models at the state, county, and local scales are compounded for the non-road sector. National models allocate equipment populations on the basis of economic activity, which may not provide an accurate estimate of equipment populations at smaller scales. Unlike motor vehicles, there is no registration process for non-road equipment; thus, no central database of non-road equipment population exists. On-road activity can be measured on roadways, while non-road equipment is employed over discrete periods of time at ever changing locations—hence, the difficulty of determining the spatial distribution of non-road equipment.

- **Other Data Needs:** The participants also identified the following other data needs:
  - Emission factors for Hazardous Air Pollutants (HAPS) and Mobile Source Air Toxics (MSAT) are generally lacking for non-road equipment.
  - There is a need for consistent guidance/methodology (NONROAD vs. EDMS) for aircraft and ground support equipment emissions.
  - While there is interest in understanding the effects of speciated PM constituents on human health, there is little data on emission factors for PM speciation or for HAPs for non-road equipment.
  - In addition, the lack of reliable and affordable instruments for measuring the above-mentioned constituents make emission measurements unavailable.
Identify changes in fuels, technologies, and use patterns anticipated in the short run (3-5yr) and long term (7+ yr).

Participants identified several major changes occurring in the mobile-source sector, including within the non-road sector, that may significantly affect emission estimates for the sector in the near term and long term. Research is needed to ensure that adequate data is available to account for the impacts of these technology changes on non-road sector emission estimates. Application of all of these technologies and their emission reduction benefits (as well as potential negatives, such as ammonia and NO2 emission increases from control devices) should be accounted for in revised models and estimation procedures. Future technological changes identified by the breakout group include:

**Short Term**
- Alternative / New Fuels
  - Biodiesel blends
  - Ethanol blends
  - Ultra Low Sulfur Diesel (all sectors)
- Control technologies
  - Selective Catalytic Reduction – NH3 slip
  - Diesel Particle Filters – NO2 slip, speciated PM, Regeneration emissions
  - Diesel Oxidation Catalysts
  - Crankcase Filters
- New Engines (EPA mandated)
- New Lube Oils
- Idle Reduction
  - Cold ironing
  - Locomotive APUs

**Long Term**
- Alternative / New Fuels
  - Fischer Tropsch Diesel
  - Bio-butanol
  - Di-methyl-ether
- Increased Intermodal Freight Activity
- Hybridization
  - Locomotive, marine, construction
- New engine design
  - Homogeneous Charge combustion Ignition, SI, Compressed Natural Gas

Incorporate information from state and local emissions development activities to improve emissions estimation tools and techniques.

There are currently some valid and accepted tools for preparing emissions estimates from the non-road sector. These have been discussed in previous sections. These include the EPA NONROAD model as well as the EDMS model. However, some of the improvements mentioned above need to be made to allow end users to use these tools to improve inventory estimates on a variety of scales, including those from the project level all the way to the regional level. In addition, there are a number of existing emission estimates and inventories that have been completed by individual entities. If air quality analysts were made aware of the procedures and data utilized by those entities in their specific region, it might allow regulatory staff to utilize better, more consistent estimation procedures through improved emission estimation.
factors, activity data, or other information. Access to such data sources could help improve the inventory. In addition, aggregation of all of these smaller inventories to the regional level would allow for improvement in the regional inventory, as opposed to the commonly used procedure of allocating national estimates to the regional level.

**Undertake joint activities for improving emissions estimates in the Northeast and Mid-Atlantic Regions.**

Recommended actions suggested by the non-road breakout participants include the following:

- Work with EPA to rapidly modify the existing NONROAD 2005 model to allow for easier modification to the model inputs, including the following:
  - Account for voluntary and local retrofit programs and fuel specifications, idle reduction, speed reduction, etc.
  - Create the ability to utilize information from the EPA Diesel Emissions Quantifier, or allow for individual data input.
  - Incorporate specific fleet information.
  - Include Hazardous Air Pollutants (HAPS) / Mobile Source Air Toxics (MSAT) and additional PM emission factors (from SPECIATE or other sources).
  - Include GHG emission factors (in addition to CO₂).
- Create a non-road (construction equipment) clearinghouse for information exchange and equipment tracking.
  - Several localities, entities, and projects are tracking the populations of equipment utilized in their contracts, including fleet-specific information, diesel retrofit information, fuel specifications, etc.
  - The data collected in these programs could be aggregated in a single database to allow entities to track equipment use, location, and compliance across the region.
  - Existing entities may coordinate activities, (e.g., PANYNJ, NYDEP, NYSDOT, LMCCC)
- Create a regional database of individual emission inventories.
  - Several entities, states, projects, localities, etc. have developed specific emission inventories for their region, often with bottom-up estimates of non-road equipment populations, activity, and emissions.
  - Development of a centralized database of the emission estimates could help aggregate those estimates and improve portions of the regional inventory
• Development of such a database might also help improve consistency across the region, as entities may look at other estimation procedures that have been used and adopt those for their own improved emission estimates.

• At the time of this workshop, the Northeast Diesel Collaborative had begun identifying some of these data sources and participants suggested this effort could continue with assistance from NESCAUM, MARAMA, NYSERDA, and other regional entities.

• Select and seek adoption of standardized techniques, guidance and protocols for marine equipment. (This development could follow along the lines of the ERTAC rail emissions inventory initiative.) Use “Current Methodologies and Best Practices in Preparing Port Emission Inventories,” prepared by ICF for the U.S. EPA.

• Initiate a Regional (urban centered) study similar to the USEPA Region 7 study.

• Evaluate equipment activity and emissions associated with large urban and ex-urban construction projects – urban and major construction projects may have different non-road fleet types and activity than suburban and rural projects (i.e., old large infrastructure, major buildings, etc.)

• With cooperation by the USEPA and other regional partners, this study would supplement the data from Region 7 with a data set for a different subset of activity that is more useful to refining estimates for urban regions.

• Several large construction projects are planned or ongoing that could be individually monitored and be integrated into such a research program e.g., the Hudson River Tunnel, World Trade Center Redevelopment, projects managed by the Lower Manhattan Construction Command Center, and others in the region. The cooperation of entities engaged in these projects to require contractors to accommodate activity and emission testing of construction equipment would be helpful. Entities that have already voluntarily adopted Environmental Performance Commitments to reduce environmental impacts may be possible collaborators.

• Develop and deploy Emission Measurement Instruments for improved emission estimates from real-world sources.

• Develop instrumentation for HAPs and MSAT emission evaluations in-use;

• Develop instrumentation to refine PM measurement and speciation (particle number, size distribution, and characteristics—e.g., organic make up).
• Undertake accountability studies.
  ▪ As emissions estimates for non-road and on-road sources are improved, attention should be paid to assessing their impact on ambient air quality.
  ▪ Aerosol source markers of diesel powered engines should be used to assess the contribution of non-road and on-road sources to local ambient air quality.

As a result of further discussions, NYSERDA will be undertaking a project to establish a Clean Diesel/Best Available Technology Non-Road Clearinghouse – Construction Applications. The goal of the project is to create a useful, web-based clearinghouse and database to allow contractors and regulators to specify appropriate non-road best available technology (BAT) for construction applications in New York State, which can be expanded to cover other non-road applications, if warranted. The clearinghouse will help reduce the cost of discovery, selection and contract change requests for BAT associated with construction.

New York City and several neighboring counties require contractors working on municipally funded projects to use BAT. In addition, the Port Authority of New York & New Jersey (PA) and other entities engaged in Lower Manhattan Reconstruction such as the Federal Transit Administration (FTA) have adopted environmental performance commitments that specify the use of BAT. Currently, these NYS entities, which pay some premium for BAT, have no means to share information, and have advocated for such a clearinghouse. In addition, U.S. EPA Region 2 staff has expressed interest and willingness to support this endeavor.

**Non-road Breakout Group Participants**

Dorian Bailey, Project Engineer, Port Authority of New York and New Jersey (PANYNJ);
Jonathon Bass, Environmental Specialist, NYS Department of Transportation (NYSDOT);
Tim Hansen, Manager Mobile Source R&D, Southern Research Institute (Southern);
Dave Healy, Air Quality Analyst/Modeler, New Hampshire Dept. of Environmental Services (NHDES);
Marie Kelly, Air Quality Scientist, Allegany County Health Department – Air Quality;
Thomas Lanni, Research Scientist, NYS Department of Environmental Conservation (NYSDEC);
Barry Liebowitz, Sr. Project Manager, NYSERDA – Environmental Research;
Kevin McGarry, Environmental Engineer, NYS Department of Environmental Conservation;
Bill Pennell, Management Coordinator, NARSTO;
Kenneth Santal, Regional Planner, MassDEP, Boston; and
Kassahun Sellaise, Engineer, City of Philadelphia – Air Management Services.
6 Improving Estimates of Emissions on High Electricity Demand Days

Issue

Peak electricity demand generally corresponds to days when the potential for poor air quality is greatest. Typically, these are hazy, hot and humid summer days. Peak demand often requires the electricity generating sector to call upon all available resources to maintain a reliable electricity system. The resources called upon to meet the peak electricity demand are load-following and peaking units that typically have minimal or no pollution control. Demand response assets are called upon to lower electricity demand by either curtailing load or shifting to alternate power sources, including small generators. These alternate power sources are diesel or natural gas generators used primarily for emergency power, and as such are usually uncontrolled. The increased use of load following units, peaking units, and demand response actions helps transmission owners and system operators address local or system-wide reliability concerns.

State and local environmental agencies are required to develop plans to bring areas into attainment with air quality standards or continue maintenance of good air quality. In 2006 and 2008, USEPA promulgated new national ambient air quality standards for particulate matter ($\text{PM}_{2.5}$) and ozone, respectively. These new standards add to the difficulty and complexity that state and local governments are already experiencing in meeting the existing air quality standards. Current techniques for preparing emission inventories do not fully capture emissions from the electricity generating sector on high electricity demand days (HEDD), particularly nitrogen oxides (NOx) and $\text{PM}_{2.5}$. Peaking units are not included in predictive electricity generation models and demand response generators are often not included in emission inventories at all. States are required to inventory based on annual and ozone season day (OSD) emissions to meet their State Implementation Plan (SIP) requirements. OSD is defined as a typical summer day. Peaking units and demand response generators do not usually run on the typical day but may instead run on the HEDD, and therefore, are often missed in the OSD inventory. Not every HEDD is a demand response event. The OSD inventory is used to develop the modeling inventory which approximates hourly emissions for each source or source category by location to be used as inputs to the air quality model. Techniques to characterize the operation of and emissions from the HEDD sources are not well developed. This potentially leads to an important information gap in the current inventory and may not result in the best control decisions in the air quality planning effort.
Discussion Topics

Two major topics for discussion were identified: the need for reliable methodologies for determining emissions and the need to develop techniques for estimating future emissions.

Methods for Determining HEDD Emissions

High quality and readily available information exists for NOx and SO2 for central station power plants that report to EPA data obtained from continuous emissions monitoring systems (CEMS). Data are also readily available for smaller sources that report to EPA but the widespread use of “low mass emitter” estimation techniques over-estimates emissions from some sources. However, for sources that do not report emissions data to EPA, the level of detail needed (including time of day) to precisely characterize the impact of these sources is unavailable. In addition, good quality, speciated PM2.5 emissions data are nearly non-existent for most sources.

Techniques for Estimating Future Emissions

Refined techniques are needed for estimating future year emissions that take into account population demographics, alternate technologies, demand response and energy efficiency programs, emission control programs, and other factors impacting generation profiles. Quantification of the emission impacts expected from each of the above areas need to be addressed. Technology requirements to develop the techniques to estimate emissions on HEDD need to be identified and explored.

Workshop Discussions

Discussions in breakout groups were informed by four presentations regarding the issues of maintaining the reliability of the electricity grid and HEDD emissions.

Dispatch of Electricity Generators on High Electricity Demand Days

Peter Carney of the New York Independent System Operator (NYISO) described the State’s energy and auxiliary markets and the NYISO reliability rules. These factors may contribute to poor air quality in the NYC area on HEDD. He pointed out the New Source Review provisions of EPA regulations that make it difficult to permit new dual-fueled units with the capability of instantaneous fuel switching, which would reduce emissions from existing oil units.
Estimating Emissions from Combustion Sources in New York State

John Barnes of the New York State Department of Environmental Conservation (NYSDEC) explained the need to develop a strategy to bring the State into compliance with the ozone standard. He described existing emissions data and identified data gaps for emergency generators and demand response sources.

