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Wood Biomass for Heat & Power
Addressing Public Health Impacts

SUMMARY OF A 2011 SYMPOSIUM

University of Massachusetts
UMASS Lowell
Learning with Purpose

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Sustainable Production

Wood Biomass for Heat & Power: Addressing Public Health Impacts

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About this Report

This report provides a comprehensive summary of the information and discussion at a day-long science policy symposium, "Wood Biomass for Heat and Power: Addressing Public Health Impacts," held November 7, 2011 at the Massachusetts Medical Society in Waltham, Massachusetts. It also includes recommendations developed by the University of Massachusetts Lowell's Lowell Center for Sustainable Production for broad policy and program changes which are aligned with action steps generated by Symposium participants. The report describes the most recent science on health risks associated with exposure to woodsmoke. Its suggested policy and practice changes reflect collaborative work by the range of organizations across Northeast states engaged in decisions about wood biomass combustion at the industrial, commercial, institutional and electricity generating scales.

The authors have made every effort to accurately describe the content of the Symposium and to structure the report so that it is useful to participants and to people who were not in attendance. Views expressed in this report are opinions of the authors, presenters and other Symposium participants and do not necessarily reflect the position of the organizations that provided financial support for the meeting: The Heinz Endowments and the New York State Research and Development Authority (NYSERDA contract #: 26335).

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Ed Miller, American Lung Association of New England
Lisa Rector, Northeast States for Coordinated Air Use Management
Betsy Rosenfeld, US Department of Health and Human Services
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We are also grateful to the Massachusetts Medical Society which hosted the event, contributing a meeting space conducive to productive work, and staff time that made the logistics flow smoothly. Finally, we deeply appreciate the financial support from the Heinz Endowments and the New York State Research and Development Authority which made possible the extensive preparation for the Symposium, subsidized costs so that participants could attend free of charge, and covered expenses associated with the preparation of this Symposium summary.

Photocredits

Cover: Ellen Burkhard, New York State Energy Research and Development Authority
Back cover: David Parsons, National Renewable Energy Laboratory

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Glossary of Terms Used

AERMOD: U.S. Environmental Protection Agency's preferred computer program for simulating the dispersion of air pollutants (see below) under steady-state conditions. See EPA's website[§] for a more technical description of AERMOD.

Air dispersion modeling: The mathematical simulation of the dispersion of air pollutants in ambient air. Models are used to estimate or to predict the downwind concentration of air pollutants emitted from sources such as industrial facilities or vehicular traffic.

Fine Particulate matter ($PM_{2.5}$): Fine particulate matter (also called fine particles) is a complex mixture of extremely small solid particles, liquid particles or droplets, but not gaseous compounds. The mixture, which includes acids, organic chemicals, metals and soil or dust particles, is found in smoke and haze, and is emitted from combustion sources such as motor vehicles and industrial, commercial and institutional facilities. These particles are defined by their size and are 2.5 microns in diameter and smaller ($PM_{2.5}$).

Distributed energy: The generation of heat or electricity from many small-scale energy sources in the location where it is used, including, for example, the use of institutional boilers or residential wood stoves to heat buildings. This is in contrast to energy generation that is centralized at power plants, and transmitted for use far away from where it is generated.

Electric Generating Units (EGU): Facilities the primary function of which is to generate electricity for the grid. EGUs are not considered ICI units (see below).

Electrostatic precipitator (ESP): According to the U.S. Environmental Protection Agency, an electrostatic precipitator (ESP) is "a particle control device that uses electrical forces to move the particles out of the flowing gas stream and onto collector plates. The ESP places electrical charges on the particles, causing them to be attracted to oppositely-charged metal plates located in the precipitator. The particles are removed from the plates by "rapping" and collected in a hopper located below the unit. The removal efficiencies for ESPs are highly variable; however, for very small particles alone, the removal efficiency is about 99 percent."

Health Impact Assessment (HIA): Health Impact Assessment is a tool for objectively assessing the potential health effects of a project or policy *before* it is built or implemented. HIAs use a structured framework consisting of the following stages: (1) screening, (2) scoping, (3) assessment, (4) recommendations, (5) reporting, and (6) evaluation. Stakeholders are engaged during each stage to identify priority concerns and discuss practical recommendations for mitigating problems.

[§] See: http://www.epa.gov/scram001/dispersion_prefrec.htm.

Industrial, Commercial and Institutional (ICI) combustion units: Industrial combustion units are typically used in manufacturing operations that require steam and/or hot water, and can be fairly large in size. Some industrial combustion units may also burn fuel to create electricity used on site and/or sold to the grid. Commercial units refer to combustion units operating in facilities such as hotels, restaurants, laundries and other commercial/retail establishments to provide heat and hot water. Institutional units provide heat and hot water for facilities such as hospitals, schools and other municipal buildings.

Intake fraction: The ratio of the mass of pollution inhaled to the mass of pollution released.

National Ambient Air Quality Standards (NAAQS): The Clean Air Act requires the EPA to establish National Ambient Air Quality Standards (NAAQS) for six pollutants considered harmful to public health and the environment: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. The standards are intended to be set at the level required to provide an ample margin of safety in protecting public health, including sensitive populations such as children, the elderly, and individuals suffering from respiratory diseases. The NAAQS are regularly revised as the relevant scientific literature evolves.

Receptor modeling: Mathematical simulations used to identify the original source of a pollutant on the basis of measurements of pollutant concentrations at a particular location.

Executive Summary

Background and Symposium Goals

Growing support for renewable energy--as a strategy for reducing environmental impacts and dependence on foreign oil--has stimulated interest in the use of biomass as a fuel source. The U.S. Department of Energy estimates that with aggressive action, biomass energy could replace 30% of current demand for petroleum-based fuels nationwide by 2030.[1] In addition, organizations promoting biomass, including trade associations, have established a collaborative vision calling for 25% of all thermal energy requirements in the Northeast and New York to be met with renewable resources by 2025, 74% of which is to be derived from biomass, including wood and crops such as switch grass.[2] Consistent with these goals, and driven by subsidies tied to the purchase of capital equipment and the relatively low cost of wood, the combustion of wood biomass to heat buildings and generate electricity is proliferating across the Northeast.

Increased wood-burning carries public health risks. Most industrial, commercial and institutional (ICI) and electricity generating units (EGUs) that burn wood emit higher concentrations of hazardous pollutants—such as fine particulate matter, volatile organic compounds, and carbon monoxide—than do boilers burning other fuels, including oil and natural gas.[3] Extensive evidence from air pollution studies, as well as research on woodsmoke specifically, suggests that fine particulates in emissions from wood combustion harm respiratory health and contribute to other health conditions.[4] Gaps in information and inconsistent state requirements for limiting emissions hamper efforts both to characterize risks from ICI/EGU sources and to protect public health. Moreover, public policies do not routinely promote the installation of cleanest-burning units which are widely used in European countries and increasingly available in the U.S. thermal market. These smaller-scale units can dramatically reduce concentrations of pollutants, particularly if state-of-the-art control technologies are used.

"Wood Biomass for Heat & Power: Addressing Public Health Impacts," was held on November 7, 2011 at the Massachusetts Medical Society's headquarters in Waltham, Massachusetts. With guidance from a planning committee, the Lowell Center for Sustainable Production (Lowell Center), based at the University of Massachusetts Lowell, convened and facilitated the Symposium. Representatives from the range of agencies responsible for biomass-related decisions participated, including state and federal departments of health, environment, education, energy and forestry. Other attendees included health

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[1] U.S. Department of Energy. *U.S. Billion Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. Department of Energy.* RD Perlack and BJ Stokes (leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. August 2011. Available at: http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf. Accessed: September 15, 2012.

[2] *Heating the Northeast with Renewable Biomass: A Vision for 2025.* Biomass Thermal Energy Council, Alliance for Green Heat, Maine Pellet Fuels Association, New York Biomass Energy Alliance, Pellet Fuels Institute. April 28, 2010. Available at: https://www.biomassthermal.org/resource/pdfs/heatne_vision_full.pdf. Accessed: September 15, 2012.

[3] Environmental Protection Agency. *AP 42, Fifth Edition*. Available at: http://www.epa.gov/ttnchie1/ap42/. Accessed: September 15, 2012.

[4] Naeher LP, Brauer M, Lipsett M, et al. Woodsmoke health effects: A review, *Inhal Toxicol.* 2007;19(1):67-106.

professionals, scientists, and representatives from the biomass industry and health advocacy organizations. All nine northeast states were represented.

The Symposium Planning Committee set two goals for the meeting:

1. Exchange information about the state of the science regarding health effects from emissions associated with wood biomass combustion, with a focus on industrial, commercial and institutional uses.
2. Discuss policy and program changes that hold promise for enhancing public health protection from non-residential wood combustion.

Following opening remarks, Polly Hoppin, Research Professor and Program Director at the University of Massachusetts, Lowell, introduced Terry Miller, the U.S. Department of Agriculture, Forest Service Director's Field Representative, and Betsy Rosenfeld, Deputy Regional Health Administrator of the U.S. Department of Health and Services, Region 1 (New England). Mr. Miller and Ms. Rosenfeld provided their organizational perspectives on the issue—the importance of keeping the benefits of wood biomass for local economies, energy independence and forest health in mind while also addressing health concerns (Mr. Miller), and the opportunities the Symposium provided for working with diverse partners on complex issues, and for preventing detrimental impacts on public health (Ms. Rosenfeld). The three introductory speakers set a tone for the day of constructive collaboration and identification of common ground.

State of the Science on Woodsmoke Emissions and Health

The first morning session featured presentations by Dr. Doug Dockery (Harvard University School of Public Health), Dr. Michael Brauer (University of British Columbia) and Dr. Anette Kocbach Bølling (Norwegian Institute of Public Health). Their presentations provided an overview of what is known about risks to human health from the primary pollutants in woodsmoke. Key conclusions follow.

Dr. Doug Dockery, "Particulate Matter, Air Toxics & Health: The Big Picture"

- The size of pollutant particles matters. Evidence from epidemiological studies demonstrates that fine particulate air pollution ($PM_{2.5}$), a pollutant generated by combustion of wood and other fuels, is associated with significant health effects. These include a shortening of life expectancy, as well as increases in specific health conditions such as asthma attacks, heart attacks, chronic obstructive pulmonary disease, and a range of other conditions.
- Improved air quality leads to measurable improvements in public health.
- All levels of reductions in air pollution improve public health, even in communities that are already in compliance with the current $PM_{2.5}$ air quality standards established by the Environmental Protection Agency (EPA). (The current annual standard is 15 ug/m^3 and the current 24-hour standard is 35 ug/m^3.)

- EPA is expected to tighten the $PM_{2.5}$ standards in 2012.[5]

Dr. Michael Brauer, "Biomass Emissions, Exposure and Health Effects"

- Location matters. Distributed energy sources, such as boilers in institutions or commercial establishments, create high potential for exposure to emissions. To protect public health, it is important to benchmark any new pollution source against the cleanest technology in the region and to ensure that the siting of new sources takes into consideration proximity to populations.
- There is consistent scientific evidence that biomass combustion emissions contribute to respiratory disease, and growing evidence that these exposures are also associated with systemic inflammation. The primary knowledge gap regarding the health effects of exposure to biomass emissions is cardiovascular impacts. This evidence is minimal, and mixed.

Dr. Anette Kocbach Bølling, "The Toxicity of Woodsmoke Particles Generated Under Different Combustion Conditions"

- Toxicological research suggests that improved combustion conditions reduce health impacts, both because of lower emissions and also lower toxicity due to more complete combustion.
- The toxicity of particles in woodsmoke depends not only on the number or mass of particles emitted, but also on their physicochemical properties.
- The inorganic ash particles emitted from complete combustion conditions appear to be less harmful than the particles generated under conditions of incomplete combustion.
- Knowledge about the relative toxicity of organic carbon and soot particles that result from incomplete combustion is insufficient.
- Small-scale units installed in schools and hospitals are of particular concern. They have variable technologies and limited emission controls, and may expose potentially vulnerable populations, such as students and medical patients.

ICI Wood Burning in the Northeast

The second morning session featured presentations by Mr. Steve Snook (Vermont Department of Environmental Conservation), Dr. Ellen Burkhard (New York State Energy Research and Development Authority (NYSERDA)), and Dr. Phil Hopke (Clarkson University). These presentations provided a bridge between information on the public health hazards of $PM_{2.5}$ and woodsmoke—the focus of the first session—and information on exposures from non-residential wood combustion. Two discussants, Ms. Lisa Rector (Northeast States for Coordinated Air Use Management) and Dr. Mark Utell (University of Rochester Medical Center), reflected on the lessons for medical and policy decision-making from all five morning presentations. Key conclusions follow.

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[5] In June 2012, U.S. EPA issued its proposed revisions to the PM2.5 standard. The proposed rule changes the annual standard from 15 ug/m^3 to 12-13 ug/m^3 and keeps the 24-hour standard the same at 35 ug/m^3.

Mr. Steve Snook, "Air Emissions and Permitting: ICI Biomass Boilers"

- Emissions of pollutants from wood-fueled combustion systems vary widely. Policies should include monitoring or other requirements to ensure that a given unit emits what is promised based on the manufacturer's specifications.
- Air permits are based on regulatory thresholds, and these vary across the Northeast states. As a consequence, smaller institutional units in some Northeast states will not require a permit. Moreover, new systems may be designed to avoid exceeding a regulatory threshold. Consistent stringent permit requirements across the Northeast states could provide greater assurance that the emissions from biomass-fueled boilers will pose fewer risks to health than under current regulations.
- The majority of ICI boiler permits may not require air dispersion modeling (which estimates concentrations of pollutants at certain distances from the combustion source). The main exception is in New Hampshire where air dispersion modeling is required for any unit over 2 MMBtu/hr (heat input). Yet even where modeling is a component of the permit process, it is designed to determine whether or not the facility will exceed the National Ambient Air Quality Standards, which do not address short-term impacts of $PM_{2.5}$ (i.e. high emission events lasting less than 24 hrs).

Dr. Ellen Burkhard, "Energy & Emissions Performance of Commercial Wood Boilers"

- NYSERDA's Research and Development Program demonstrates that advanced wood boilers can achieve:
  - the same combustion efficiency as oil-fired boilers;
  - lower $PM_{2.5}$ emissions than direct-fired wood chip combustion technology, with particles composed primarily of inorganic salts;
  - PM2.5 levels that are similar to oil-fired boilers if post-combustion controls with electrostatic precipitators (ESPs) are used.

Dr. Phil Hopke, "Estimating Public Health Impacts: Air Receptor Modeling & Measurement"

- Prior to April 2011, the U.S. Environmental Protection Agency's AERMOD system for conducting air dispersion modeling may have underestimated the building downwash effect, resulting in underestimations of pollutant concentrations in the vicinity of wood boilers with short stacks, such as those found at schools.
- Receptor modeling has shown that woodsmoke in winter represents a significant source of $PM_{2.5}$.
- Exposures to $PM_{2.5}$ in woodsmoke can be significantly higher in localized areas than they are across the entire community or region.

Ms. Lisa Rector, Discussant

- There is significant lack of understanding of emissions from wood boilers as they are actually operating. Available data on emissions from ICI boilers are from tests taken when emissions are likely the lowest (e.g., at peak load); these data may underestimate more typical levels of emissions.

- State regulation of wood combustion units will impact the type of technology installed. However, few regulatory incentives are in place to encourage the use of the most advanced and clean technologies for institutional-scale boilers.
- In addition to promoting the installation of advanced boiler technology and the use of the most effective emission control technologies, states also need to address the issue of fuel type, as the choice of fuels impacts emissions.

Dr. Mark Utell, Discussant

- Not only do children spend more time outside, where particles are prevalent, but like adults, exercise results in increased deposition of particles in their lungs. If there is woodsmoke pollution in the school yard when children are playing and exercising outside, the deposition of ultra-fine particles in their lungs can be very high.
- It is important to expand beyond what the body of research implies for susceptible populations to also address impacts on the general population.
- The bulk of toxicology research on woodsmoke focuses primarily on respiratory effects, yet it also important to keep in mind potential impacts on the cardiovascular system.

Panel and Roundtable Discussions

The afternoon session began with a panel of representatives from a health advocacy organization, the biomass industry, and those state agencies responsible for policies and programs on biomass energy that have implications for public health: health, environment, energy, and education. Panelists described their organizations' roles with regard to wood biomass combustion, and gave their perspectives on constraints and opportunities for protecting public health.

Several panelists characterized the air quality permitting process as a primary constraint in protecting public health from wood biomass combustion. Smaller scale boilers fly under the regulatory radar in some states. Limited resources can undermine government capacity to ensure compliance and to conduct detailed long-term monitoring studies of environmental and public health impacts in multiple regions of a state. Panelists also noted that the air quality permit process does not include the authority to specify types of fuels or where facilities should be sited, both of which affect air quality. The air quality permitting process also fails to engage the public in discussion of health concerns early enough to influence the design of the project.

Finally, panelists noted inconsistencies in policies within and between states, highlighting the missed opportunities for the promotion of cleanest-burning units by renewable energy initiatives. One panelist challenged government programs to support the development of innovations that have the potential to provide ground-breaking technological advances through reward-based initiatives such as design competitions.

The lack of structures for coordination among agencies with expertise and responsibilities for wood biomass also impede public health protection. In some states, energy agencies are just beginning to systematically invite input by government health experts in their planning processes. Historically, there have been no mechanisms for identifying and weighing tradeoffs among the societal goals pursued by different agencies. Laws that agencies are obligated to implement do not require or otherwise encourage the establishment of common agendas. As a consequence, input by health agencies in energy policy or project decisions comes at the eleventh hour, if at all. Lack of structured opportunities for input and, in the case of health professionals, severe and increasing overload in clinical responsibilities, are responsible for delayed and sometimes unconstructive engagement by the public.

In the context of these constraints, the panelists recommended specific opportunities for collaboration among their organizations. Some of these recommendations were revisited in roundtable discussions after the panel, which identified priority action steps to advance policy and program priorities. A survey conducted one week after the Symposium asked participants to rank the action steps in order of priority across the six roundtable topics. To derive the common goal, guiding principles and recommendations below, Lowell Center staff synthesized the comments made by presenters and panelists, and the action steps proposed in the roundtable discussions that were further prioritized by the survey.

Symposium Recommendations

Common Goal and Guiding Principles

Across the broad array of disciplines, organizations and sectors represented at the Symposium, the majority of participants concurred that policies and programs promoting wood biomass energy should prioritize the protection of public health. A goal of "healthy renewable energy" requires strategies that efficiently reduce dependence on fossil fuels, achieve carbon neutrality, and enhance local economies without increasing risks to public health.

The Lowell Center identified four principles emerging from the Symposium that can guide more specific recommendations to advance healthy renewable energy.

- It is important to fill relevant data gaps, but there is sufficient scientific information to proceed with common-sense actions to reduce exposures to woodsmoke. For example, studies are needed to evaluate the health impacts of peak emissions and emissions from non-optimal boiler operations, particularly for high risk populations. Better information about likely impacts of localized pollution on susceptible populations will inform decisions about boiler siting, choice of boiler technology, and fuel, as well as policy decisions (for example, whether or not to promote the installation of wood boilers in schools). Yet, eliminating incentives for boilers that do not meet the highest emission standards should not wait for research results.
- Though there may be disagreement about the pace of change that is needed or feasible, all policies should drive continual improvements in efficiency and reducing emissions.
- Coordination among agencies within states and across the Northeast is needed to maximize the effectiveness and efficiency of regulations, programs and other tools to protect public health.

- It is important to consider the health and environmental impacts of wood biomass technologies across the life cycle. For example, wood pellets may burn more cleanly than wood fuel, but the manufacturing process uses more energy and is itself polluting. Moreover, health risks from wood biomass energy are not limited to stack emissions from wood-burning units. Workers who make wood chips and pellets are at risk of accidental injury as well as health impacts associated with wood dust, molds and endotoxins. On the other hand, improvements in local economies associated with wood biomass activities can carry health benefits. Moreover, forestry practices can have both positive and negative implications for forest ecosystem health and climate change. An examination of the full life-cycle supports a more complete consideration of trade-offs among all of the impacts.

Recommendations and Priority Action Steps

Informed by the presentations, panel, roundtables and plenary discussions, the Lowell Center generated five broad recommendations, which align with the priority action steps proposed by the roundtables, described below.