Peaking Unit Emissions

Roger Caiazza of NRG Energy described how emissions data are determined for EGUs and low mass emitters. He illustrated how emissions data reported by electricity companies to the EPA Clean Air Markets Division sometimes overestimate actual emissions, and he recommended that NYSDEC work with source owners to improve emissions data for these units. He also suggested that a new PM source testing methodology is necessary to improve the inventory.

Characterizing Demand Response Emissions During HEDD Events

Don DiCristofaro of EnerNOC characterized HEDD emissions compared with demand response (DR) sources and pointed out that not every HEDD is a DR event. All available resources (both generators and curtailment) are used during a DR event, and their separate contributions should be determined. Emissions data from engines used in DR should be available from operators. Mr. DiCristofaro also suggested that additional sources will be using ultra-low sulfur diesel, but that future regulations may limit engine use. Finally, a clear definition of HEDD needs to be made.

These presentations provided a background for the work group’s discussions regarding emissions on HEDD and system reliability. The following is a summary of data needs and efforts required to improve emissions estimates.

Current Emissions Estimates and Data Gaps

The current emissions inventories in the mid-Atlantic and Northeast regions adequately address \( \text{SO}_2 \) and \( \text{NO}_x \) emissions from electricity generating units that report quarterly data to EPA. Those data could be improved somewhat if the biases introduced in those data sets for emissions trading purposes were removed. Data gaps exist with respect to demand response generators placed in service during these days. Demand response activities are those actions taken to avoid system reliability problems when the ability of the generation or transmission assets to meet the demand is stressed. There are two categories of demand response activities—curtailment and generation. Curtailment entails reducing electricity demand at a facility (e.g., reducing or rescheduling manufacturing activities, raising the temperature at the facility, etc.). Generation entails producing power with on-site equipment thus reducing the demand for electricity from the grid. One or both of these activities could be used at any given facility enrolled in a demand response program; however, only the total load reduction during a
demand response event is determined by the sponsoring organizations (NYISO, New York Power Authority, Long Island Power Authority, and Consolidated Edison). Therefore, the data required to quantify emissions from generation sources during specific demand response events are not collected. Such emissions could be significant. For example, demand response generators could potentially emit nearly 160 tons of NO\textsubscript{x} per day in the New York City airshed.

Emissions estimation is further confounded by certain bureaucratic requirements involving the permitting of central station power peaking units that can be fired with oil or natural gas. Emissions estimates treat these units as oil-fired only units (resulting in over-estimation of emissions). Furthermore, the NYISO is prevented from supplying specific information about demand response sources by FERC regulation. These barriers make the estimation of NO\textsubscript{x} and PM\textsubscript{2.5} emissions during HEDD difficult. In addition, for peaking and other low capacity generators, default emission calculations are used almost exclusively in lieu of CEMs to determine compliance with emissions trading programs. These data are also used for emissions inventory and modeling purposes which likely result in an overestimation of emissions from these units.

**Needs for Emissions Estimates in Key Areas.**

Quantifying emissions on the HEDD is a key to projecting ozone attainment as well as attainment of the PM\textsubscript{2.5} standard. Efforts are needed to determine the number and location of demand response generators. To develop emissions models for non-attainment areas which can be used to supplement current inventory estimates, emissions modelers need to understand how to model the NYISO dispatching rules such as those for minimum oil burn and how demand response events are called.

**Tools and Techniques for Improving Emissions Estimates**

Resolution of the issue of emissions from demand response sources on HEDD will depend on increased cooperation and coordination with entities responsible for insuring the reliability and availability of electricity. A number of projects need to be initiated with such cooperation including:

1. Updating emission factors, including adjusting reported emissions to more accurately reflect actual emissions where default emission factors are used for compliance purposes;
2. Coordinating with ISOs and energy services companies that aggregate demand response assets to provide a means of identifying the location, age and maintenance of units, and operational patterns of demand response sources;
3. Analyzing methods for projecting emissions from generating sources on HEDD (for example, is the IPM model a reliable tool for projecting future emissions profiles considering local reliability rules and transmission constraints may not be adequately factored into the model?); and
4. Collaborating with health departments to identify potential consequences of combined high temperature stress and air quality (e.g., increased hospitalization rates for asthma during heat waves).

Specific Studies or Actions to Improve Emission Estimates

A high priority should be given to improving the quantification of emissions from demand response sources, especially in and around nonattainment areas such as New York City. The identification of units by fuels, engine category, age, and maintenance practice along with estimation of use patterns for at least a subset of units in the city is the first step towards improving knowledge of this category. Close collaboration among NYSDEC, the NYISO, the City of New York (e.g., the mayor’s office), and the energy services companies will be needed to develop a plan for such a survey.

A second priority is to update and improve the emission factors for demand response units based upon age and engine categories. That data, along with demand response event data should be incorporated into a computer model based on a statistical sample. Close coordination with environmental organizations, EPA, and the generation communities will be needed for this exercise.
Improving Estimates of Emissions from Space Heating Using Liquid Fuels

Combustion of liquid fuels for space heating represents a source category that has recently received increased attention. Based on an analysis of data available from the 2002 version of MANE-VU’s emissions inventory and the National Emissions Inventory (NEI), criteria pollutant and air toxic emissions from residential, institutional and commercial combustion of liquid fuels (LPG, #1-kerosene, #2-home heating oil/diesel and #6-residual oil) contribute to regional atmospheric pollution. Within the MANE-VU region, combustion of these fuels by these source categories account for the following fractions of these pollutants: sulfur dioxide (10%), nitrogen oxides (7%), ammonia (2%), mercury (15%), nickel (13%) and selenium (8%). Based on these percentages, one can reasonably conclude that levels of fine particles, ozone and trace metals in the atmosphere are significantly affected by emissions from this source category.

Issues and Concerns Raised in Breakout Session Presentations

In addition to a pre-workshop white paper by Dr. John Graham of NESCAUM, which outlined issues of concern for liquid-fuel space heating and some suggestions for improving emissions estimates for this source category, the breakout group heard presentations by Dr. Morton Lippmann of New York University, Carter Strickland of the City of New York, Dr. Graham, Dr. Tom Butcher of Brookhaven National Lab, and Dr. John Batey. These presentations and the white paper posed the following areas of concern:

Health Effects

Dr. Morton Lippmann reported that epidemiology studies regressing PM components on daily mortality data from the NMMPAS study showed significant associations with Nickel and Vanadium. This result was consistent with a Sulfur-in-fuel intervention study in Hong Kong demonstrating reduced monthly mortality coincident with reduced Nickel, Vanadium, and Sulfur concentrations. Data from PM speciation monitors and IMPROVE monitors indicates that Nickel and Vanadium have substantially higher concentrations in New York City than in any other U.S. city. (See Figure 5, below.)

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1 The Mid-Atlantic/Northeast Visibility Union (MANE-VU) is a regional planning organization for improving visibility in federally protected lands of the Northeast. It covers the region comprised by its members: Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, the Penobscot Indian Nation, Rhode Island, the St. Regis Mohawk Tribe, and Vermont.

New York City’s long term plan—PlaNYC—includes the vision that New York City (NYC) will have the cleanest air quality of any big city in America. The yardstick for measuring progress on this goal is city level data on PM$_{2.5}$. In order to meet this goal, NYC plans to reduce on-road vehicle emissions, reduce off-road and non-road emissions, reduce building emissions, pursue natural solutions, and seek to better understand the scope of the challenge. Fourteen initiatives are being pursued, and one is to promote the use of cleaner burning heating fuels.

In NYC one of the biggest users of #6 residual oil is the school system. The City has set aside $750 Million to replace 100 boilers. In addition, PlaNYC includes a goal of progressively using more biofuel to reduce sulfur content of fuel used in the City.

In exploring emissions that contribute to PM problems in the City, health-effects researchers have found that the categories of emissions sources used in the US National emissions Inventory (NEI) are not very useful, and that the data are outdated. There are five counties in NYC. A lot of data on emissions in the counties is just pro-rated state level data.

![Figure 5 SPATIAL US VARIABILITY OF NI CONCENTRATIONS (BASED ON PM2.5 SPECIATION DATA) (MAP PREPARED BY ZEV ROSS, SPATIAL ANALYSIS, ITHACA NY)](image)
New York City Source Issues

There are about 10,000 registered boilers in NYC that use residual oil. Boilers 350 Btu/hr or larger are required to register. Current emissions information is not sufficient to estimate how much oil is burned in New York City compared to New York State. Lack of source information not only makes it difficult to assess the effects of space heating on human health, but it also makes it difficult to construct an accurate greenhouse gas (GHG) inventory for the City.

New York City has continued to issue permits for use of residual oil in new construction. The registered primary fuel is #4 or #6 in about 1600 new units. (The backup fuel is gas.) The amount of residual fuel used by Columbia University and other institutions is pretty substantial.

Technology Issues

Emissions from liquid-fired furnaces will be changing due to adoption of new technologies and changes in fuels. Dr. Tom Butcher reported that condensing furnaces, which are more efficient, are increasing in popularity worldwide. Moreover, tuning the operation of heating systems can improve the efficiency even without replacing equipment or changing fuel. The goal is to lower the temperature of the water returning to the boiler. More efficient radiators or controls that can modulate the temperature of the water as it leaves the boiler (so it’s hotter on colder days and cooler on warmer days) can also increase efficiency.

With respect to fuels, reducing the sulfur content of fuels not only reduces sulfur emissions but also improves boiler efficiency and lowers fuel consumption. Dr. John Batey reported that reducing the Sulfur content of fuel prevents scale deposits on the inside of boilers, reducing maintenance costs. A recent study of boiler scaling in a sample of 30 residential houses showed that reducing the sulfur content to 500 ppm significantly reduces scaling.

Dr. Batey reported that blending biodiesel with home heating oil reduces odors and greenhouse gas emissions. Currently, B5 is the only ASTM approved biofuel. (Fuel containing 5% biodiesel is legally considered heating oil and can be burned in burners listed as approved for burning fuel oil.) If the biodiesel content is increased to 50%, burner modifications are necessary.

Breakout Session Findings and Recommendations

The breakout session focused on the following issues and remedies:

- Gaps in current emissions estimates
- Emissions data needs not addressed by current inventories
- Emissions changes due to changes in fuels
- Tools and methods for improving emissions estimates
- Recommended studies and collaborative efforts
Gaps in Current Emissions Estimates

There are numerous problems, ranging from basic technical information to the way space heating is treated in existing inventories, that make it difficult to assess the effects of this source category on the urban scale. First of all, oil combustion in small sources is treated as an area source—emissions are estimated on a county-wide basis. Area source fuel use is calculated by subtracting oil use reported by major point sources from state total oil use reported by the U.S. Energy Information Agency. The remainder is allocated to counties in the state on the basis of population or other indicators of commercial activity. Fuel sulfur content is typically estimated from national survey data or regulatory maximum limits. However, the biggest gap in the inventory seems to be lack of information on distributed/emergency generators.

Other data gaps identified in the breakout session include the following:
- What is the actual S and trace metal content of heating fuel & residual oil?
- How much biodiesel is blended in the fuel?
- What are the location and characteristics of equipment burning residual oil?
- What is the geographic distribution of residual oil burning in major urban counties such as New York City?
- What is the age and rate of replacement of residual oil burning equipment?
- What is actually being emitted? More detailed speciation is needed.
- Can better emissions factors be developed for various species of interest?
- What are the temporal patterns of emissions from fuel oil burning?
- What is the S to PM relationship in residual oil?
- How can we obtain better information on changes in boiler efficiency as boilers age?

The relative importance of these data gaps depends on the intended use of the data.

Unmet Information Needs

Emissions inventories are used for regional modeling for purposes of SIP attainment demonstrations, for local analysis, and for national trends analysis. For larger scale analyses of ozone and fine particles, the current data is generally adequate. However, there is concern that the existing inventory may have shortcomings that will be important for local health studies and possibly for analysis of 24-hour fine particle nonattainment problems.