1. Constructively engage the public in wood biomass decisions, providing opportunities for full participation in project and policy planning, including providing and considering relevant data, weighing trade-offs, and proposing solutions.
2. Prioritize public health in wood biomass decision-making across the Northeast. Public health implications need to be considered early in the energy planning process, and health maximized while still respecting other important societal goals, such as energy efficiency, carbon neutrality, sustainable forestry practices, reduced dependence on fossil fuels and economic revitalization.
3. Promote a better understanding and consideration of the health impacts on susceptible and vulnerable populations, as well as measures to prevent or reduce exposures to individuals and communities. Particular attention should be paid to both the risks from localized peak exposures and the installation of wood boilers in schools.
4. Incentivize and reward only high-efficiency, clean, wood-fired combustion, with consistent standards across the Northeast, focusing not only on technologies but also on outcomes.
5. Fill gaps in existing air quality regulation and air quality monitoring capacity, including lack of regulatory scrutiny of smaller ICI units in some states. Consider other regulatory measures to protect public health and discourage all but the cleanest-burning wood biomass units.

In roundtable discussions, Symposium participants discussed six broad topics: (1) Encouraging Cleanest-Burning Combustion Technologies; (2) Regulatory Programs, Policies and Tools for ICI Wood Combustion; (3) Guidance and Educational Materials; (4) Filling Policy-Relevant Research Gaps; (5) Public Health Engagement in Energy Decision-Making; and (6) Public Health and Large-Scale Wood Biomass Combustion. The roundtables recommended over twenty action steps. Results from the Symposium follow-up survey indicated particularly strong support for the following:

1. Formally integrate health into energy planning processes by advancing Health Impact Assessment.

2. Develop standardized Health Impact Assessment methods appropriate for the broad range of energy projects.
3. Establish regional specifications for appliances, including efficiency and emission standards.
4. Design and conduct an efficient study of the health effects (or biological markers) to address whether children are being adversely affected by woodsmoke emissions in their schools.
5. Develop a best practices guide for optimizing biomass heating combustion efficiency & performance.
6. Establish regional specification standards for wood biomass fuel (e.g., ash and moisture content etc.).
7. Provide incentives to off-set the up-front costs of new cleanest burning wood biomass heating projects.
8. Improve understanding of the emission rates and ambient air impacts of air toxics associated with large-scale wood biomass combustion, given variability in operating and load characteristics, fuel types and meteorological and topographical conditions.[6]
9. Establish a regional working group to integrate public health into the energy decision-making process.

Respondents most frequently prioritized the first two action steps, urging adoption of health impact assessment as a tool for systematically considering the health implications of energy policy and projects.

Conclusion

The reviews of the state of the science by leading researchers at the Symposium clearly established the public health hazards of the proliferation of wood combustion as a source of heat and power. Priorities identified by Symposium participants comprise an agenda for action by a range of constituencies that would fill the research gaps, and take steps now—given inherent uncertainty in the science—to prioritize the protection of public health as wood biomass and other renewable energy initiatives unfold. But beyond the content summarized in this report, the Symposium fostered communication across sectors and disciplines, enabling people who have historically not worked together to connect, identify common ground, and build relationships. In the months since the Symposium, some participating organizations have begun to capitalize on these relationships, exchanging information and strategies. With the publication of this report, the Lowell Center encourages participants and their colleagues to systematically revisit the recommendations they have the potential to advance, and to identify opportunities to work together—across agencies, across sectors and across states—to implement those recommendations that need action by multiple parties. The Lowell Center looks forward to continuing to collaborate with Northeast partners to advance policies, programs and practices that will elevate health in discussions and action on wood biomass combustion, protect public health, and more broadly, advance the common vision of healthy renewable energy.

[6] Though the roundtable group that generated this action step was charged with focusing on large-scale biomass facilities, plenary discussion over the course of the day suggested broad support for this recommendation across all scales.

Preface

Background

Growing support for renewable energy--as a strategy for reducing environmental impacts and dependence on foreign oil--has stimulated interest in the use of biomass as a fuel source. According to recent analyses by the U.S. Energy Information Administration, electricity generation from biomass is forecast to increase nearly fourfold from 2010 to 2035—driven in large part by state-level Renewable Portfolio Standards as well as favorable economies in regions with significant forestry residues.[1] The U.S. Department of Energy estimates that with aggressive action, biomass energy could replace 30% of current demand for petroleum-based fuels nationwide by 2030.[2] In addition, biomass organizations, including trade associations, have called for 25% of all thermal energy requirements in the Northeast and New York to be met with renewable resources by 2025, with 74% to be derived from biomass, including wood and crops such as switch grass.[3]

Consistent with these goals, the combustion of wood biomass to generate electricity is proliferating across the Northeast.[4] In Maine, 20% of the state's total electrical power generation—renewable and non-renewable—was derived from wood-based fuels in 2010.[5] In 2010, New Hampshire and Vermont derived roughly 5% and 7% of their power from wood respectively, while other Northeast states are below 1%.[6]

Burning wood for heat is also gaining momentum. Both private and public investment in wood-fired heating is growing.[7] Lured by low operating costs, schools, colleges/universities, prisons, and hospitals are switching from fuel oil to biomass, especially wood. Based on energy output, the cost of wood for

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[1] U.S. Energy Information Administration. EIA projects U.S. Non- Hydro renewable Power Generation Increases, Lead by Wind and Biomass. February 12, 2012. Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=5170#. Accessed April 15, 2012.

[2] U.S. Department of Energy. *U.S. Billion Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. Department of Energy.* RD Perlack and BJ Stokes (leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. August 2011. Available at: http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf. Accessed: September 15, 2012.

[3] *Heating the Northeast with Renewable Biomass: A Vision for 2025*. Biomass Thermal Energy Council, Alliance for Green Heat, Maine Pellet Fuels Association, et al. April 28, 2010. Available at: http://www.biomassthermal.org/resource/pdfs/heatne_vision_full.pdf. Accessed: January 23, 2012.

[4] Energy Information Administration. *Renewable Potential Maps.* Accessed: January 15, 2011. Available at: http://www.eia.doe.gov/emeu/reps/rpmap/rp_contents.html.

[5] U.S. Energy Information Administration. Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Available at: http://www.eia.gov/electricity/data/state/. Accessed August 15, 2012.

[6] U.S. Energy Information Administration. Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Available at: http://www.eia.gov/electricity/data/state/. Accessed August 15, 2012.

[7] Bergman R and J Zerbe. *Primer on wood biomass for energy*. United States Department of Agriculture, State and Private Forestry Technology Marketing Unit. May 26, 2004. Available at: http://www.fpl.fs.fed.us/documnts/tmu/biomass_energy/primer_on_wood_biomass_for_energy.pdf. Accessed: April 15, 2012.

these small institutional combustion units can be less than half the cost of fuel oil.[8] Financial incentives such as state-based Fuels for Schools programs funded by the U.S. Forest Service offset capital costs and help drive the change-out of oil boilers for wood-fueled heating systems.

Many wood burning industrial, commercial and institutional (ICI) and electricity generating units (EGUs) emit higher concentrations of hazardous pollutants—such as fine particulate matter, volatile organic compounds, and carbon monoxide—than do boilers burning other fuels, including oil and natural gas.[9] Extensive evidence from air pollution studies, as well as research on woodsmoke specifically, suggests that fine particulates in emissions from ICI/EGU wood combustion can harm respiratory health and contribute to other health conditions.[10]

In the Northeast, anticipated growth in the use of wood biomass for heat and power could lead to hundreds of new wood combustion sources close to population centers in which some residents are disproportionately susceptible to a range of health problems, compounding health risks from exposure to existing residential woodsmoke. Yet estimates of actual exposure concentrations from the different types of ICI/EGU wood combustion units are lacking. Gaps in information and inconsistent state requirements for limiting emissions hamper efforts to characterize risks and protect public health.

Despite the hazards of woodsmoke and likely exposures, the public health impacts of ICI/EGU wood combustion have been largely absent in policy debates. Advocates have challenged and scientists have examined the sustainability of large-scale biomass proliferation and its impact on carbon releases. Yet with the exception of eleventh hour local-level concerns about facility siting, health concerns do not surface. The situation is similar for smaller-scale units installed in institutions like schools and hospitals. Moreover, public policy does not routinely provide incentives for cleanest-burning thermal units which are widely used in other countries, available in the U.S. market, and can dramatically reduce concentrations of pollutants.

Symposium Planning

Review of relevant scientific literature and analysis of state and federal policies by researchers at the Lowell Center for Sustainable Production (Lowell Center), University of Massachusetts, Lowell, identified a pressing need for the systematic consideration of public health impacts by projects, programs and policies promoting biomass energy at the ICI/EGU scales. [11] This research also uncovered a range of opportunities for addressing public health concerns while respecting other societal priorities, including economic revitalization, forest health and environmental stewardship.

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[8] Biomass Energy Resource Center. *Benefits for Schools and Communities.* Accessed October 15, 2010. Available at: http://www.biomasscenter.org. Accessed: April 15, 2012.

[9] Environmental Protection Agency. *AP 42, Fifth Edition*. Available at: http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s06.pdf. Accessed: September 15, 2012.

[10] Naeher LP, Brauer M, Lipsett M, et al. Woodsmoke health effects: A review. *Inhal Toxicol* 2007;19(1):67-106.

[11] The research was conducted by faculty and staff at the University's Lowell Center for Sustainable Production. The Lowell Center conducts research and analysis, and convenes leaders across sectors and disciplines to craft solutions to problems at the intersection of health, environment and economy.

Drawing on the background research, the Lowell Center convened a planning committee to help design a day-long science policy symposium to explore the state of the science on public health impacts of wood biomass, and to identify steps for elevating health in wood biomass decisions and protecting public health. The Planning Committee—comprised of leading air pollution researchers, federal and state agency officials, as well as medical society and health advocacy leaders—met over the course of several months to provide feedback on proposed Symposium goals, agenda, and speakers. The Heinz Endowments and the New York State Energy Research and Development Authority (NYSERDA) provided the funds to prepare for and convene the meeting.

Symposium Goals

"Wood Biomass for Heat & Power: Addressing Public Health Impacts" was held on November 7, 2011 at the Massachusetts Medical Society's headquarters in Waltham, Massachusetts. It was convened and facilitated by the Lowell Center. Representatives from the range of agencies responsible for biomass-related decisions participated, including state and federal departments of health, environment, education, energy, and forestry. Other attendees included health professionals, scientists, and representatives from the biomass industry and health advocacy organizations. (See Appendix A for list of attendees.) All nine Northeast states were represented.

The Symposium Planning Committee set two goals for the meeting:

1. Exchange information about the state of the science regarding health effects from emissions associated with wood biomass combustion, with a focus on institutional, commercial and industrial scale uses.
2. Discuss policy and program changes that hold promise for protecting public health from non-residential wood combustion.

The Symposium included presentations, responses by discussants and participants, panel discussions, and roundtable break-out groups charged with identifying priority action steps. (See Appendix B for the Symposium agenda). Section 1 of this report provides highlights from introductory remarks by representatives of the U.S. Forest Service and the U.S. Department of Health and Human Services, which established the context for the day. Section 2 summarizes the first plenary presentations which reviewed the state of the science on health effects associated with emissions from wood biomass combustion. Section 3 summarizes the second plenary, which provided overviews of the regulatory structure for ICI/EGU wood combustion units in the Northeast, and of what is known and not known about emissions. Section 4 summarizes the afternoon panel discussion, which explored organizational constraints and perceived opportunities for elevating health in renewable energy decision-making among a range of government and non-government organizations. Section 5 reviews the roundtable discussions on six priority topics. Section 6 concludes the report with a synthesis of ideas for elevating health and enhancing public health protection in decisions about wood biomass, derived from the Symposium presentations, discussions and follow-up survey.

Section 1. Introductory Remarks: Framing the Issue of Non-Residential Wood Combustion and Public Health

Dr. Polly Hoppin, Research Professor at the University of Massachusetts Lowell and Program Director of the Lowell Center for Sustainable Production (Lowell Center), opened the Symposium. She summarized the background information described in the Preface of this report, and acknowledged the role of Lowell Center staff, Planning Committee and funders in making the Symposium possible.

Dr. Hoppin introduced Terry Miller, representing the U.S. Forest Service and Betsy Rosenfeld, representing the U.S. Department of Health and Human Services (DHHS). Mr. Miller and Ms. Rosenfeld provided institutional perspectives, highlighting the importance of forestry and of health considerations, respectively, in wood biomass decision-making. Their enthusiasm about the their respective fields, the goals of the Symposium, and the potential for the diverse participants to find common ground set a tone of constructive dialogue for the day. Highlights of their remarks follow.

Terry Miller, Director's Field Representative, Forest Service – U.S. Department of Agriculture

Mr. Miller is a forester by training, with expertise in land stewardship, ecosystem and forest management. He oversees Forest Service USDA activities in the six New England states and New York. Mr. Miller began by summarizing the Forest Service's position and activities regarding wood biomass. "Healthy forests, clean water, clean air and the forest products they provide are essential to meeting the needs of society. Woody biomass is one of a suite of benefits and amenities that managed forests can sustainably provide to meet those needs." Mr. Miller's branch of the Forest Service works closely with state foresters, conservation leaders, nonprofit organizations, and local communities interested in maintaining healthy forest ecosystems and habitats. He also helps manage state forest lands, and provides technical advice to private landowners so they can "keep forests as forests."

New England is an important region for forests, and for the Forest Service, boasting the number one, two and number four most densely forested states in the country: Maine (86% forest cover), New Hampshire (78%) and Vermont (76%). With 52.5% forest cover, Massachusetts ranks 15th. Forested land areas in the U.S. have declined 3% since 1980, largely due to commercial and residential development. Ninety-two percent of all forested land in the Northeast is privately owned.

Sustainable forest management makes possible the multiple benefits of forests:

- scenery and places for recreation, solitude and wilderness
- habitat for a wide range of wildlife
- sources of clean and plentiful water
- production of oxygen by photosynthesis, and sequestration of carbon for the long-term in the form of wood fiber
- wood

Mr. Miller then turned to the role of biomass in providing markets for integrated forest products, which he sees as essential for meeting the societal goal of "keeping forests as forests."

> *Selling wood chips or biomass is one of a shrinking range of options that landowners now have to profit financially from their forested land. Biomass makes valuable use of low-grade wood that comes from thinning and uneven aged management, and gives value back to the landowner for doing the right thing. As saw mills and pulp mills have disappeared from our landscape, it has become progressively harder for landowners who want to keep their land in forest cover to afford the cost of doing so. Increasingly, the land held by otherwise conservation-minded families, is being sold or converted to other uses out of economic necessity.*

He closed his remarks with a story about rural School District 58 in Phillips, Maine, which now heats its three schools with wood pellets made at a pellet mill eight miles away. Pellet heating has enabled the district to become independent from oil and has reduced heating costs by 50%. Mr. Miller described the superintendent's perspective on how clean the units burn, relative to the previous oil furnaces: after three months of using the pellet heating system, people in the community were still calling to ask why the heating units were not running, because they were not seeing smoke coming from the stacks. He encouraged Symposium participants to:

> *Keep one eye on the big picture…as we spend this day examining public health effects, [remember] the many demands society has placed on our nation's private forest lands. For many of the thousands of small private woodlot owners, the decision to keep forests as forests is not always an easy one. Technology should be challenged to improve pollution abatement for biomass heating systems and power systems, and address some of the health concerns [that will be raised] today. Yet we should keep our options open.*

Betsy Rosenfeld, Deputy Regional Health Administrator, U.S. Department Health & Human Services, Region 1 (New England)

Ms. Rosenfeld described her role representing the federal public health service community, noting that current U.S. DHHS Secretary Kathleen Sebelius is paying significant attention to environmental public health. At both the national and regional levels, DHHS is working closely with EPA to integrate federal programs and policies focused on health care and public health with those focused on the environment. These efforts are working "to strike the balance between protecting the health of communities, with a strong preventative emphasis, and encouraging technological innovation." DHHS participated in the planning of this Symposium in this spirit: seeking to promote public health in the context of innovation in energy production.

Ms. Rosenfeld emphasized two points. First, she stressed the value of convening diverse partners to work on complex issues. The New England regional office of U.S. DHHS frequently takes this approach. An example of this has been DHHS' role in establishing the New England Asthma Regional Council (ARC), which convenes public health professionals and other stakeholders concerned about asthma, including health insurers, business owners, asthma patients, housing managers, clinicians, and environmental advocates, with a special focus on integrating environmental with clinical approaches. Under the ARC umbrella, diverse partners have worked together to expand insurance coverage for cost-effective environmental interventions for asthma; to retrofit buses to reduce children's diesel exposure; and to establish programs in schools that reduce the environmental triggers of asthma—initiatives that are improving the lives of people with asthma while also constraining costs. She noted that where consensus has not been possible among ARC participants, the process of sharing information and negotiating among differing perspectives has caused people to think about the problem at hand in a different way, laying the groundwork for joint initiatives down the road. This Symposium has great potential to lead to innovative solutions to public health threats while also meeting other important societal goals.

Second, Ms. Rosenfeld reflected on the importance of prevention. While the delivery of medical care is a core focus for the U.S. DHHS (the department is the country's largest health insurer, in charge of both Medicaid and Medicare), DHHS is also a public health agency charged with anticipating risks to public health that require investment now to prevent downstream heath impacts. She highlighted the Affordable Care Act, which not only increases insurance coverage for the U.S. population, but also expands programs that maximize the potential for prevention to reverse rates of chronic disease and reduce costs. She sees DHHS's role at this Symposium to encourage the diverse range of stakeholders represented to anticipate public health issues down the road, and identify opportunities to avert those impacts now.

Ms. Rosenfeld noted that the timing of a discussion about elevating public health in decision-making about institution-scale biomass is ideal because we are still in the early stages of proliferation of the technology.

> *More often than not, we find ourselves 15 or 20 years into investments in a technology, with mounting evidence documenting harm. This Symposium is our opportunity to take a preventive approach from the beginning, so that in 2020, we are not sitting in a room wishing we had been more deliberate and more pro-active about the elements of biomass energy that will create issues for public health if not addressed now. Let us seize the opportunity to identify overlapping interests and to make productive decisions….let us relish this moment where, if we engage in the discussion together with respect and collegiality, with fidelity to our respective interests, but with positional flexibility and willingness to look for overlapping priorities, we may just transcend having that experience, a decade or two down the road, where progress is more difficult and more painful.*

Section 2. State of the Science on Woodsmoke Emissions and Health

Presentations by Dr. Doug Dockery (Harvard University), Dr. Michael Brauer (University of British Columbia) and Dr. Anette Kocbach Bølling (Norwegian Institute of Public Health) provided an overview of the science on the primary pollutants found in woodsmoke that are relevant to human health. Dr. Dockery focused on fine particulates, a primary pollutant of concern in wood biomass combustion emissions, presenting the evidence in the context of current federal standards. Dr. Brauer discussed the epidemiologic evidence, summarizing what is known and not known about the health effects associated with exposure to emissions from wood biomass combustion. Dr. Kocbach Bølling reviewed the relevant toxicological literature, focusing on the physiochemical properties of combustion particles.

Particulate Matter, Air Toxics and Health: The Big Picture
Doug Dockery, Harvard School of Public Health

Recently, there has been substantial national discussion about reducing the burden of federal regulations on the business community. Every year, the Office of Management of Budget (OMB) evaluates and reports back to Congress on the benefits and costs of regulations and unfunded mandates. In 2007, OMB found that the largest estimated benefits of all federal regulations (not just environmental regulations) can be attributed to the reduction in the public's exposure to air pollution, and specifically to a single type of air pollutant—fine particulate matter ($PM_{2.5}$).

It is estimated that the benefits of implementing the Clean Air Act, specifically the standards associated with controlling $PM_{2.5,}$ amount to between $19 billion to $167 billion each year. Costs of implementing the standards are estimated at $7 billion. Thus, the benefits outweigh the costs by 2 to 20 times. These benefits are derived largely from decreases in mortality. However cost savings from reductions in hospital admissions for illnesses associated with $PM_{2.5}$, such as asthma and chronic obstructive pulmonary disease, also contribute to dollars saved.

What is Particulate Matter?

Particulate matter is a complex mixture of extremely small solid particles, liquid particles or droplets, but not gaseous compounds. The mixture includes acids, organic chemicals, metals, and soil or dust particles. Particulate matter is comprised of both coarse and fine particles. A coarse particle is any particle less than 10 microns (PM_{10}) but larger than 2.5 microns in diameter that can be collected on a filter. (For size reference, the diameter of a human hair is ~50-70 microns and beach sand is ~90 microns in diameter). Coarse particle pollution is derived primarily from sources such as wind-blown dust, pollen, and mold that are re-suspended in air. Fine particles are 2.5 microns in diameter and smaller. They are found in smoke and haze, and emitted by combustion sources including motor vehicles and power plants that burn various fuels.

The size of pollutant particles is relevant to their potential to harm health. When inhaled, coarse particles are largely deposited in the upper airways (nasal, pharyngeal, and laryngeal regions). Fine particles are largely deposited in the deep lung (alveolar regions), where they penetrate the blood stream and can have systemic effects.

What is the Evidence of the Impact of Fine Particles on Mortality?