The biggest health issue relative to fuel-oil combustion seems to be the impact of the use of residual oil in urban areas; however, we have no information concerning the effects of this source outside the urban area. Given this concern, there is need for more information on sources of nickel and vanadium emissions and potential strategies for reducing those emissions. Good information about costs and benefits of potential policy options helps policy makers. The ability of localities and states to take action to affect emissions from boilers in their jurisdictions, such as tax incentives or moratoriums, depends on supporting data.

Improvements in energy efficiency (and emissions benefits) result from replacing old fuel burning equipment with newer, more efficient equipment. In many cases, this is possible when fuel with lower sulfur content is available. We need more information on the population
and distribution of old equipment in order to support the creation of incentives to replace old equipment to reduce emissions and improve efficiency.

**Effects of Regulatory, Fuel, and Technology Changes on Data Needs**

The National Ambient Air Quality Standards have been tightened for ozone and fine particles, and EPA recently made the NAAQS for lead significantly more stringent. Implementation of the new lead standard will include a substantially expanded TSP monitoring network. This regulatory change may also result in an increased need to review lead emissions estimates from waste oil combustion. Emissions factors may still assume that the lead content of waste oil is the same as when gasoline contained lead.

Emissions limits and reporting requirements for carbon dioxide are anticipated in the next few years, either from regional or national programs. This change will make fuel use estimates more important as a tracking mechanism. It may also provide opportunities to gather more information on the age and type of equipment being used in order to facilitate and quantify energy efficiency improvements.

Dr. John Graham reported that with funding provided by NYSERDA, NESCAUM has conducted some sampling to measure actual fuel metals content for Hg, Ni, V, S, Mn, Co, Zn, As, Sb, and Pb at the point of sale. NESCAUM has characterized about 30 samples out of a planned sample population of 200. Testing is expected to include biodiesel, if commercial biofuel samples are available. Brookhaven National Laboratory is also doing some work with biodiesel, and they may be able to share some samples. Preliminary results for #2 oil indicate a much lower mercury content than previously assumed based on EPA emissions factors. Sampling for this study was scheduled for the winter of 2008-2009, and a report will be prepared after all sample analysis is complete. The goal of the study is to provide information to EPA that they can use to update their emissions factors for trace metals in fuel oil.

Dr. Tom Butcher reported that Battelle Memorial Institute is conducting work for NYSERDA to test the effects on PM emissions of blending biodiesel with residual fuel oil. An increase in the use of biodiesel and other alternative fuels is expected in response to federal and state initiatives. This change will affect the emissions profile of sources using these fuels and increase the need to understand fuel composition and source emission rates.

As fuel costs increase, users are expected to increase the amount of energy-efficient equipment in use. Tracking the effect of this trend on emissions will require additional data.

With respect to fuels, fuel sulfur content has been generally lower than the maximum allowed. Sulfur content is expected to decline further in the future. MANE-VU has adopted a strategy to reduce the sulfur content of both distillate and residual oil. The effects of this on emission rates of other pollutants should be determined. One breakout session participant stated that when you reduce the Sulfur content of heating fuel, the Nitrogen content seems to decline as well for reasons that are not well understood.

There is an international effort to establish a Sulfur Emissions Control Area (SECA) for ships off the North American coast. If this action goes into place, it will change emissions from
ships. Recent studies have shown that emissions offshore can have significant impacts in near coastal areas.

A report being prepared for NYSERDA on the effects of low sulfur fuel seems to indicate that seals in current boilers may deteriorate faster with the use of ultra low sulfur fuel. New seal materials or pump designs may resolve this issue, but it may have an impact on the speed with which low sulfur fuel requirements are adopted.

**Tools and Techniques for Improving Emissions Estimates**

The breakout group discussed a number of potential approaches for improving emissions estimates for this category. The following suggestions were made:

- Use measured sulfur in oil reported by Title V sources to represent actual fuel sulfur content in a county.
- Share data and ideas through regional organizations. (Sharing information with peers can help if new information or techniques are available.)
- New Jersey has a new rule requiring reporting of annual tune-ups of emergency/back-up generators. (Tune-ups will reduce emissions.)
- Coordinate actions taken to improve air quality related emissions information with the development of green house gas (GHG) emissions inventories.
- Read the “Petroleum Infrastructure Study” recently published by NYSERDA (regarding allocated fuel use information). This study estimates far more emergency generators than are registered.
- Set lower permit thresholds for residual oil.
- State tax data may be available in some states that could be used to improve the spatial allocation of emissions estimates.
- Analyze residual fuel sales data.

The most promising of these tools and techniques are reflected in the groups’ final recommendations for the emissions inventory. These recommendations are summarized in the next section.

**Recommended Actions for Improving Emissions Estimates**

The work group identified four major actions that could be undertaken to improve the emissions estimates from space heating with liquid fuels:

- Document energy savings and emissions reductions from replacing outdated equipment. (E.g., conduct a survey in limited areas of concern—cities with old, large apartment buildings or commercial buildings or schools that are burning residual oil.)
- As part of effort to develop GHG emissions inventory, require reporting of the location and size of equipment (e.g., age, characteristics, fuels, operating times).
• Mine data from other sources, e.g.:
  – NYC registration (and perhaps other cities) can be used.
  – Schools (and other institutions) may use residual oil and sometimes convert to wood—conduct a survey of schools.
  – Seek collaboration with other state agencies to obtain information on fuel taxation, and develop agreements on preserving confidentiality.
• Educate schools regarding impacts of emissions from residual fuels and wood burning.

The group refined this initial identification by focusing on actions that would a) improve the fuel use inventory overall, and b) address residual oil concerns regarding health effects.

The following actions were recommended to improve the fuel use inventory:

• To improve spatial allocation:
  – Investigate urban/rural allocation or use of employment data.
  – Investigate use of sales tax information.
• To improve temporal allocation, use heating degree days instead of a seasonal adjustment factor.
• To improve emissions factors:
  – Analyze Title V Sulfur content information and improve estimates of S content in area source information.
  – Evaluate studies underway that might help improve emissions factors for trace emissions including Ni and V.
• Conduct a special study of NYC data followed by comparisons to other cities.
• Mine the NYC registration data and fuel tax data to assess the population and use of residual oil.
  – Compare with current estimates.
  – Assess need for improvement.
  – If possible, pursue this in other states as well.
• Continue further source apportionment work on monitoring data presented by Dr. Lippmann, e.g., local boilers v. EGU v. port v. mobile sources v. other sources

Remaining questions include the following:
  – Is sales tax data available to improve activity data (for both residual and distillate)?
  – How widespread is the residual oil problem?
  – What data is most important to address the problem?
  – What are potential policy responses?
Improving Estimates of Emissions from Space Heating with Biomass

Statement of the Problem

Biomass combustion (e.g., wood) can be a low cost home heating energy source, particularly in non-urban areas of the Northeast with ready access to sufficient wood supplies. However, poorly designed or older wood burning devices can be a significant source of fine particulate matter (PM$_{2.5}$) and air toxics at local and regional levels, and thus pose a serious public health threat if not properly managed.

Wood burning emits significant quantities of known health-damaging pollutants, including several carcinogenic compounds (e.g., polycyclic aromatic hydrocarbons, benzene, aldehydes, respirable particulate matter, carbon monoxide, nitrogen oxides, and other free radicals). Recent reviews of the health literature indicates wood smoke exposure likely leads to a range of adverse effects, including increases in respiratory symptoms (e.g., coughing, wheezing, chest tightness), lung function decreases, increases in asthma symptoms, visits to emergency rooms, and hospitalizations (Naeher et al., 2007; NYSERDA, 2008). The close proximity of high-emitting wood burning devices that fail to adequately disperse emissions within neighborhoods, such as outdoor wood boilers (OWBs) with short chimneys, fireplaces and older indoor woodstoves, is an increasing concern facing state health and environmental agencies as the popularity of wood combustion for space and water heating increases (Schreiber and Chinery, 2008). One field measurement in New York State (NYS) showed concentrations as high as 8,880 ug/m$^3$ at a distance of 50 feet from an outdoor wood boiler, periodic values greater than 1,000 ug/m$^3$ at 150 feet, and frequent values greater than 400 ug/m$^3$ at 150 feet (NESCAUM, 2006).

Inventory and usage studies indicate that wood smoke is a large contributor to primary PM$_{2.5}$ in the northeastern U.S. In New York State, the carbon fraction is 55 percent of primary PM$_{2.5}$ emissions state-wide (Figure 6). Residential fuel combustion (almost all wood), diesel sources, and commercial cooking are major contributors. Relative contributions of source sectors, however, are quite different in the urban New York City nonattainment area (NAA) as compared to rural areas. For example, whereas more than half of carbonaceous PM$_{2.5}$ in the New York NAA is from on-road and non-road mobile sources, almost all (>90 percent) of carbonaceous PM$_{2.5}$ emissions in rural counties are attributed to residential wood combustion (NYSERDA, 2008).
The Northeast Census Region (New England, NJ, NY, and PA) consumes over twice as many cords of wood in woodstoves annually as the Midwest, South, or West. Upwards of 80 percent of the woodstoves currently in use were manufactured without efficient combustion designs or pollution control devices, which have been required since 1988. Moreover, the growing use of OWBs, pellet stoves, and fireplaces has presented regulators with an added air quality problem because these devices are exempt from EPA wood stove New Source Performance Standards (NSPS). For example, OWB sales, based on industry data, are rapidly increasing on an annual basis with national OWB sales more than doubling between 2004 and 2005 (24,650 to 67,546).

A key issue in assessing potential wood smoke problems in the Northeast is the location of wood burning compounded by landscape features that can create significant PM$_{2.5}$ spatial variability, including “hotspots,” on top of regional PM$_{2.5}$ contributions. Wood burning appliances often are operated in close proximity to residential areas so that a large fraction of emissions results in concentrations to which people are actually exposed (Bennett et al., 2002). This can be further compounded in spatially constrained areas, such as narrow valleys, where stagnant cold wintertime conditions can lead to a build up of wood smoke with little out-of-valley venting. Researchers have also observed a strong relationship between the fine fraction (PM$_{2.5}$ and PM$_{1}$) of indoor and outdoor wood smoke particles (Kingham et al., 2008). This raises concern for sensitive populations, such as children, who could be put at increased risk of exposure to wood particulate, especially from high emitting devices such as OWBs, old woodstoves, and poorly controlled institutional wood boilers that may be placed in areas where they spend significant portions of their day.

Over the last several years there have been numerous complaints about wood smoke made to the New York State Department of Health, to the Department of Environmental Conservation, and to the Attorney General’s Office. Complaints regarding outdoor wood boilers were so numerous, that the Attorney General’s Office produced a publication, “Smoke...
Gets in Your Lungs,” describing the problem being experienced with these high emitting sources (Schreiber and Chinery, 2008). Currently in New York State, there is no statewide regulation but approximately 60 local communities in New York State have banned or regulated OWBs.

At the time of this workshop, the NYS Department of Health was conducting a survey of ambient air impacts in residential areas surrounding outdoor wood boilers. Specifically, Department scientists measured real-time fine particulate levels (PM$_{2.5}$) and meteorological conditions around five randomly selected outdoor wood boilers and were comparing measurements to those made distant from the boilers. Preliminary findings indicated that fine particulate levels were higher in areas near the outdoor wood boilers when compared to measurements made distant from the boiler. Certain meteorological conditions, such as calm winds and winds from the boiler toward the monitor, and sometimes at night appear to be associated with elevated PM$_{2.5}$ levels. Data analysis was on-going and a report will be made available upon completion.

![Figure 7 COMPARISON OF EMISSION LIMITS FOR SMALL SOLID FUEL BOILERS (lb/mmBtu)](image)

The importance of wood smoke as a contributor to PM$_{2.5}$ in many locations indicates strategies to reduce wood smoke emissions may be an effective approach to lowering PM$_{2.5}$ exposures (Naehler et al., 2007). The U.S. EPA has developed a programmatic model, the “Great American Wood Stove Changeout Program,” that encourages localities to provide a financial
incentive to replace wood stoves manufactured before 1988 with newer EPA-Tier II stoves. These older models account for more than 80% of the wood stoves in use today. Washington State has set their emissions standards lower than the EPA Tier II level, and there are now high-efficiency gasification wood stoves for sale by European manufacturers. This creates an opportunity in the U.S. to control wood smoke emissions beyond current limits through the introduction of higher-efficiency, cleaner technologies. (See Figure 7, above.)

One major wood stove changeout effort by EPA took place in Libby Montana where wood smoke was the major contributor to high levels of PM. With contributions of one million dollars from members of the Hearth, Patio, and Barbeque Association (HPBA), $100,000 from EPA, and $1,000,000 from government earmarks, a total of 1,130 woodstoves that were not EPA certified were replaced with EPA Tier II certified stoves. Measurements of PM$_{2.5}$ before and after the changeout program indicate that significant emissions reductions took place, resulting in a thirty percent decrease in the annual average PM$_{2.5}$ outdoor ambient concentrations and a 70% decrease in indoor concentrations after the program.

Numerous biomass fuels other than wood are emerging as well. Sometimes they are mixed with sawdust for improved binding in pellet form, sometimes they are not. The agricultural sector is pursuing pellet production from various grasses such as Switch Grass and Reed Canary Grass. There is also interest to use hay that does not meet specifications for animal feed, and dried corn kernels have been used as a pellet fuel for some time. Cornell University and others are investigating the requirements for making pellets from grass and they are also performing preliminary combustion studies to gauge grass-fired heating appliance performance. Due to the higher ash content in these feedstocks, technologies burning grass pellets typically require a different design, including mechanical ash removal, compared to wood combustion units. The higher ash content of these feedstocks makes it important to perform careful emissions tests for them as well. The higher Cl content presents material compatibility issues, such that combustion equipment may need to have stainless steel components to resist corrosion. In Europe, grasses are typically reserved for units with emissions controls due to the increased particle emissions from the greater inorganic (ash) component.

**What emission information gaps need to be filled?**

**Status of Northeast Wood Combustion Emission Inventories—How good are the inventories?**

The U.S. EPA’s National Emissions Inventory (NEI) either incorporates wood combustion information provided by states and local regions, or uses default data when local data are absent. About half of the states submitted residential wood combustion data for the 2002 NEI. However, the 2002 data do not cover several emerging and increasingly important wood combustion source categories. EPA has begun work to address these gaps, and to improve emission factors for previously included wood combustion devices. EPA plans to add outdoor hydronic heaters (commonly called outdoor wood boilers or OWBs), wax logs, and indoor wood
furnaces and update emission factors for all residential wood burning devices for the next iteration of the NEI.

MARAMA supported the development of two different northeastern residential wood combustion (RWC) inventories for the year 2002 that employed two very different approaches. E.H. Pechan & Assoc., Inc. (Pechan) used telephone surveys to gauge RWC activity that resulted in an inventory of RWC emissions about twice as high as those of the NEI. The Pechan inventory included wood appliances not found in the NEI (i.e., pellet stoves, OWBs, indoor wood furnaces) as well as a different wood density value. The Pechan approach gave an estimate of 154,242 tons of PM emissions in the MANE-VU region1 from indoor and outdoor RWC in 2002 (Pechan, 2004). Later, after the release of data from the 2000 census of housing, OMNI Environmental Services (OMNI) developed a different RWC inventory using US Census data, American Housing Survey reports, Simmons Marketing Research data, Hearth, Patio, and Barbeque Association surveys, and various state surveys. OMNI also applied state-specific wood density factors and revised emissions factors for some types of equipment. The OMNI approach gave an estimate of 92,471 tons of PM from RWC in 2002 in the MANE-VU region (OMNI, 2006).

There are a number of data gaps to be addressed that can help refine and reconcile the various estimates of residential wood smoke emissions in the Northeast. Information on the location and use patterns for OWBs and other wood burning devices is one such data gap. While anecdotal, it appears likely that since 2002, wood combustion has increased due to rising fossil fuel prices. To verify this, better data on the sales and use of wood burning devices will be critical to ascertaining sound inventories for wood combustion. Additional areas for emissions inventory improvements include adding other appliances not yet incorporated into inventories (pellet stoves, stoves burning biomass other than wood), refining the rural/urban split of wood combustion, incorporating more state-level burn rates, refining estimates of wood density values, and updating the proportion of EPA-certified appliances.

Characterizing small commercial units, in the 1 to 10 mmBtu size range, is also very important. A number of states, the US Forest Service, and the U.S. Department of Agriculture are promoting commercial scale wood combustion. Numerous northern states have implemented “Fuels for Schools” programs in which they provide financial incentives for schools to convert their existing heating systems to wood-chip-fired systems. While these systems provide significant economic savings, there is little data on the emissions or energy performance of these commercial wood-fired systems. Most emissions information available on units in this category is dated, and reports typically cite EPA’s AP-42 values. Due to the “Fuels for Schools” push for these units and the information that has emerged on particle-health effects in general, children as a susceptible population, and toxicology and epidemiology of wood smoke in particular, characterizing these units should be a priority.

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1 The Mid-Atlantic/Northeast Visibility Union (MANE-VU) is a regional planning organization for improving visibility in federally protected lands of the Northeast. It covers the region comprised by its members: Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, the Penobscot Indian Nation, Rhode Island, the St. Regis Mohawk Tribe, and Vermont.
Spatial Distribution of Wood Smoke – Where are the problem areas?

State ambient air pollution monitoring networks are typically not dense enough, particularly outside of urban areas, to fully capture the spatial variability of wood smoke, and states do not have the financial or personnel resources to significantly expand their current monitoring programs. While areas of relatively high wood burning may be “rural,” they are not necessarily lightly populated (and can include towns with populations of several thousands and upwards). Therefore, there is a need for cost-effective approaches to identify local areas with potentially high wood smoke levels that can lead to effective management programs. One approach being pursued by NESCAUM with researchers at the University of British Columbia is investigating the use of U.S. Census data and other available wood combustion information coupled with GIS mapping techniques to map spatial wood smoke distributions in the Adirondack region. The project will use mobile and fixed monitoring techniques that discriminate specifically for wood smoke particulate to compare to the mapping results. If spatial patterns can be produced reasonably well, as previously demonstrated in the Pacific Northwest (Su et al., 2008), the mapping technique will offer a low cost screening tool to identify wood smoke hot spots.

Temporal Patterns of Wood Smoke – What do we know about diurnal trends in wood smoke?

As illustrated in Figure 8, below, observations of diurnal wood smoke profiles in four widely separated communities in New England using a real-time optical absorption technique that selectively detects wood smoke show a remarkably similar diurnal profile of wood smoke emissions (Allen et al., 2004).

Figure 8 WINTER DIURNAL PROFILES OF ESTIMATED WOOD SMOKE IN FOUR DIFFERENT NEW ENGLAND COMMUNITIES: RUTLAND, VT; THOMASTON, CT; SPRINGFIELD, MA; BURLINGTON, VT. The hourly averages are across all days of the week.
The nighttime maximum in wood smoke is the result of increased residential heating demand in the evening hours combined with changes in meteorology – there is less wood smoke dispersion under stable conditions and occasional strong inversions at night that dissipate with daytime increases in solar radiation, temperature, wind speed, and mixing depth. Surprisingly, wood smoke levels in a small Connecticut town (Thomaston) are very similar to levels in the larger city of Springfield, MA. Rutland, VT has a similar temporal pattern of wood smoke as Thomaston, CT and Springfield, MA, but higher average concentrations due to its location within a confined valley. Burlington, VT, on the other hand, has a different diurnal profile and lower wood smoke concentrations than the other three sites, which may be due to its proximity to Lake Champlain.

**Emissions Profiles for Wood Combustion Appliances – How variable are wood smoke emissions from individual sources and how do emissions change with wood properties?**

Emissions from wood burning appliances can be highly variable depending on fuels and operating parameters. Stack testing by NESCAUM of an outdoor wood-fired boiler indicates that PM$_{2.5}$ emissions can range by an order of magnitude (24 to 265 grams per hour) with different wood types and physical characteristics. With “real-world” emissions varying greatly with fuel type and characteristics, potential large uncertainties in emission estimates may occur using an assumed standard emission factor. Fuel parameters, such as moisture content and species, play a vital role in determining air emission outcomes. Test results suggest that emissions from various seasoned hardwood loads occur within a range from 55 g/hr to 96 g/hr. When the moisture content of the fuel charge increases by 10 percent, emissions increase by 50 percent to 170 percent compared to seasoned hardwood. Emissions testing using softwood similar to that used for indoor woodstove testing indicated that emissions from this fuel type could be over two to almost five times higher than those from burning hardwood (NESCAUM, 2008).

Emissions profile measurements should capture information on numerous pollutants and energy efficiency (EE) so that they can be expressed as an output based value, because the emissions benefits for improved EE are disproportionately greater than the increased EE and to provide a comparison among technologies being displaced. At a minimum, emissions profiles need to include EC, OC, PAH, dioxins, furans, trace elements, particle size and number, SO$_2$, NOx, N$_2$O and CO$_2$ for the various biomass feed stocks in representative classes of appliances. This will assist in air planning, climate change programs promoting renewable technologies, technology development efforts, and comparisons with other fuel types. (See Table 1.)
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Natural Gas</th>
<th>Distillate/No. 2 Fuel Oil*</th>
<th>Wood**</th>
<th>Coal – Bituminous***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PM</td>
<td>0.007</td>
<td>0.014</td>
<td>0.33 – 0.56</td>
<td>0.46</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>0.007</td>
<td>0.0059</td>
<td>0.25 – 0.43</td>
<td>0.12</td>
</tr>
<tr>
<td>VOC</td>
<td>0.005</td>
<td>0.002</td>
<td>0.017</td>
<td>0.002</td>
</tr>
<tr>
<td>CO</td>
<td>0.08</td>
<td>0.04</td>
<td>0.60</td>
<td>0.2</td>
</tr>
<tr>
<td>CO(_{2})</td>
<td>118</td>
<td>159</td>
<td>195</td>
<td>212</td>
</tr>
<tr>
<td>NO(_{x})</td>
<td>0.1</td>
<td>0.14</td>
<td>0.22 – 0.49</td>
<td>0.42</td>
</tr>
<tr>
<td>SO(_{2})</td>
<td>0.0006</td>
<td>0.002 – 0.25</td>
<td>0.025</td>
<td>1.5 – 5.8</td>
</tr>
</tbody>
</table>

* The SO\(_{2}\) emissions for fuel oil will vary depending on sulfur content (assumed range of 15 ppm – 2500 ppm).

** Ranges occur due to use of wood with and without bark.

*** Assumed spreader stoker with multiple cyclones and no flyash reinjection. The SO\(_{2}\) emissions for bituminous coal will vary depending on sulfur content (assumed range of 1% – 4%).

Table 1 COMPARISON OF EMISSION RATES FROM SMALL BOILERS ACROSS FOUR FUEL TYPES\(^2\) (lb/mmBtu input)

Data Needs Created by Changes in Fuels, Technologies, and Use Patterns

Changes in Fuels

Increased oil prices were the major driver for the recent increase in residential heating with biomass. Woody biomass was the primary biomass fuel but there is also considerable interest in making pellets from perennial grasses. The price of distillate fuel oil in New York State was 73% higher in 2006 compared to 2001 and continued to rise to a peak of $4.77 per gallon in July 2008. During the same time, sales of outdoor wood boilers increased in the northeast, growing by an estimated 12% per year (Schreiber, et al., 2008). It is anticipated that this growth rate increased greatly during 2007 and 2008 but sales data are not available.

High-efficiency residential wood combustion may be encouraged through tax credits. In the 2008 federal financial stimulus package, Troubled Assets Relief Program (TARP), a tax credit of $300 was added for the purchases of a new wood stove having energy efficiency greater than 75%. This potentially applies to wood-fired boilers with 75% thermal efficiency as well. In

addition, a tax credit of 30% with a cap of $2,000 for solar-thermal equipment could aid in reducing costs for hot water storage for those wood-fired boilers integrating with solar thermal hot water systems. The cost of a hot water storage system is in the range of $7,000 depending on the size of the system. While this technology-forcing approach will encourage a market for high-efficiency units, to achieve actual emissions reductions, old units being replaced by new must be removed from resale markets, as in the EPA Great American Woodstove Changeout Program.