In the mid 1970's, Dr. Dockery and colleagues began the Six Cities Study.[18] This study investigated the effects of air pollution on mortality in random sample of people in six cities across the country. The six cities included two "heavily polluted" cities (Steubenville, OH and St. Louis, MO), two "moderately polluted" cities (Watertown, MA and Harriman, TN), and two "clean cities" (Topeka, KS and Portage, WI). Individuals enrolled in the study were asked about their health status, their smoking history, their occupational history as well as a range of other disease risk factors. The study followed participants or their families for 16 years to ascertain survival information. It found that individuals living in the two "heavily polluted" cities were dying at a faster rate (i.e., years earlier) than those in the two "clean cities". Those living in the "moderately polluted" cities died faster than those in the "clean cities," but more slowly than those in the "heavily polluted cities." After adjusting for a range of risk factors (e.g., age, sex, cigarette smoking, occupation, education and obesity), the study found that life expectancy decreases with increasing concentration of $PM_{2.5}$ in ambient air.

National Ambient Air Quality Standards for $PM_{2.5}$

Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) is required to: (a) identify air pollutants that are anticipated to endanger health, (b) issue air quality criteria which accurately reflect the latest science on public health impacts, (c) set standards to protect health with adequate margins of safety, and (d) routinely review the data every five years. In 1997, EPA established an annual standard of $PM_{2.5}$ of 15 ug/m^3—roughly the same as the level observed in Watertown, MA, one of the "moderately polluted" cities in which study participants died prematurely relative to those living in "clean" cities in the Six Cities Study. [19] In 2006, the daily $PM_{2.5}$ standard was reduced to 35 ug/m^3.[20]

In a 2010 analysis of $PM_{2.5}$ air quality data, EPA found that 62 counties, home to 26% of the U.S. population, are not in compliance with the $PM_{2.5}$ standards. Nine counties in the Northeast (13% of the U.S. population) are not in compliance.[21] [22] These are primarily in the major metropolitan areas of New York, New Jersey and Pennsylvania where industrial and mobile pollution are the primary sources of

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18 Dockery DW, Pope CA, Xiping X, et al. An association between air pollution and mortality in six U.S. cities, *N Engl J Med.* 1993;329:1753.

19 The annual $PM_{2.5}$ standard is met when the annual average of the quarterly mean $PM_{2.5}$ concentrations is less than or equal to 15 µg/m^3 (3-year average).

20 The 24-hour $PM_{2.5}$ standard is met when the 98th percentile value is less than or equal to 35 µg/m^3 (3-year average)

21 See: Schmidt M, Hassett-Sipple B, Rajan P. *PM2.5 Air Quality Analyses. Memorandum to PM NAAQS review docket. EPA-HQ-OAR-2007-0492*. July 22, 2010. Available at: http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_2007_td.html. Accessed: September 15, 2012.

22 In a subsequent 2011 analysis, EPA estimated that all Northeast counties would be in compliance with $PM_{2.5}$ standards. See: Schmidt M. *Air Quality Analyses—Update. Memorandum to PM NAAQS review docket. EPA-HQ-OAR-2007-0492.* April 15, 2011. Available at: http://www.epa.gov/ttnnaaqs/standards/pm/data/Schmidt041511.pdf. Accessed: September 15, 2012.

concern for $PM_{2.5}$ emissions. Residential wood biomass burning plays a large role in other locations that are also out of compliance, such as areas in Montana.

Since $PM_{2.5}$ was first regulated in the U.S. in 1997, ambient levels have steadily decreased in response to increasingly stringent standards under the Clean Air Act. Levels of other criteria air pollutants (PM_{10}, NO_2, SO_2, CO, lead and O_3) have also decreased. Thus, the Clean Air Act has resulted in the majority of U.S. residents being able to breathe air that is substantially cleaner than it was 30 years ago.

Has Cleaner Ambient Air Resulted in Measurable Improvements to Health?

Dr. Dockery and colleagues recently evaluated associations between life expectancy and fine-particulate air pollution in 51 metropolitan areas in the US.[23] They compared data from 1979 to 1982 with matched data for the period 1997 to 2001. Even within the first time period, the study revealed what the earlier Six Cities Study had found: increasing levels of fine particulate air pollution were associated with lower life expectancy. The data two decades later revealed that levels of fine particulate pollution had decreased significantly and that life expectancy had increased across the 51 metropolitan areas.

In addition, the study affirmed the association between lower life expectancy and higher levels of fine particulate air pollution when life expectancy in communities with higher levels of fine particulate pollution was compared with life expectancy in communities with lower levels during the same time period. A decrease of 10 ug/m^3 in the concentration of fine particulate matter was associated with an estimated increase in average life expectancy of 0.6 years. For comparison, life expectancy is estimated to be 6.8 years shorter for the average smoker. If one-fifth of the population are current smokers, the decrease in average life-expectancy would be one-fifth of 6.8 years, or 1.6 years. Compare this to the estimated loss of 0.6 years due to $PM_{2.5}$ air pollution, which affects nearly 100% of the population.

These data suggest that there is no indication of a bright line below which $PM_{2.5}$ concentration will not affect health. The study of the 51 communities suggests that continued improvements in life expectancy are associated with reductions in fine particulate pollution even when they fall below average annual concentrations of 15 ug/m^3. The robustness of the association shows that the corollary is also true: even at levels below 15 ug/m^3, fine particulate pollution is associated with reduced life expectancy.

Consistent with Clean Air Act requirements for regular review of ambient air quality standards to take into account emerging science, EPA has been reviewing new evidence since the annual $PM_{2.5}$ standard was last revised in 2006. Based on this review and recommendation of its Clean Air Science Advisory Committee (CASAC), EPA is expected to lower the current $PM_{2.5}$ standards in 2012. The Agency is considering reducing the annual standard from 15 ug/m^3 to somewhere in the range of 11 - 13 ug/m^3, and reducing the 24-hr standard to 30 ug/m^3.[24]

[23] Pope III CA, Ezzati M, Dockery DW. Fine-particulate air pollution and life expectancy in the United States, *N Engl J Med* 2009; 360:376-386.
[24] In June 2012, U.S. EPA issued its proposed revisions to the PM2.5 standard. The proposed rule changes the annual standard from 15 ug/m^3 to 12-13 ug/m^3 and keeps the 24-hour standard the same at 35 ug/m^3.

Lowering the standards will result in a higher percentage of communities being out of compliance. For example, if the annual $PM_{2.5}$ standard is reduced to 13 ug/m^3 and the 24-hr standard remains the same, an estimated 151 U.S. counties will be out of compliance (43% of the U.S. population), including 19 counties in the Northeast (24% of the Northeast population). If the annual standard is set at 11 ug/m^3 and the 24-hr standard is also reduced to 30 ug/m^3, an estimated 343 U.S. counties, where 73% of the population lives, will be out of compliance, including 53 counties in the Northeast (70% of the Northeast population).[25]

Conclusions

- The size of particles matters. Fine particulate air pollution is associated with significant health effects, including a shortening of life expectancy (the primary focus of this presentation) as well as increases in health conditions such as asthma attacks, heart attacks, chronic obstructive pulmonary disease and a range of other conditions.
- Improved air quality leads to measurable improvements in public health.
- All levels of reductions in air pollution improve public health, even in communities that are already in compliance with the current $PM_{2.5}$ air quality standards.
- EPA is expected to tighten the $PM_{2.5}$ standards in 2012.

Symposium Participant Questions and Comments

Question: *Improvements in life expectancy over the last few decades can be attributed to factors other than air pollution. How are these confounding factors addressed in the air pollution research?*
Response: There are a variety of factors contributing to improvements in life expectancy, which are adjusted for in the analysis of the air pollution research presented. The research found that approximately 16% of the improvement in life expectancy overall can be attributed to the reduction in air pollution. Other significant contributors that have helped to improve life expectancy include factors such as reductions in tobacco smoking, cholesterol control medications, etc.

Comment: EPA's Science Advisory committee for the Office of Children's Health Protection recommended a lowering of the PM2.5 NAAQS as the standard was primarily based on adult studies even though children are more susceptible.

Biomass Emissions, Exposure and Health Effects
Michael Brauer, School of Population and Public Health, University of British Columbia

Depending on the location, variable percentages of fine particle ($PM_{2.5}$) pollution in ambient air are from the burning of wood and other biomass material. The science on health effects associated with $PM_{2.5}$ regardless of the source is relevant to assessing health risks associated with exposure to biomass

[25] Schmidt M, Hasset-Sipple B, Rajan P. *Air Quality Analyses Memorandum to PM NAAQS Review Docket. EPA-HQ-OAR-2007-0492*. July 22, 2010.

combustion. In addition to this broad literature, it is also important to examine the science on exposure to biomass combustion products in particular. This was the focus of Dr. Brauer's presentation.

Putting Biomass Combustion in Context

Most of what is known about links between wood biomass combustion and health is not from studies of pollutants produced by ICI/EGU wood boilers—the focus of this Symposium. Biomass combustion, especially at the electric utility, commercial and institutional scales is rather new. Until very recently, the concentration of populations affected by ICI/EGU facilities has not been large enough to support epidemiologic investigations. Consequently, evidence examining health risks associated with wood biomass combustion is primarily from studies of exposure to residential woodsmoke. Yet this evidence has relevance to the non-residential scales.