State forestry programs have been and are expected to continue promoting wood as a fuel as part of their healthy forest, market development, and woody biomass programs. These programs typically focus efforts on the use of wood systems in commercial and institutional buildings such as schools, prisons, and hospitals. The fuel commonly used in commercial boilers is in the form of wood chips with approximately 40% moisture content, using mill end wood chips (chips without bark) and bole chips (chips with bark). There are several schools planning to change from oil to wood combustion in Vermont, where currently 25% of all pupils attend a school heated with wood. At least one school in New York State has made this change due to fuel cost savings and several others may switch as well.

Some states and federal governments developing programs focused on mitigating climate change are in the process of performing life-cycle analyses for various biomass crops. In New York State, a “biomass roadmap” is being developed with the five objectives below:

1) Address lifecycle environmental and public health consequences of renewable fuels compared to fossil fuels;
2) Outline sustainability criteria and best management practices to mitigate potential negative impacts;
3) Analyze New York State land use, resource condition, and feedstock supply (baseline and potential) and local, state, and regional economic effects;
4) Evaluate technological and economic barriers to large scale feedstock production in New York State and analyzes potential solutions;
5) Compare current and future renewable fuel feedstock and process technologies to each other, current and future fossil fuels, and competing uses for biomass in terms of sustainability criteria, highest-value uses, and commercial viability in New York State.

Changes in technology, controls, and processes – What is the experience in improved designs for wood combustion efficiency and use of control technologies?

Significant improvements in emissions performance can be obtained when devices employ improved combustion techniques and, depending on the size of the unit, advanced emission controls, such as ESPs. (See Table 2 below.)
European state-of-the-art technologies for improved wood boilers achieving 85-90% efficiency include a two-stage combustion principle and an injection of secondary air prior to a hot combustion chamber. Other improvements include electronic combustion control that ensures optimal operation, and forced ventilation to achieve good mixing and less dependence on the ambient climate conditions, such as air temperature and wind. Also, wood boilers equipped with a heat accumulation tank can avoid part-load operation, resulting in better emissions performance (NYSERDA, 2008).

In the U.S., there is currently little movement towards cleaner units due to a lack of regulatory requirements and economic incentives. As a result, technically feasible advanced designs and control technologies generally are not being used. The use of advanced controls and boiler designs, however, could lower PM$_{2.5}$ emission levels by up to two orders of magnitude (Table 2). Table 3 below compares different control technology options for wood combustion devices.

<table>
<thead>
<tr>
<th>Commercial boilers</th>
<th>Thermal Efficiency (%)</th>
<th>Particle emissions (lb/mmBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US conventional wood chip uncontrolled</td>
<td>70-75</td>
<td>~0.3-0.6</td>
</tr>
<tr>
<td>U.S. conventional wood chip*</td>
<td>70-75</td>
<td>0.2-0.25</td>
</tr>
<tr>
<td>U.S. Conventional wood chip with ESP or bag house</td>
<td>70-75</td>
<td>0.03</td>
</tr>
<tr>
<td>European high efficiency and low emission chip or pellet (residential and commercial)*</td>
<td>85-90</td>
<td>0.01-0.07</td>
</tr>
<tr>
<td>European high efficiency and low emission chip or pellet w/ESP or bag house</td>
<td>85-90</td>
<td>0.002-0.01</td>
</tr>
</tbody>
</table>

*System incorporates use of cyclone

Table 2 COMPARISON OF PERFORMANCE LEVELS AMONG SMALL COMMERCIAL/INSTITUTIONAL WOOD BOILERS (Albrecht, personal communication)
### Table 3 COMPARISON OF FEASIBLE CONTROL DEVICES FOR WOOD BOILERS

<table>
<thead>
<tr>
<th>Control</th>
<th>Removal Effectiveness</th>
<th>Costs</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cyclones</strong></td>
<td>PM$_{10}$ - Moderate control efficiency ~50%</td>
<td>Installation $7-10K</td>
<td>• Inexpensive</td>
</tr>
<tr>
<td></td>
<td>PM$_{2.5}$ - ineffective</td>
<td>Maintenance Minimal</td>
<td>• Ineffective at removing fine PM</td>
</tr>
<tr>
<td><strong>Multicyclones</strong></td>
<td>PM$_{10}$ - Moderate control efficiency ~75%</td>
<td>Installation $10-16K</td>
<td>• Inexpensive</td>
</tr>
<tr>
<td></td>
<td>PM$_{2.5}$ - ineffective</td>
<td>Maintenance Minimal</td>
<td>• Ineffective at removing fine PM</td>
</tr>
<tr>
<td><strong>Core Separator</strong></td>
<td>In question</td>
<td>Installation $100K</td>
<td>• Questions about availability and effectiveness</td>
</tr>
<tr>
<td></td>
<td>Anticipate 60% removal of PM$_{2.5}$</td>
<td>Maintenance Unknown</td>
<td></td>
</tr>
<tr>
<td><strong>Baghouses/fabric filter</strong></td>
<td>PM$_{10}$ - 98% and higher</td>
<td>Installation $80-130K</td>
<td>• Higher cost</td>
</tr>
<tr>
<td></td>
<td>PM$_{2.5}$ - 98% and higher</td>
<td>Maintenance $10K</td>
<td>• Highly effective for PM fine removal</td>
</tr>
<tr>
<td><strong>ESP</strong></td>
<td>PM$_{10}$ - 90% and higher</td>
<td>Installation $100-175K</td>
<td>• Higher cost</td>
</tr>
<tr>
<td></td>
<td>PM$_{2.5}$ - 90% and higher</td>
<td>Maintenance $1-2K</td>
<td>• Highly effective for PM fine removal</td>
</tr>
</tbody>
</table>

### Changes in use patterns: Market Drivers and Programs incorporating biomass-heating in the Region

A number of factors are leading to increased use of biomass in the region. The strongest driver is the cost of home heating oil. This has lead to the installation of large numbers of inefficient OWBs. Some U.S. manufacturers have begun to switch to 2-stage combustion and produce high efficiency units and the European manufacturers are keen to make their products available in the U.S. market.

High fuel prices have resulted in many older wood stove units being used by homeowners that had not used them in years as a way to control heating costs. The wood stove technology commonly available in the U.S. could also benefit from improved combustion design. These units typically are assigned an efficiency value of 63%. In contrast, European manufacturers have now developed gasification “room heaters” with efficiency values of over 85%.
A number of state and federal initiatives aim to increase the use of renewable fuels for climate change mitigation, national security, and economic development reasons. These programs sometimes focus on “displacing petroleum” and have not all linked their programs to maximize energy-efficiency and emissions performance. This may evolve in time as EPA and states move toward output-based emissions standards. Until that time, less efficient, higher emitting boilers with long lifetimes will continue to be installed. Some states, including Vermont and Maine, have already regulated OWBs using an output-based emissions limit which sets a “technology floor” and encourages this category of combustion appliance toward higher energy-efficiency and emissions performance.

**Vermont:** The State of Vermont has a 25 by ’25 Program with the goal of 25% of statewide energy to come from forests and farms. This program focuses on electricity as well as space and water heating. The program is divided into two major categories: (1) A farm- and forest-specific category, which includes the sectors of energy crops, agricultural waste, and wood energy; and (2) a non-farm- and forest-specific category, which includes wind energy, solar energy, hydroelectricity, geothermal energy, and energy efficiency.

**NESCAUM and Massachusetts:** The Northeast and Mid-Atlantic Governor’s Association recently held a meeting to discuss renewable energy. One break-out that focused on bioenergy resulted in an effort to create a Northeast regional market for high-efficiency biomass heating technologies. One concept that has been put forward is the development of a model rule, which incorporates an emission standards and acceptance of European safety testing. This concept would link with a model rule currently under development at NESCAUM. NESCAUM’s model rule focuses on emission standards from commercial, institutional, and industrial biomass boilers not regulated under by the federal NSPS for boilers. The model rule provides a template for states to use when adopting state regulations and promotes consistency among the states. The commercial boiler model rule built upon the model rule efforts NESCAUM undertook to address OWB emissions. In addition, the Massachusetts Department of Energy Resources will investigate the European and U.S. safety requirements and look to recommend regional requirements to avoid multiple state requirements.

**New York:** New York’s Lands and Forests with support from the U.S. Forest Service is developing a program aimed at growing the market to convert “logging leftovers” into biomass fuel. Currently two-million tons enters the low-grade wood market as pulp or biofuel. Another one-million tons is left behind on the forest floor. Lands and Forests is performing pre-feasibility studies at facilities in the Adirondacks to evaluate whether they can heat with wood chips. A similar program is being conducted in the Catskills.

The New York State Energy Research and Development Authority (NYSERDA) is a state government energy organization that partners with many other state and federal agencies and in this role takes the “energy” approach to new fuels and appliances. Its biomass heating R&D program seeks to advance the energy and emissions performance of biomass technologies and evaluate them in comparison to the oil-fired systems they are displacing. NYSERDA is currently supporting several research projects characterizing the energy-efficiency and emissions-performance of biomass technologies and is working with in-state manufacturers to produce high performing units.
Tools and Techniques to Improve Emissions Estimates

To better estimate emissions from biomass heating equipment in residential and small/medium commercial applications, improvement is needed in estimating the number of wood-burning appliance types in use, their general locations, and the amount of fuel burned; characterization of various feedstocks; and the emissions profile for each appliance. Additionally, realistic duty cycles need to be developed for technology evaluations.

Participants recommended the emissions from this equipment be expressed as a value based on heat output. The numbers of units as well as spatial distribution need to be better characterized, due to rapid, ongoing deployment of inefficient technologies. This information could be improved by using trade association data for national sales, which might require an EPA Section 114 order to manufacturers to provide information on how many units have been sold and in which states. Estimates could also be improved by knowing about upcoming renewable fuel initiatives and incentive programs, in order to gauge market drivers. A process should be developed to update all aspects of the inventories more quickly as new technologies emerge.

Feedstock characterization for energy content, moisture content, and composition will be helpful in improving emission estimates, since feedstocks will have varying ash content and other components. A review of the European fuel performance standards may be insightful. In addition, life-cycle analyses need to be conducted for biomass feedstocks (all greenhouse gases and EC).

The emissions profile for each type of equipment and fuel combination needs to be expanded to include PM_{2.5}, EC, OC, PAH, SO_{2}, NOx, CO, and CO_{2}. Additionally, information on particle size and number, Cl, dioxin/furans, trace metals, N_{2}O, and CH_{4} should be added. These emissions rates will vary not only with efficiency of combustion but with the biomass feedstock. The energy efficiency of appliances for various feedstock types is needed to make a comparison between emerging technologies and the fossil units they are displacing. For this reason, output-based emissions rates are needed.

Currently, EPA certification of woodstoves and the voluntary OWB program use a test method developed to compare the performance of technologies under a defined set of conditions. The test conditions were put in place to ensure that a unit would perform well under a variety of conditions rather than under common operating conditions. However, these conditions can be quite different from how the units are actually used, so use of these numbers for inventory purposes may not be appropriate. Realistic duty cycles need to be developed to better represent “in-use” conditions of these heating equipment types. This will not only improve emission estimates for air planning agencies but will help public health agencies as well.

Collaboration Opportunities for the Region

Participants noted a lot of activity was going on in various levels of government and in the private sector and agencies could benefit from improved sharing of information. This
includes Governors’ initiatives, state, regional and federal air, forestry, economic development, and energy agencies. These groups need to share information on actual and emerging conditions at the local level and technical research data in order to improve emissions estimates as conditions change.

States that have put in place OWB regulations have effectively set a technology “floor” and will limit the lowest efficiency residential technologies from entering their market as they simultaneously look to promote their own domestic renewable fuel use in such programs as Vermont’s 25x25. NESCAUM has performed in-use measurements of OWBs to estimate how emissions in the field may vary from those obtained in the laboratory.

Building on the efforts of NYSDEC, NYSOAG, and the NYSERDA report “Assessment of Carbonaceous PM$_{2.5}$ for NY and the Region,” NYSERDA initiated a major RD&D effort with numerous partners (NESCAUM, EPA ORD, BNL, Clarkson University, Cornell University, SUNY Canton, Alternative Fuel Boilers, and Advanced Climate Technologies). This effort, totaling $2.3 million in investment, is characterizing the energy and environmental performance of biomass technologies, supporting technology development with manufacturing partners, and demonstrating advanced biomass technologies at the small commercial scale.

- For residential scale technologies, EPA ORD is evaluating a wide range of boilers including an OWB, a recent model dual-fuel OWB, a high-efficiency split-wood boiler, and a state-of-the-art pellet boiler imported from Europe. A duty-cycle will be developed based on the “call for heat” demand of a home in the Northeast.

- Evaluations of small commercial-scale biomass boilers will be conducted by NESCAUM and VT DEC, and Clarkson University for conventional and high-efficiency units respectively.

- A wood smoke field study with a GIS model is being conducted by NESCAUM to improve spatial and diurnal wood smoke information in northern New York State.

- Advanced biomass boiler technologies are being developed that will displace current oil-fired systems. Alternative Fuel Boilers and Advanced Climate Technologies, two New York State based companies are manufacturing 2-stage gasification combustion units with thermal efficiencies of 87 and 90% respectively. The companies are working with NYSERDA to evaluate and demonstrate these technologies.

**Future Activities**

NYSERDA will be expanding its biomass combustion program focusing on RD&D of high efficiency wood-combustion as well as projects to improve communication and outreach on the topic of wood combustion and high-efficiency technologies. Projects were anticipated to be underway by mid-2009.
Biomass Heating Work Group Participants

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Yvonne Hall, Ontario Ministry of Environment  
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Paul Miller, NESCAUM  
Lisa Rector, NESCAUM  
Dan Riley, Vermont Air Pollution Control Division

References


9 Improving Estimates of Agricultural Ammonia Emissions

Like SO$_2$ and NO$_x$, ammonia is important to the atmospheric chemistry of fine particles, and is a local and regional pollutant that reacts and is transported in the atmosphere (as ammonium sulfate and ammonium nitrate). Current ammonia emissions estimates are highly uncertain. Because of its important role in particle formation, workshop participants recommended that ammonia emissions estimates be improved at least to a level comparable with current SO$_2$ and NO$_x$ emission estimates. The goal is to accurately estimate ammonia emissions at a spatial resolution of about 12 to 36 km, and at temporal scale of approximately one hour.

A comprehensive review of the science related to atmospheric ammonia is beyond the scope of this report. Rather, this section provides a brief overview, identifying key gaps, and is intended to inform the development of strategies to improve ammonia emissions estimates.

The Problem

Estimates of ammonia emissions are less accurate and reliable than estimates of emissions of other air contaminants (SO$_2$, NO$_x$, VOC, PM, and CO). Two major reasons account for this fact: first, ammonia is currently not regulated under the US Clean Air Act as a precursor to ambient fine PM or as contributor to acidic deposition and nutrient enrichment of terrestrial and aquatic ecosystems. Second, most ammonia emissions are difficult to quantify, as they come primarily from livestock management and fertilizer application for production of food. The 2002 National Emission Inventory (NEI) indicates that these agricultural sources accounted for approximately 86% of the estimated U.S. total ammonia emissions.

Ammonia is important to air quality because it reacts in the atmosphere with pollutants such as SO$_2$ and NO$_x$ (which are mostly emitted by power plants, large industrial sources, and on road and off road mobile sources) to produce the ammonium sulfate and ammonium nitrate fractions of ambient fine PM as well as causing wet and dry deposition of ammonia and ammonium ions. Because it is a key pollutant in the formation of secondary ambient PM, accurate estimates of ammonia emissions are crucial to obtaining realistic air quality modeling results and in developing effective regional haze and PM control strategies. Additional important impacts of ammonia include:

- soil and freshwater acidification;
• eutrophication of ecosystems with consequent species loss;
• modification of the transport and deposition patterns of SO$_2$ and NOx; and
• aerosol production affecting radiative-forcing (the “greenhouse effect”).

In a recent evaluation of the USEPA’s study of Concentrated Animal Feeding Operations (CAFOs), the United States Government Accountability Office stated that ammonia emissions from CAFOs are on the rise (GAO, 2008). The study estimated that the number of CAFOs increased from 3600 in 1982 to 12,000 in 2002, an increase of over 230%. For animal production, this change has meant a movement to significantly larger operations that can house as many as 2 million chickens or 800,000 hogs at one facility (GAO, 2008). It should be noted that according to the 2002 animal census, the average number of hogs per facility is 800 nationwide and 1,500 in Iowa (Flora, 2007). This is depicted in Figure 9.

![Figure 9 AVERAGE NUMBER OF HOGS PER FARM (IOWA & U.S., 1974-2002) (Flora 2007)](image)

The USEPA estimated ammonia emissions in the U.S. to be about 4 million tons per year in 2002 (USEPA, 2006), and the trend for ammonia emissions is most probably increasing in the absence of any strategies to control ammonia emissions. By comparison, 17 million tons per year of NOx and 13 million tons per year for SO$_2$ were emitted in 2007 and the trend for these pollutants is downward (USEPA, 2008). As can be seen in Figure 10, emissions in the eleven eastern states and the District of Columbia, known as MANE-VU\(^1\) are currently at 300,000 tons per year and are expected to rise in future years.

\(^1\) The Mid-Atlantic/Northeast Visibility Union (MANE-VU) comprises of Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.
Figure 10 MANE VU AMMONIA EMISSIONS PROJECTIONS

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</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>178</td>
<td>170</td>
<td>144</td>
<td>120</td>
<td>102</td>
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<tr>
<td>Lead</td>
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<td>0.023</td>
<td>0.005</td>
<td>0.004</td>
<td>0.003</td>
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<td>Nitrogen Oxides (NO₂)</td>
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<td>PM₁₀</td>
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<tr>
<td>Sulfur Dioxide (SO₂)</td>
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<td>19</td>
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<tr>
<td>Totals</td>
<td>267</td>
<td>250</td>
<td>220</td>
<td>191</td>
<td>161</td>
<td>145</td>
<td>129</td>
</tr>
</tbody>
</table>

Table 4. NATIONAL EMISSIONS ESTIMATES (FIRES AND DUST EXCLUDED) FOR COMMON POLLUTANTS AND THEIR PRECURSORS (USEPA, 2008)
Ammonia Emission Sources

According to current best estimates, agriculture is the major source of ammonia emissions in the Mid-Atlantic and Northeast Regions (Figure 11). Ammonia emissions result primarily from intensive animal husbandry operations such as dairy operations and rearing facilities for beef cattle, hogs and poultry. According to a statement by Henry Tyrrell of the US Department of Agriculture,

“Only about 10% of the nitrogen in feed for beef cattle is converted to meat; the rest is excreted in animal’s feces (~30% N) and urine (~60% N). Dairy cattle are somewhat more efficient, but about 35% of total N is still lost in the urine. In these operations, ammonia is produced when urea that is present in the urine is mixed with the urease enzyme, primarily in the feces. The N in urine is particularly volatile, and much of it ends up in the atmosphere, although much of the nitrogen in lagoon-stored manure also volatilizes. The amount of ammonia emitted becomes daunting when agricultural statistics are considered. In 1998, there were approximately 34 million beef cattle, 9 million dairy cows, 60 million pigs, 7.6 million sheep and lambs, and over 400 million chickens being raised for meat, milk, eggs, etc. Even these large numbers are dwarfed by broiler chickens – 7.6 billion raised last year. This number of animals produces substantial ammonia emissions – about 10,000 metric tons NH$_3$/day.” (Air Quality Research Subcommittee, 2000)
Improvement and Evaluation of Current Ammonia Estimates

Emissions estimates in the 2002 MANE VU inventory were generated using a model developed by Carnegie Mellon University (Davidson, 2001). Inputs to the model were the following: Activity data: The USDA animal inventory – Annual average, county based; Source Emissions Rate Estimates: Literature review.

Recent Work to Improve Ammonia Emissions Estimates

While using the CMU model provided a substantial improvement over previous approaches to estimating ammonia for the region, much work remains to be done. In an effort to improve estimates of ammonia emissions, LADCO asked a contractor (Sonoma Technologies, Inc.—STI) to review the CMU model and provide suggestions for improvement. Contractor recommendations are contained in a report titled “Recommended Improvements to the CMU Ammonia Emission Inventory Model for use by LADCO” (Chinkin, 2003).

STI recommended a number of changes to the emission factors used for source categories. The net effect of STI’s recommendations was a 15% reduction in estimates of overall Midwest ammonia emissions, with mobile sources playing a more prominent role, although still secondary to agriculture. Soil emissions were also highlighted by STI as a source of ammonia that may prove to be large and at the same time have a high level of uncertainty (a point also made by the CMU study). Some estimates are that soil emissions could be 40% of the total emissions. High-quality emission factors for this category do not exist, and, unlike major efforts that are described below that are currently under way to improve emission estimates from livestock operations and fertilizer applications, no serious effort is currently underway to address soil emissions.

More recently, EPA and the CAFO industry have initiated a two-year “National Air Emissions Monitoring Study” to develop protocols for measuring and quantifying air emissions (including ammonia) from animal feeding operations. This universities-led research effort started in 2007, and it was scheduled to be completed in 2009. However, concerns were raised by the Government Accounting Office (GAO 2008) that the study may not represent statistically valid sample of all CAFOs, and may not collect enough information necessary for EPA to develop planned protocols.

The 2003 report of the National Academy of Sciences (NAS, 2003) recommended developing a process-based model to improve livestock ammonia emissions estimates. Such a modeling approach would allow a more dynamic estimate of emissions of ammonia and related species from such sources. Process based models are complex and required detailed input information. The Lake Michigan Air Directors Consortium (LADCO) has been developing simplified process models for certain types of farms.
Temporal and Spatial Distribution of Ammonia Emissions

Understanding the spatial and temporal variation in ammonia emissions at a level of detail that is comparable to emissions of SO\textsubscript{2} and NOx is important to estimating local and regional air quality impact. The United States Department of Agriculture (USDA) animal census provides annual average animal populations. However, the populations of some animal types change through the year. Changes in meteorological variables (such as temperature and humidity) also affect ammonia emissions. Finally, animal husbandry practices affect the timing and amount of emissions.

The CMU model addresses some aspects of temporal variability but not to the degree needed for atmospheric modeling purposes. For example, emissions during manure spreading in the spring occur during only a few days. Currently those emissions are averaged over several months.

Refinement in spatial distribution is also important for ammonia emissions. Figures 12 through 14 show total annual emissions of NOx, SO\textsubscript{2} and ammonia in the United States in 1998. As can be seen in these figures, ammonia sources are concentrated in different locations/states than NOx and SO\textsubscript{2} emissions and occur in areas with substantial agricultural and animal operations activities. This distribution is different than NOx, and SO\textsubscript{2} emissions which are located near population centers or where large amounts of electric generation occur.

Figure 12  DENSITY MAP OF 1998 NITROGEN OXIDES EMISSIONS BY COUNTY (EPA OAQPS, 2002)
While ammonia deposits close to the source (<10-100 km), ammonium (NH$_4^+$) may be transferred (as ammonium sulfate and ammonium nitrate) much longer distances (100-1000 km) (Asman et al. 1998). Hence ammonia emissions contribute to PM and acidic species transport issues. Measurements of acidic wet and dry deposition show substantial amounts of ammonium ions associated with sulfate and nitrate ions.

Ammonia availability outside the area where it is emitted is limited by the fact that it is quickly deposited if it is not reacted to form an ammonium compound. The spatial distribution of ammonia is therefore an important driver for ambient reactions between ammonia, NOx and SO$_2$. However, recent work has suggested that net dry deposition of ammonia is reduced in fertilized agricultural land, resulting in longer transport of ammonia (and its salts) than is currently accounted for in the CMAQ model (Dennis, 2006).
Breakout Session Recommendations for Improving Ammonia Emission Estimates

Ammonia in an important actor in fine particle formation, and it plays important roles in acidic deposition and in nutrient enhancement of both terrestrial and aquatic ecosystems. Because of their importance in particle formation, ammonia emissions need to be characterized to the same level of accuracy, reliability, and spatial and temporal resolution as NOx and SO\textsubscript{2} emissions. Given this goal, the ammonia emissions breakout session returned the following four priority recommendations:

**Largest CAFOs should be treated as point sources**

Emissions from the largest CAFOs may be quite large. One task is to explore the possibility of treating the largest CAFOs as point sources in the inventory and calculating their emissions based on specific characteristics of the facility. Information necessary to do this may be available in publicly-available NPDES permits.