There are several important background considerations about biomass combustion that help to frame a review of health impacts from ICI/EGU units:

- Biomass is widely considered an available, inexpensive, and secure fuel. In the Pacific Northwest, as well as other areas of the US, rates of wood burning for residential heating correlates with the costs of other fuels—as the cost of natural gas or heating oil rises, use of biomass for heating increases. Biomass is also being promoted as a renewable, greenhouse-gas neutral fuel. Recent issues of *Science* featured papers supporting these views as well as calling them into question, including raising concerns about health.[26]
- Until recently, there have been minimal advances in emission reduction technology for biomass combustion sources. In contrast, air pollution regulations have helped to spur technology advances for motor vehicle emission controls that have resulted in significant tail-pipe emission reductions—roughly 95% over the last 30 years or so.
- Cold outdoor air tends to stagnate (low wind speed and inversions) in the winter, when wood-burning for heating purposes peaks. These meteorological conditions can increase the local concentration woodsmoke pollution.
- Air quality regulations and management generally focus on health associated with air pollutants by improving overall air quality in regional air-sheds. While this has generally worked, research has shown that specific locations of sources and receptors matter. Research examining the spatial behavior of woodsmoke emissions from individual residential wood combustion sources shows that these emissions can impact air quality 3km - 10km away from the source. Moreover, during cold weather conditions, the plume of woodsmoke concentrates in low lying areas such as river valleys (see Figure 1).
- Proximity to combustion sources affects potential human exposures. This is an obvious connection, but an important concept for understanding health impacts from wood.
- Biomass heating is effective because the source is placed where it is needed. This type of "distributed," rather than "centralized" energy source creates a scenario in which sources of

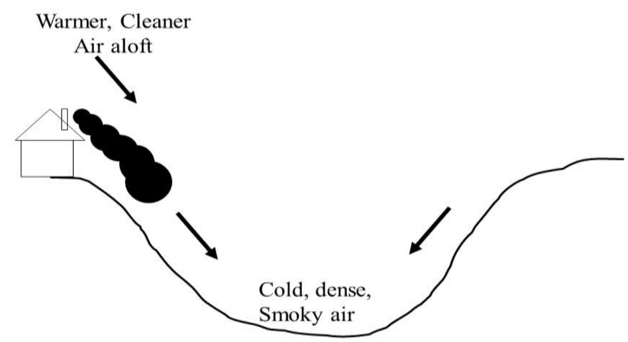
[26] See: Richter DD Jr, Jenkins DH, Karakash JT, et al. Resource policy. Wood energy in America, *Science.* 2009;323(5920):1432-3. Also see subsequent letters to the editor: *Science.* 2009;324.

pollution can be in close proximity to human populations. Thus the intake fraction—the ratio of how much pollution is inhaled versus the overall rate of emission—can be quite high in these circumstances.

Evidence of Human Health Effects from Biomass Combustion

In 2007, a comprehensive literature review on the health effects of wood biomass combustion addressed the primary question: "Do woodsmoke particles pose different levels of health risk compared to other particles in air, such as those from motor vehicle sources?".[27] The review found no evidence in the toxicological or epidemiological literature that fine particles in woodsmoke are less likely to cause respiratory disease than fine particles from other sources. However, the evidence linking cardiovascular effects with woodsmoke exposure is more ambiguous in part because of lack of research. This gap in knowledge is important to fill because the majority of health benefits and cost savings that Dr. Dockery described in his presentation come from improvements in cardiovascular health. Examples of the research to date examining associations between exposure to woodsmoke and cardiovascular effects include:

FIGURE 1: Drainage of Woodsmoke in Valleys During Cold Days



Source: Brauer, M. Biomass Emissions, Exposure and Health Effects. *Wood Biomass for Heat and Power: Addressing Public Health Impacts Symposium.* November 7, 2011.

- Mixed evidence for increases in cardiovascular effects (mortality and cardiac arrest) in communities affected by wildfires.[28]
- Evidence of systemic inflammation among wildland firefighters.[29]
- Mixed evidence of systemic inflammation among volunteers exposed to woodsmoke (i.e., controlled exposure studies).[30]

[27] Naeher LP, Brauer M, Lipsett M, et al. Woodsmoke health effects: a review, *Inhal Toxicol.* 2007;19(1):67-106.
[28] See for example: (1) Dennekamp M, Erbas B, Sim M, et al. Air pollution from bushfires and out of hospital cardiac arrests in Melbourne Australia, *Epidemiology.* 22(1):S53. (2) Henderson SB, Brauer M, Kennedy S, et al. Three measures of forest fire smoke exposure and their association with respiratory and cardiovascular physician visits and hospital admissions, *Epidemiology.* 2009;20(6):S82. (3) Delfino RJ, Brummel S, Wu J, et al. The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003, *Occup Environ Med.* 2009;66(3):189-97.
[29] See for example: Swiston JR, Davidson W, Attridge S, et al. Woodsmoke exposure induces a pulmonary and systemic inflammatory response in firefighters, *Eur Respir J.* 2008;32(1):129-38.
[30] See for example: (1) Sallsten, G Gustafson P, Johansson L, et al. Experimental woodsmoke exposure in humans, *Inhal. Toxicol*. 18(11):855–864. (2) Barregard L, Sällsten G, Gustafson P, et al. Experimental exposure to wood-smoke particles in healthy humans: effects on markers of inflammation, coagulation, and lipid peroxidation, *Inhal Toxicol.* 2006;(11):845-53. (3) Barregard L, Sällsten G, Andersson L, et al. Experimental exposure to woodsmoke:

Dr. Bauer and colleagues continue to develop better models of estimating woodsmoke exposure as well as examining associated health impacts. Recent research using extensive woodsmoke air pollution data in Vancouver, British Columbia explored a range of health effects.[31] The findings include a 30% increased risk of otitis media (middle ear infections) and an 8% increase of bronchiolitis (a respiratory tract infection and leading cause of hospitalizations for children under one year old) among infants and children exposed to heavy woodsmoke pollution compared to those exposed to the lowest levels. The study did not observe increases in risk for some health outcomes that have been observed in studies of traffic pollution, including cardiovascular mortality, incidence of asthma (new onset cases of asthma, not exacerbation of existing disease), or pregnancy outcomes.

Also in British Columbia, researchers recently investigated the impact of an indoor HEPA air filtration device on $PM_{2.5}$ exposures and predictors of cardiovascular morbidity among residents of a community in which woodsmoke is the primary source of fine particulate pollution. In the study, use of a HEPA air filtration system significantly reduced indoor fine particulate pollution associated with woodsmoke, which was in turn linked to both improvements in endothelial function (a measure of blood vessel health) and reduced systemic inflammation.[32] This study adds to the body of evidence that predictors of cardiovascular morbidity can be favorably influenced by reducing indoor $PM_{2.5}$ concentrations associated with woodsmoke.

Conclusions

- Location matters. Distributed energy sources, such as boilers in institutions or establishments, create high potential for exposure to emissions. To protect public health, it is important to benchmark any new pollution source against the cleanest technology in the region and to ensure that the siting of new sources takes into consideration proximity to populations.
- There is consistent evidence that biomass combustion emissions contribute to respiratory disease, and growing evidence that these exposures are also associated with systemic inflammation. The primary knowledge gap regarding the health effects of exposure to biomass emissions is cardiovascular impacts; the evidence is minimal, and mixed.

Symposium Participant Questions and Comments

Question: *Have there been studies on the health impact of indoor air quality associated with woodsmoke?*

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effects on airway inflammation and oxidative stress, *Occup Environ Med.* 2008;65(5):319-24. (4) Allen RW, Carlsten C, Karlen B, et al. An air filter intervention study of oxidative stress, endothelial dysfunction, and inflammation among healthy adults in a woodsmoke-impacted community, *Am J Respi Crit Care Med.* 2011; 183:1222-1230.

[31] See: (1) MacIntyre EA, Karr CJ, Demers P, et al. Exposure to residential air pollution and otitis media during the first two years of life, *Epidemiology.* 2011;22(1):81-9. (2) Karr CJ, Demer PA, Koehoorn MW, et al. Influence of ambient air pollutant sources on clinical encounters for infant bronchiolitis, *Am J Respir Crit Care Med.* 2009;180(10):995-1001. (3) Clark NA, Demers P, Karr C, et al. Effect of early life exposure to air pollution on development of childhood asthma, *Environ Health Perspect.* 2010;188(2):118:284-290.

[32] See: An air filter intervention study of oxidative stress, endothelial dysfunction, and inflammation among healthy adults in a woodsmoke-impacted community, *Am J Respi Crit Care Med.* 2011;183:1222-1230.

Response: Whether the pollution is emitted indoors or outdoors, the vast majority of exposure occurs indoors given that is where people spend most of their time. Depending on building construction, approximately 70% of the fine particulate emitted from a residential wood burning unit infiltrates indoor spaces. In the majority of the residential woodsmoke studies, exposures are primarily assessed indoors.

Question: *Are we using the right metrics to measure health impacts associated with fine particulate pollution when the data are typically composed of annual averages and averages over a 24-hour period?*
Response: When health studies are conducted on woodsmoke-associated fine particulate pollution, a number of more sensitive exposure metrics are used, such as seasonality and variations within a 24-hr period. However, in the regulatory context, only annual and 24-hr standards are used for fine particulate matter. The largest gap for understanding health impacts is not so much the temporal resolution of the data (i.e. should we be examining levels finer than 24-hr averages), but rather spatial resolution. It matters where air pollution monitors are located. However, currently there are no air pollution monitors in locations that we know have some of the highest levels of air pollution. We lack air pollution monitors in more rural areas as well.

Question: *Based on the results on the HEPA-filtration device intervention study, would you recommend that people affected by woodsmoke use such a device?*
Response: Individual-level rather than population-level interventions and recommendations are clearly not the most effective approach to protect public health, especially the most vulnerable among us. However, the research does support air quality improvements with use of a HEPA-filtration system and is a recommended and relatively cost-effective approach (average filtration device $100-200) to protect an individual's health.

The Toxicity of Woodsmoke Particles Generated Under Different Combustion Conditions
Anette Kocbach Bølling, Norwegian Institute of Public Health

Factors Influencing Combustion Conditions

There are several factors that influence the combustion conditions in a wood biomass combustion unit which in turn influence the composition and toxicity of the woodsmoke particles emitted. Primary factors include:

- Type and quality of fuel (e.g., moisture and ash content in logs, chips or pellets)
- Type of combustion technology
- Operating conditions (e.g., load)

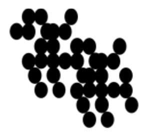
These factors determine how complete the combustion process is by influencing, for example, the oxygen supply and the temperature in the combustion chamber. The completeness of the combustion process determines not only the amount of particles emitted, but also their physical and chemical properties.

Classes of Woodsmoke Particles

Woodsmoke particles can be divided into three classes based on the combustion conditions and their physicochemical properties (see Figure 2):

1. Organic carbon particles that result from air-starved-combustion conditions;
2. Soot particles that result from high-temperature, incomplete combustion conditions (temperature and oxygen supply are better than the conditions that result in primarily emissions organic carbon particles, but not sufficient for complete combustion of organic compounds); and
3. Inorganic ash particles that result from complete combustion conditions.

FIGURE 2: Three Classes of Woodsmoke Combustion Particles

	Organic carbon	**Soot**	**Inorganic ash**
			
Combustion type	Air starved "poor combustion"	High temperature "flaming combustion"	"Complete combustion"
Particle Size	50-600 nm	20-50 nm for single carbon particles	50-125 nm
Solubility	Depends on ageing (i.e. changes in physicochemical properties occurring in the atmosphere)	Insoluble	Soluble
Chemical composition	Organic compounds like hydrocarbons	Elemental carbon and condensed organics	Alkali salts (e.g KCl and K_2SO_4) metals

Source: : Kocbach Bølling A, Pagels J, Yttri KE, Barregard L, et al. Health effects of residential woodsmoke particles: the importance of combustion conditions and physicochemical particle properties, *Part Fibre Toxicol.* 2009;6:29.