If treated as a point source, their specific characteristics and locations should be determined and mapped on a GIS system. Spatial coordinates would enable use in the grids used in the CMAQ or similar modeling platforms. Such spatial mapping would be very useful in resolving ammonia emissions at a spatial scale similar to SO\textsubscript{2} and NOx.

**Assemble and review current scientific information about ammonia emissions and atmospheric behavior**

Much work is currently being done at universities and government agencies throughout the United States to understand ammonia emissions from CAFOs, and its subsequent atmospheric and deposition/enrichment behavior. For example, work is underway at the University of California, Davis to develop a process-based model of emissions from animal feeding operations. This work will be helpful to understand and model the temporal profile of ammonia emissions from animal housing and manure storage and land application. In addition, in recent years researchers nationwide have been collecting ammonia emissions data from a variety of animal types and husbandry practices during various meteorological regimes.

Finally, researchers, including Dr. Robin Dennis of USEPA, have recently reevaluated the deposition patterns of ammonia and have concluded that dry deposition is over-predicted in current atmospheric models such as CMAQ. Dry deposition velocity estimates have been revisitied and revised calculations will be incorporated into a new version of CMAQ due to be released in 2009.

Participants recommended contacting these researchers to understand and integrate the scientific work that has been done. They recommended preparing a report that collects, synthesizes and integrates this information into the air quality management field so that it can be used to inform air quality programs and policy. Finally, the group recommended a science meeting be held in 2009 to present these
results to the regulatory agencies. Following this work, they recommended an analysis to identify remaining gaps in our knowledge.

The participants recommended that the MANE-VU states consider this information in determining the best approach to estimate emissions for the next emissions inventory. One possible approach would be to use the existing CMU model with updated activity data and emission factors. Refinements may include 1) using a Northeastern US version of the UC Davis model to establish temporal profiles, and 2) developing a separate point source inventory for larger CAFO facilities.

**Obtain Information about farms and trends in the region**

The MANE VU 2002 Version 3 inventory was based on the 1997 animal census. The 2007 animal census will be available from USDA in February 2009. Participants recommended states obtain the new census and analyze the data for trends from previous census data (1997 and 2002). In addition, states could contact USDA representatives responsible for the census to determine if additional information that is being collected would improve its utility for air quality planning. Contact with those responsible for the census at USDA should be made to encourage collaboration on making these data as useful as possible for air planning purposes.

A National Pollution Discharge and Elimination System (NPDES) permit is required for CAFOs that discharge wastewater into federal waters. These permits include many details about the farms, including their locations, size, and manure storage and application characteristics. These permits should be accessed and analyzed in all states. In addition, the NPDES requirements for CAFOs are being revised. This revision should be evaluated to understand its impact on the information reported.

Agricultural extension personnel in each state should be identified and contacted to determine if databases are available that could be used to characterize farms and ammonia emissions in the area.

Farm emissions and discharges are of interest to USEPA and environmental groups, including the Chesapeake Bay Foundation. These groups should be contacted to determine if information that they have collected may be useful to characterize farm air emissions. Ms. Sally Shaver is the contact person at USEPA who has worked with USDA.

As discussed earlier, efforts are underway to develop a process-based model for livestock ammonia emissions. Coordination with LADCO and UC Davis will allow better calibration of this model for the MANE VU region. To evaluate the new generation of process-based models, 2008 farm population data should be collected. State-specific farm characteristics should be utilized, where available, or reasonable default values developed. Farm-specific data should also be collected, or develop reasonable default values. The model should then be run to estimate emissions with better time resolution and with the use of local data. An up-scaling of these results should be done to generate state, regional, and national ammonia emission estimates. The model should
then be evaluated using the baseline real farm data to increase confidence in the process-based model.

**Confirm ammonia emissions estimates by comparison with ambient measurements and use of inverse modeling**

Ammonia emission estimates should be confirmed by using independent techniques. One approach is to compare emission estimates to measurements of ammonia in the ambient air and ammonium ion in wet deposition. To do this in real-time, a routine continuous monitoring technique for ambient NH$_3$ must be developed. Another approach for evaluation emissions estimates is to use “inverse modeling techniques” using CMAQ (Gilliland et al., 2003). Using inverse modeling can help reduce uncertainties and improve ammonia emission estimates. Ammonia is an attractive candidate for inverse modeling, because the modeled response in ammonium ion in wet deposition is strongly linear with changes in ammonia emissions. Gilliland et al. showed that correcting the ammonia emission estimates was an essential step for reasonable model prediction of other Nitrogen compounds. Gilliland et al. estimated that the NEI value for annual ammonia emissions in the US was about 37% too high to optimize modeled wet NH$_4$ ion concentration. EPA planned to decrease its estimates of ammonia emissions by about 23% by altering emission factors for nondairy cows and swine. This approach could also be followed in the Northeast.

**References**


GAO (2008) Concentrated Animal Feeding Operations: EPA needs more information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern. GAO-08-944


Appendix A
Workshop Organizers and Advisory Committee

Organizers
Praveen Amar, Northeast States for Coordinated Air Use Management (NESCAUM)
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Bill Pennell, NARSTO
Susan Wierman, Mid-Atlantic Regional Air Management Association

Advisory Committee
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Mark Desloriers, Environment Canada, Pollution Data Branch
Howard Feldman, American Petroleum Institute
Oliver Gao, Cornell University
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Gopal Sistla, New York State Department of Environmental Conservation
Rob Sliwinski, New York State Department of Environmental Conservation
Doug Soloman, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards
Carter Strickland, New York City Mayor's Office
Appendix B

Agenda

A Renewed Effort to Improve
Northeast and Mid-Atlantic Regional Emission Estimates

MARAMA – NESCAUM - NYSERDA - NARSTO Workshop
November 12-13, 2008
Desmond Hotel and Conference Center
660 Albany Shaker Road
Albany, New York, 12211
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Purpose/Objectives:
- Characterize current emissions estimates of several high-priority source categories and identify current data gaps such as emissions profiles (including speciation), spatial distribution, activity patterns, among others;
- Identify changes in fuels, technologies, and use patterns that are anticipated in the short (3-5 years) and long term (7 or more years) and the data needs they will create;
- Identify tools that could be applied to improve emissions estimates; and
- Explore potential collaboration opportunities.

Wednesday, November 12

10:00 am  Welcome
Bill Pennell, Management Coordinator, NARSTO

10:10 am  Why We Need a Regional Approach: Policy Perspectives
Jared Snyder, Assistant Commissioner, NYSDEC

10:30 am  Regional Air Quality and Emissions Overview
Susan Wierman, Executive Director, MARAMA
10:50 am  Intra-urban Pollution Gradients and Public Health Impacts  
Thomas Matte, Director of Environmental Research, Bureau of  
Environmental Surveillance and Policy, New York City Department of  
Health and Mental Hygiene

11:10 am  Emerging Trends in Energy Technology and Fuels and Potential  
Environmental Implications  
Janet Joseph, Program Director, Clean Energy Research and Market  
Development, NYSERDA

11:30 am  Mobile Source Developments and Issues (MOVES Update)  
Gene Tierney, Environmental Scientist, EPA OTAQ

11:50 am  Role of Ammonia, Status of Ammonia Emissions Estimates and  
Prospects for Improvements  
Praveen Amar, Director, Science and Policy, NESCAUM

12:15 pm  Courtyard Lunch Buffet (provided, 1 hour)

1:15 pm  Updating the National Emissions Inventory  
Roy Huntley, Environmental Engineer, EIAG, EPA OAQPS

1:35 pm  Charge to the Work Groups (Major Themes, Process)  
Susan Wierman, Executive Director, MARAMA

1:55 pm  Emission Estimates Needs for the Next Round of Modeling  
Tad Aburn, Chair, MARAMA, Director, Maryland Department of the  
Environment, Air and Radiation Management Administration

2:15 pm  Break

2:30 pm  Workgroup Breakout Sessions (2.5 hours) (suggested focus on topics  
1-3 below)  
(see the accompanying breakout session chart for assignments &  
location)

- Emissions from Space Heating (liquid fuels, #2, #4, #6, bio-heat, LSD, ULS)  
- Emissions from Space Heating with Biomass/Wood  
- Non-road Mobile Source Emissions  
- On-road Mobile Source Emissions  
- Emissions on High Electricity Demand Days  
- Emissions from Agricultural/Ammonia Sources
Agenda for Breakout Sessions:

A. Speaker to present background—status of emission estimates, what projects are ongoing, some issues will be identified in advance in the white paper.
B. Leader to pose questions to participants and coordinate responses
C. Work group to prepare presentation to address the questions and define proposed studies/actions to improve the emission estimates

To Be Addressed by Each Group:

1. Identify the needs that existing emission estimates fail to meet in this category.
2. Characterize current emissions estimates and identify current data gaps such as emissions profiles (including speciation), spatial distribution, activity patterns and others.
3. Identify changes in fuels, technologies and use patterns that are anticipated in the short (3-5 years) - and long-term (7 years or more) and the data needs they will create.
4. Identify the tools and techniques available to help improve the emissions estimates.
5. Identify specific studies or actions that should be undertaken to improve the emission estimates for the northeast and mid-Atlantic region.

5:30 pm Reception in the Lodge

Thursday, November 13

7:30 am Continental Breakfast

8:30 am Progress Reports from Workgroups on Unmet Needs (items 1-3)
(10 minutes for each group)
Workgroup Leads

9:30 am Continued Workgroup Breakout Session (suggested focus on items 4-5)
(As above, 2.5 hours)

12:00 pm Courtyard Lunch Buffet (provided, 1 hour)

1:00 pm Reports from Breakout Workgroups on Recommended Approach (items 4-5)
(15 minutes for each group)
Workgroup Leads
3:00 pm  Workshop Conclusion—Summary, Next Steps  
Bill Pennell, NARSTO; Susan Wierman, MARAMA; Praveen Amar, NESCAUM; Ellen Burkhard, NYSERDA

3:30 pm  Optional Field Trip - High Efficiency Wood Boiler Field Trip (limited space)

Follow-up actions for workshop organizers:

3:30 pm  Confer and Develop Summary of Workshop  
Organizers and Workgroup Leads

5:00 pm  Adjourn
Appendix C
Session Leaders and Contributing Authors

1  On-road Mobile Source Emissions
   H. Oliver Gao, Cornell University
   Dick Gibbs, NYSERDA

2  Emissions from Non-road Mobile Sources
   Barry Liebowitz, NYSERDA
   Tim Hansen, Southern Research Institute

3  Emissions on High Electricity Demand Days
   Chris Salmi, New Jersey Department of Environmental Protection
   Rob Sliwinski, New York State Department of Environmental Conservation
   Sandi Meier, NYSERDA

4  Emissions from Space Heating with Liquid Fuels
   Carter Strickland, New York City Mayor’s Office of Sustainability
   John Graham, NESCAUM

5  Emissions from Space Heating with Biomass
   Ellen Burkhard, NYSERDA
   Lisa Rector, NESCAUM
   Paul Miller, NESCAUM

6  Agricultural Ammonia Emissions
   Julie McDill, MARAMA
   Praveen Amar, NESCAUM
# Appendix D
## Workshop Participants

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Footnotes - Key to Participation in Breakout Sessions

1 On-road Mobile
2 Non-road Mobile
3 High Electric Demand Days
4 Space Heating with Liquid Fuels
5 Space Heating with Biomass
6 Agricultural Ammonia
Appendix E
Workshop Evaluation by Participants

Number of Attendees: 80

1. Please rate the meeting facilities and arrangements (check one) (42 responses) (4.4 avg.)

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<td>4 (19)</td>
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Comments:
- The room was cold. (6)
- Nice hotel, meeting rooms, and friendly staff. (5)
- Good location/support.
- Good acoustics/spaces.
- Excellent food. (2)
- Very well organized.