Emissions from wood combustion units often contain a mixture of these different classes of combustion particles, yet organic carbon and soot tend to dominate the emissions from conventional combustion systems in which efficient and complete combustion is more difficult to achieve. In advanced combustion systems, such as two-stage or gasification technologies, alkali salts (inorganic ash) are the primary particles emitted.

The three particle classes differ in shape, size, solubility, and composition, which in turn influence their toxicity (Figure 2). As Dr. Dockery's presentation emphasized, size matters. The size of the particles determines the deposition fraction in the lung (e.g. internal dose) as well as the site of deposition. However, the deposition probability and site are also influenced by other physicochemical properties such as a particle's ability to absorb water (hygroscopicity), which is known to differ between the three types of woodsmoke particles. The relative deposition efficiency and site for the three particle classes have not been well characterized. Particles from complete and incomplete combustion conditions in a pellet burner are deposited in the lungs to a lower extent than diesel exhaust particles, but the relative deposition of organic carbon and soot particles has not been determined.[33] The solubility of the particles determines the clearance rate from the lungs, meaning how fast the particles are removed from the lung by the body's normal defense mechanisms. For example, soluble inorganic ash particles are cleared rapidly from the lungs compared to insoluble soot particles. Lastly, the three particle classes vary in chemical composition, which is also important for the biological effects of the particles.

Woodsmoke Particle Toxicology Studies

The toxicity of woodsmoke particles has been studied in a range of model systems:

- Human inhalation studies (i.e. chamber studies) report that woodsmoke exposure can induce various effects including inflammation in the distal airways, increased oxidative stress in the lungs, and also systemic inflammation and blood coagulation.[34]
- Animal inhalation studies using relatively low woodsmoke concentrations—parallel to levels of exposure people may receive in developed countries—report that woodsmoke induces both airway and systemic effects, including decreased lung function, mild airway inflammation, systemic immunotoxicity, and increases in platelet levels.[35]
- A number of cell culture studies support findings in the human inhalation studies and demonstrate that woodsmoke particles can induce both inflammatory and toxic responses in lung cells.[36]

Based on the existing experimental studies, woodsmoke particles do not seem to affect health any less than particles from other combustion sources. Woodsmoke may impact health differently than particles from other sources with respect to affecting different endpoints or inducing different effects on the cellular level, but they do not seem to be less harmful.

The main findings in three studies comparing the inflammatory response and toxicity of woodsmoke particles from different combustion conditions were summarized:

1. The first study compared woodsmoke particles from a modern residential wood stove collected under two different combustion conditions: (a) low oxygen supply or "poor combustion" in

[33] See: Löndahl J, Pagels J, Boman C, et al. Deposition of biomass combustion aerosol particles in the human respiratory tract, *Inhal Toxicol*. 2008; 20(10):923-33.
[34] See for example: (1) Sallsten, G Gustafson P, Johansson L, et al. Experimental woodsmoke exposure in humans, *Inhal. Toxicol*. 18(11):855–864. (2) Barregard L, Sällsten G, Gustafson P, et al. Experimental exposure to wood-smoke particles in healthy humans: effects on markers of inflammation, coagulation, and lipid peroxidation, *Inhal Toxicol.* 2006;(11):845-53. (3) Barregard L, Sällsten G, Andersson L, et al. Experimental exposure to woodsmoke: effects on airway inflammation and oxidative stress, *Occup Environ Med.* 2008;65(5):319-24.
[35] See a review of this literature in: Naeher LP, Brauer M, Lipsett M, et al. Woodsmoke health effects: a review, *Inhal Toxicol*. 2007;19(1):67-106.
[36] See for example: Kocbach A, Namork E, Schwarze PE. Pro-inflammatory potential of woodsmoke and traffic-derived particles in a monocytic cell line, *Toxicology.* 2008;247:123-132.

which the emissions were dominated by organic carbon; and (b) high oxygen supply or "flaming combustion," in which the particles emitted were primarily soot particles. Mice were exposed to emissions from each combustion condition via intratracheal instillation (i.e. injection into the lungs). Two different human cell lines were also exposed. In exposed mice, particles from "poor combustion" were more potent inducers of inflammatory markers than particles from "flaming combustion." These findings were also consistent with results from the human cell line study.[37]

2. The second study investigated the toxicity of inorganic ash particles from "complete combustion" conditions occurring in large biomass combustion plants using various fuels: (a) wood chips, (b) straw, (c) bark and (d) waste wood. The toxicity of the emissions from each of the fuel sources were examined using a human epithelial cell line and also a rat inhalation model. Particles from waste wood and bark combustion induced a release of inflammatory markers in the cell culture study, while none of the particles induced an inflammatory response in the lungs of the rats. The investigators explain the difference in response between the two model systems by the following hypothesis: soluble particles are dissolved and cleared from the lung, but clearance is not possible in the cell culture system. The study also included insoluble particles from coal combustion and soot reference particles called carbon black. Both these insoluble particles induced an inflammatory response in the lungs of the rats after four weeks of exposure.[38]
3. The third study compared the particles emitted from a wide range of combustion conditions from three different types of wood stoves (old, modern and 2-staged) and studied their potential to induce cell death. The findings included:
    - Particles from "complete combustion conditions" (inorganic ash particles), generated from the two-stage wood stove demonstrated the lowest toxicity.
    - Particles from "flaming combustion" conditions (soot particles) induced toxicity at lower concentrations, with similar effects as the reference sample from diesel exhaust.
    - Particles from "poor combustion conditions" were the most toxic. [39]

Several other studies also compared the toxicity of particles from different combustion conditions and came to conclusions supporting the findings listed above. The studies do however have important limitations:

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[37] Danielsen PH, Loft S, Jacobsen NR, et al. Oxidative stress, inflammation, and DNA damage in rats after intratracheal instillation or oral exposure to ambient air and wood smoke particulate matter, *Toxicol Sci.* 2010 Dec;118(2):574-85. Danielsen PH, Møller P, Jensen KA, et al. Oxidative stress, DNA damage, and inflammation induced by ambient air and woodsmoke particulate matter in human A549 and THP-1 cell lines, *Chem Res Toxicol.* 2011;24:168-184.

[38] Bellmann et al in Joikiniemi J, Hytönen K, Tissari J et al. Biomass combustion in residential heating: particulate measurements, sampling, and physicochemcial and toxicological characterisation. ISSN 0786-4728 *Final report of the project 'Biomass-PM' funded by ERA-NET Bioenergy Programme 2007-2008*.;University of Kuopio, Report 1/2008; 2008..

[39] Klippel, N and T Nussbaumer. Health relevance of from wood combustion in comparison to diesel soot. *15th European Biomass Conference and Exhibition.* May 2007. Available at: http://www.verenum.ch/Publikationen/W1612Berlin2007.pdf

- Most of the studies compare only particles from two different combustion conditions, but to say something more general about how the combustion conditions affect particle toxicity it is necessary to compare a wider range of particles in the same biological model system.
- The majority of studies conducted to date are cell culture studies, which cannot account for differences in deposition and clearance in the human lung. These two factors affect human toxicity, but we have limited knowledge about how these processes differ for the various types of woodsmoke particles. Based on their physiochemical properties, the soluble salt particles and the partly soluble organic carbon particles are likely to be cleared more rapidly than the insoluble soot particles.
- It should be kept in mind that, depending on the fuel type, these inorganic ash particles particularly from large biomass combustion plants may also contain high levels of heavy metals. Further studies are necessary for these particles also.

Thus, soluble inorganic ash particles from “complete combustion” conditions seem to be least hazardous for human health, based on findings that they induce the lowest level of response in the toxicological studies, and are cleared most rapidly by the lung.

Considerations for institutional, commercial and industrial-scale wood biomass combustion facilities

When considering the toxicity of particles from ICI/EGU scale facilities, it is important to consider the multiple factors that influence the amount and properties of the particles emitted. Some of these have been discussed earlier. These include (a) the fuel type and quality, (b) the combustion technology, (c) operation conditions, and (d) emission controls/particle removal systems (e.g., cyclones, multi-cyclones, or electrostatic precipitators). These factors not only affect the amount of particles emitted, but also can affect the composition. Ultimately, human toxicity depends on levels of exposure. These levels are determined by ambient concentrations, based on how the particles disperse, and the location of the facility.

The size of ICI-scale facilities varies widely, from small facilities in schools or hospitals, to medium-size district heating units that can supply multiple institutions, businesses and private houses, and finally to large-scale EGU and industrial facilities. There is also a range of combustion technologies and emission controls. The choice of these technologies will to a large extent be influenced by the emission limits and regulations in different countries and states. This makes it very difficult to generalize, yet the following broad themes are important in considering policy and programmatic opportunities to protect public health:

- The control technologies are likely to be more effective per unit of energy in larger facilities. Though larger facilities may have better particle removal systems, however, the total amount of particles emitted likely exceeds that of smaller facilities.
- The physicochemical properties of the emissions from small-scale facilities vary depending on the combustion technology used, and all three particle classes (organic carbon, soot and inorganic ash) may be emitted from these units. With increasing size of the facility, combustion

conditions are likely to improve, leading to higher emissions of inorganic ash and soot, and lower levels of organic carbon particles.

Based on these observations, small-scale facilities installed in schools and hospitals, for example, may be an area of concern. While some of these newer facilities have two-stage gasification systems and highly effective particle removal emission controls, others have direct-fired boiler technology, possibly without particle filtration systems or with emission controls that are far less effective. These are potential high emitters of soot and organic carbon and of concern especially if sited in densely populated areas, and in areas with susceptible and potentially vulnerable populations that are at greater risk of health impacts than the general public.

It is also important to keep in mind that, depending on the fuel quality, emissions from large facilities can contain relatively large amounts of heavy metals like iron, vanadium, cadmium, and arsenic. Heavy metals are known to induce a variety of harmful health effects, including cancer, and these emissions should therefore be carefully monitored.

Conclusions

- Toxicology research suggests that improved combustion conditions may reduce health impacts, both because of lower emissions and also lower toxicity due to more complete combustion.
- The toxicity of particles in woodsmoke depends not only on the number or mass of particles emitted, but also on their physicochemical properties.
- The inorganic ash particles from "complete combustion" appear to be less harmful than the particles from incomplete combustion conditions.
- Knowledge about the relative toxicity of organic carbon and soot particles that result from incomplete combustion conditions is insufficient.
- Small-scale facilities installed in schools and hospitals are of particular concern. They have variable technologies and limited emission controls, and may expose potentially vulnerable populations, such as students and medical patients to harmful pollutants.