2. What was the most important thing you learned at this meeting? (42 responses)

- Exchange of ideas.
- Big picture across sectors.
- New contacts.
- How much we don’t know.
- Found it informative to understand issues and possible path forward.
- The importance of HEDD oil usage and emissions on local health impacts, such that it was suggested that HEDD inventories be the baseline for SIPs.
- How universal the problem is among states of Emergency Generators: how many there are, where they are and how often they operate.
- The NEI looks at the average summer day rather than the peak days.
- New York ISO information quite interesting; especially that many gas fired turbines in New York City operate on oil on HEDD’s.
- Unit operating restrictions in New York City to maintain system reliability.
- The smoke issue of residual oil in urban areas and the interest of New York City.
- New York city has lots of space heating with #6 oil.
- Hearing about work done by New York and NESCAUM.
- The role of reliability relies on the operation of oil use in the local pockets.
- Health effects concern re: Ni & Vanadium.
- Public Health consideration needs to be incorporated into decision making.
- Importance of near-source emissions—OWB, HDD.
- Should also look at ultra-fine particles from policy perspective.
- Collaborators for future research.
- The amount of work going on outside of regulatory use and how can they be used.
- The common features of emission estimation for all the sources discussed.
- The area I work in is not the only area where new information is needed to enhance inventory.
- Concurrent efforts need to coalesce.
- Emission estimates used for regulatory process versus research have opposite goals and sometimes do not have necessarily mutual ends.
- Consultation
Information on scientific studies that other participants were involved with.
Other states/entities needs for inventory improvement.

That all categories have high levels of uncertainty.
There are a lot of ways to improve the estimates.
Emission estimates are fraught with data gaps and the need for additional research is great.
Regulators view of the limitations that exist with in the NEI.
NEI and IPM EGU inventory deficiencies.
Just how much improvements are possible if we are willing to put the effort into it.
Opportunities to use a typical data source to improve data used in air quality management.
Emissions estimates from different fields need to improve, but will need different tools.
Emissions estimates methods and development strategy.

There is a lot of information collected that could assist in refining on-road inventories.
MOVES issues – training, input data requirements, etc. Vehicle miles traveled data for MOVES vehicle type. (2)
The complexity of non-road emission estimates and the paucity of available data plus difficulties in collecting and organizing it.
Inventory tools need to be specific to the question being asked (e.g. regional on-road emissions vs. intersections level).
Non-road breakout session-NYSDEC using non-road for non-road sector with respect to general conformity for the entire state.
Importance of modeling to link tailpipe and ambient emissions – how this could be useful outside of the research domain.

Regional effort offsets limited resources states have.
The SIP modeling does not use or address spatial distribution of emissions below the country level.

More information regarding Austrian Biomass Activities
Biomass- state of the art wood combustion in Europe.
Tools and techniques available to help improve emissions estimate for biomass and non-road sources.
Importance of residential heating in Emission Inventory.
The impact of wood burning on air quality.

3. What follow up action will you pursue? (39 responses)

MARAMA should coordinate with NESCAUM & EPA on MOVES Training and customizing NONROAD for 2008.
Training states/transitioning states to MOVES.
Formulating NYSERDA Clean Diesel Program for the future.
Coordinate with our transportation planning department to work on preparing local driving cycles, VMT distribution, etc.
Petition other states to determine present tools/methodologies used to develop non-road emissions inventories.
Exchange/collaborate with NYDEC and FHWA.
Work with NYSERDA to mine existing electronic transportation data.
Exploring the policy-level screening; tools discussed at the breakout with others agencies in the region (i.e. MPO’s).
Document and inventory retrofits on active and upcoming department projects.
Write-up on-road recommendations as continuation of White Paper.

Work with NYDEC to evaluate HEDD Emissions into CMAQ.
Consideration to change Air Quality Planning efforts (other than attainment demonstrations) to a high emission day from a typical day.
Search for background data sources on characteristics of residual oil fired systems – efficiency, load
factors, controls.

- Contact HEDD participants regarding USEPA/OAQPS-OAP IPM sensitivity modeling using day-specific, hour-specific emission – translate to HEDD.
- Look into the data that NYSERDA has related to DR.
- Think about the programs targeted towards increasing reliability in local pockets and how to measure the value of that.
- On a different matter, follow up with policy staff at RTP working on new implementation rule 2008, 0.075PM ozone standard about tons per typical summer day vs. tons per HEDD issue.
- Discuss within the agency ways to utilize public health tracking/surveillance to investigate health outcomes as leverage for better data sources (e.g: use EPHT to look at VMT & HEDD).
- Look for priority setting for future projections and for translating to human exposure.
- Advocate for community level assessment of emissions.
- Upgrade MD NH$_3$ Inventory.
- Write reports on ammonia.
- I participated in the ammonia group, but I believe our group could improve our “report-out” if we continue the discussion over the coming few months.
- Follow up as collaboration for population/activity studies.
- Clearinghouse documenting local/regional emissions estimate improvements to facilitate data exchange (non-road and biomass).
- Potential collaboration with ambient measurements.
- At upcoming ambient monitoring projects, think more during the planning stage about how these measurements can integrate with modeling and SIP issues.
- Wood combustion – Find out who in/out can pursue path forward.
- Continue to share information and updates re: biomass combustion with other “breakout session” members.
- Implementation of some of the ideas that were suggested.
- Establish contacts on this issue with members of the workgroup and keep up with developments on the matter.
- Follow-up with team leads to make sure they have captured my needs.
- For the regional effort, rank the importance of the topics.
- Discuss study results with experts who participated in the breakout. Share information.
- Get better emissions guidance from EPA.
- Fold some of this information into the NEI.
- Actions will be driven by my states.
- Review information that comes out from this meeting.
- Await and read the recommendations when they come out.
- Wait for presentations to be sent.
- Don’t know – this was more of a learning experience as our agency deals mainly with point sources which were not addressed.

4. How useful will the recommendations developed at this workshop be to your agency? (1= of little value; 5= very valuable. (40 responses) (3.7 avg.)

1 (0) 2 (2) 3 (15) 4 (17) 5 (6)

**Recommendations**

- It is highly dependent on actions that result from recommendations.
- The useful may be higher once the final notes are summarized and circulated.
- It depends on how important our planning (modeling) group considers this information. Will forward presentations to them.
- It depends. My agency is only interested in Mobile Source Emissions.
5. **How valuable were the following breakout sessions to you?**
   (1 = of little value; 5 = very valuable) (41 responses)

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<td>4</td>
<td>5</td>
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6. **What was the most valuable about the breakouts?** (38 responses)

- I felt like we moved some of the issues forward a little bit; we had a good discussion and some good follow-up proposals. (3)
- Got some good ideas for research and collaborations. (2)
- Detailed discussion and various areas that need improvement. (2)
- The ability to hear from and communicate with variety; generator (NRG), ISO (NY), NYSERG, environmentalists about an issue. (2)
- The presentations were helpful. It was good to get people from different states and backgrounds in the same room. It encouraged everyone to think outside the box. (2)
- The cross-talk among members of my workgroup was exceptionally good. 2
- The ability to hear multiple perspectives in a round table type of setting. (2)
- Understanding the perceptions and perspectives of such a wide group. (2)
- Learning other states’ experiences.
- Learning about other approaches and initiatives related to biomass combustion.
- Opening the lines of communication; realization of the need to look at things regionally and tools to support that—not “national” tools.
- Forum for discussions about uncertainty and developing recommendations to improve estimates.
- Connecting with intellectual resources in the region.
- There was a clear delineation on the needs of the regulatory process; what’s good enough in relation to additional more complex work being suggested.
- Different perspectives, particularity with respect to industry’s views.
- An opportunity to speak in person in depth.
- Better understanding of cross cutting uses for emissions inventory-regional, local project.
- Intense engagement in a small group regarding a topic directly related to my present job.
- Provides a good discussion and exchange of ideas/experiences.
- Helped me to understand more uses for emission inventories than those I typically deal with and the different scales involved.
- The detailed discussions within the session. The reports from the other sessions were informative, but unsure how to use it to improve my inventory.
- Good discussion, change of opinion.

- Networking/discussion with counterparts in other states and New York City agencies with respect to non-road emission estimates and retrofit efforts.
- Picking Gene Tierney’s brain on MOVES.
- Dick Gibbs did a good job of facilitating the group’s objectives.
- Specific/specialized discussions on mobile source emission issues.
- Able to identify data improvement needs for MOVES model.

- HEDD meeting. Appreciation for limitations in characterizing non-CEM monitored energy sources.
- Learning how limited IPM is for local/states during HEDD episodes.

- Hearing about European designs of biomass combustors.
7. What did you like the least about the breakouts? (23 responses)

- Discussions sometimes lost focus. (3)
- Should provide opportunity to be in more than one session. (3)
- The group was too small or rather there were not enough representatives from outside New York State. It would have been good to have an EPA representative.
- Interaction between different groups.
- Too different discussions to set priorities on opportunities.
- Mix of people.
- The talk given by Ken Demerjian did not strike me as that pertinent in improving Emissions estimates.
- Timing (3): Late day schedule on first day. Time flew by too quickly. Could have been longer.
- Very esoteric for my needs but I was here mainly to learn and offer results for upcoming EPA sensitivity modeling.
- Several of the key people could only participate for the first day.
- Facilitation.
- Sometimes discussions were dominated by one or two people.
- We ran out of time; but any longer may have been tedious.
- The Thursday morning report out didn’t seem to add much to the discussions.
- Initial presentations on Day 1 were given too many slides.
- Next steps/solutions were not within scope of charge - understandably so.

8. How valuable to you were the presentations by the opening speakers? (1= of little value; 5= very valuable) (39 responses)

Opening Presentations

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9. Which of those presentations were most valuable? (33 responses)

- Thomas Matte – Intra-urban Pollution Gradients and Public Health Impacts (10)
- Gene Tierney – Mobile Source Developments and Issues (MOVES Update) (10)

All of the presentations were valuable. (7) No presentation stands out among the plenary talks. They each were a good overview of this topic area. The opening presentations were all quite good, but time may have been better spent in various “breakout sessions”. The breadth of experience provided by these speakers was a good education in terms of understanding needs/tools.

- Praveen Amar – Role of Ammonia, Status of Ammonia Emissions Estimates and Prospects for Improvements (6)
- Jared Snyder – Why We Need a Regional Approach: Policy Perspectives (4)
- Janet Joseph – Emerging Trends in Energy Technology and Fuels and Potential Environmental Implications (4)
- Susan Wierman – Regional Air Quality and Emissions Overview and Charge to the Work Groups (Major Themes, Process) (3)
- Roy Huntley – Transitioning from the National Emissions Inventory to the Emissions Inventory System (3)
- Tad Aburn – Emission Estimates Needs for the Next Round of Modeling (2)
10. Was an appropriate amount of time allotted to the various sessions, including questions and discussion, and other items on the agenda? (37 responses)

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Comments:
- We had enough time based on our limited expertise.
- The NH₃ group could have used another hour to finalize our recommendations.
- More time needed for questions.

11. Did this meeting meet your expectations? (39 responses)

Not At All (0)  No (0)  Somewhat (4)  Yes (26)  Better than Expected (9)

If not yes, please explain why:
- I was hopeful that we had more information resources available than what I was already aware of - but these weren’t identified.
- Needed greater discussion of state experience; a larger forum wherein each state discusses their approach to an emissions challenge.
- Since we aren’t part of NYSERDA, some discussions were only marginally useful.

12. Do you have any other comments or recommendations for the organizers? (16 responses)

- Thanks. (2)
- Thanks for the opportunity to work with inventory counterparts from across the NE/MA!
- A follow-up meeting to gauge progress and discuss new developments. (2)
- Post or email presentations, summary presentations and any other “supplemental” information that may have been provided by attendees.
- I hope that there will be a coordinated way of encouraging workshop participants to continue to collaborate.
- Define what assistance states need to get their inventories completed.
- Good try to pull together diagram, group and viewpoints.
- See if more information could be made available in advance of the breakout session.
- Perhaps include more policy makers to give insight as to what emissions data would be most powerful in creating policy change.
- It may have been good to have each participant attend two different “breakout sessions”. (1 on 1st day, another on day 2). This would have allowed additional opinions and ideas to be heard. (Although, this may have required another few hours of time in each “breakout”).
- I like the set-up with break out sessions and plenary sessions.
- The workshop was well organized.
- Angela was fabulous!