Symposium Participant Questions and Comments

Comment: We need to interpret Dr. Kocbach Bølling's results somewhat cautiously as the research presented about the relative toxicity of woodsmoke particles is based primarily on *in vitro* studies and focuses on direct effects on the respiratory system. We have learned from air pollution research focusing on cardiovascular effects that exposure to fine particulate pollution can impart systemic effects. These have not been examined in the research presented. In addition, it is important to note that the research presented only addresses primary emissions as immediately emitted from a source. Particle composition is often very different downwind compared to the emission source because over time, additional contaminants adhere to the particle surface as it moves through air in a given area. As Dr. Brauer stated, "location matters." Health impacts associated with specific particle components depend on where exposure occurs relative to the primary emissions at the source.

Comment: In addition, the chemical composition is likely to change due to oxidation and other chemical processes in the atmosphere. Apparently, these processes may be accelerated on the organic carbon particles as compared to soot particles, but there is need for more research to clarify the extent of the atmospheric modification of woodsmoke particles and the implications for particle toxicity.

Section 3. ICI Wood Burning in the Northeast

Presentations by Mr. Steve Snook (Vermont Department of Environmental Conservation), Dr. Ellen Burkhard (New York State Energy Research Development Authority (NYSERDA), and Dr. Phil Hopke (Clarkson University) provided a bridge between information on hazards of exposure to $PM_{2.5}$, and woodsmoke in particular—the focus of the first session—and exposures from ICI scale wood combustion. Mr. Snook gave an overview of ICI wood boilers from a regulatory perspective, including general definitions, emissions characterization as well as regulations affecting non-residential wood combustion, and variations in those regulations across the Northeast States. Dr. Burkhard's presentation focused on recent NYSERDA-sponsored research to assess emissions from advanced combustion technologies designed for institution and commercial-scale uses. Dr. Hopke's presentation provided background information on exposure assessment methods, including air dispersion modeling, as well as results from recent research using models. This information laid the groundwork for discussion about the implications of the information presented in the first session for an understanding of health risks from non-residential scale wood burning in the Northeast. Two discussants, Dr. Mark Utell (University of Rochester Medical Center) and Ms. Lisa Rector (Northeast States for Coordinated Air Use Management) reflected on the lessons from all five presentations for medical and policy decision-making.

Air Emissions and Permitting: ICI Biomass Boilers
Steve Snook, Vermont Department of Environmental Conservation

Industrial, Commercial and Institutional (ICI) Biomass Combustion Units

The term "ICI" reflects the type of facility or establishment where the combustion unit is operating.

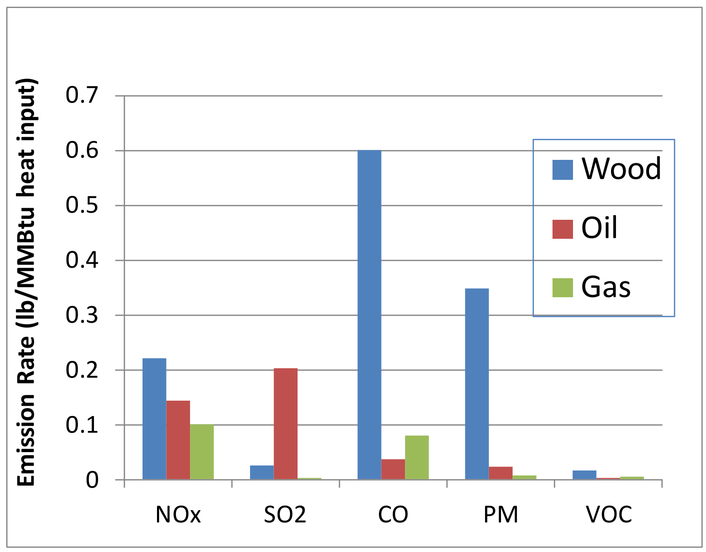
- Industrial units are used for manufacturing operations that require steam and/or hot water and can be fairly large. In comparison to commercial and institutional units, those used for industrial purposes are more likely to operate at higher loads throughout the year, given manufacturing demands, and they tend to use older technologies.
- Commercial units include those operating in facilities such as hotels, restaurants, laundries, and other commercial/retail establishments. These facilities may need hot water year-round, and their demand for heat will vary depending on the season.
- Institutional units are those used in facilities such as hospitals, schools and other municipal buildings. Schools generally use their wood boilers from November to April for heat and hot water and switch to a small gas or oil system from late spring to early fall for their hot water demand. Hospitals can have year-round demand for their wood boilers if they use steam-based systems for summer cooling.
- Facilities whose primary function is to generate electricity for the grid are not considered ICI units, but rather electric generating units (EGU).
- A significant portion of the capital expense of a wood biomass combustion system is related to fuel handling—fuel receiving/storage and fuel feeding systems—not the boiler technology.

Biomass Boiler Pollutants: What are They?

Pollutants emitted from wood biomass units are similar to those emitted as a result of combustion of most fuels, and include those regulated as "criteria pollutants": carbon monoxide (CO), sulfur dioxide (SO_2), oxides of nitrogen (NO_X), and particulate matter (PM, PM_{10}, $PM_{2.5}$).[40] A range of volatile organic compounds (VOCs) are also emitted, many of which are precursors to ozone, a criteria pollutant. For combustion technologies with good PM emission control, approximately 90% are $PM_{2.5}$ (as opposed to larger PM particles, e.g., PM_{10}). Emissions also include an array of pollutants regulated as "air toxics," such as organic compounds (acrolein, formaldehyde, polyaromatic hydrocarbons (PAHs), etc), as well as inorganic compounds (including heavy metals such as arsenic and lead as well as inorganic salts such as potassium sulfate, etc).

Until recently, wood combustion produced emissions that are higher for all criteria pollutants except SO_2, as compared to using oil and gas (Figure 3). As low-sulfur heating oil enters the market in the very near future due to more stringent sulfur standards, the SO_2 emission rate from oil will be dramatically lower. New EPA boiler regulations will also drive down PM emission rates for boilers using a range of fuels, especially for boilers over 10 MMBtu/hr.

FIGURE 3. ICI Wood Boiler Emission Rates (Based on EPA AP-42 Data)



Source: Snook, S. Air Emissions and Permitting: ICI Biomass Boilers [Displaying data from EPA AP-42]. *Wood Biomass for Heat and Power: Addressing Public Health Impacts Symposium.* November 7, 2011.

Variability in Emissions

Four factors are primarily responsible for variations in the levels of pollutants emitted from wood-fired units, and for the concentrations of pollutants that reach populations: (1) boiler design and operation characteristics, (2) emission control technology, (3) fuel type (e.g., bark, wood chips, wood pellets) and quality (including moisture content), and (4) meteorological and topographical conditions.

For example, a conventional 10 MMBtu/hr boiler with a cyclone (emission control technology) has a PM emission rate of approximately 2.5 lbs/hr. If this same boiler used a baghouse emission control device instead, PM emissions would be reduced 10-fold.[41] Factors such as operation characteristics can result in significant variations among emissions from within the same unit. For example, during the start-up period for a new wood boiler in Vermont, testing was conducted during three separate days while

[40] EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels.
[41] Emissions data based on baghouse use is based on test data from two VT facilities.

changes/improvements were made to the tuning and control of the boiler controls. The testing showed a 3-fold reduction in PM emissions after the tuning was completed. CO emissions are particularly sensitive to the appropriate tuning of the boiler for the moisture content of the wood.

In rural states, residential use of wood fuel is significant. As a result, the predominant source of PM from wood combustion is from residential use, such as wood burning stoves. In Vermont, an estimated 92% of the PM from wood combustion is from residential sources. Despite contributing far less to the regional load of fine particulate pollution, ICI wood boilers are currently of concern because of localized impacts to air quality. As Dr. Brauer said in his presentation, this is especially true if these facilities are located in valleys, subject to thermal inversions and other atmospheric conditions that impede the dispersion of the pollutants. Concern for public health is magnified at locations with higher populations of individuals with more sensitive respiratory systems, such as students at schools and patients at hospitals using wood fuel for heat. Wood-fired boilers in these settings likely displaced a fuel—either oil or gas—that emitted less PM; as a result, there will be an increase in the concentration of PM in ambient air.

State and Federal Regulations Controlling Non-Residential Wood Combustion Emissions

Whether or not an air permit for a biomass boiler is required depends on the size of the boiler. In Vermont, a construction permit is required for any biomass boiler that is larger than 900 ft^2 heat transfer surface area (e.g. any boiler larger than 90 horsepower, or approximately 6.5 MMBtu/hr (heat input)). As a consequence, in Vermont, there are many 90 horsepower boilers that were not subject to the permit review process. Biomass units of less than 10 MMBtu/hr capacity (heat input)—the size of most institutional boilers—also escape federal scrutiny. While bi-annual tune-ups on boilers less than 10MMBtu/hr are required under EPA's recent Area Source Boiler Rule issued on March 21, 2011,[42] EPA is not requiring that these units meet specific emission limits. Regulation therefore falls to the states, which vary in the size of boilers they review. The permit threshold for other Northeast states varies, ranging from 1 MMBtu/hr (heat input) in New Jersey to 10 MMBtu/hr (combined units' heat input for a given facility) in Maine. For boilers subject to emission restrictions, emission limits also vary by state.

If the boiler size threshold is met, permits in Vermont and other states are based on estimates of the mass of pollutants that a given unit will contribute to ambient air quality. These estimates rely on pollutant mass emission rates, which are calculated using data on annual fuel use and applying "emission factors", such as those from EPA's AP-42 database, which assume particular emission rates for boilers based on specific types of fuel, with certain pollution control technologies. In Vermont, an initial stack test for PM and CO is required once the boiler is installed and operating to ensure that emission rates are below the limits dictated by the permit.

For boilers larger than 10 MMBtu/hr, EPA's new Area Source Boiler Rule will likely reduce emissions. The new regulations set PM emission limits for boilers larger than 10 MMBtu/hr at 0.07 lbs/MMBtu (heat

[42] When the Area Source Boiler Rule was issued on March 21, 2011, the EPA also announced that it was being reconsidered. On December 23, 2011 the EPA issued a "proposed final rule" for the Area Source Boiler Rule. As of 8/3/2012 these latest revisions to the rule have not been issued as the final rule. The frequency of boiler tune-ups may change in the new final rule.

input). PM emission limits for boilers 10 MMBtu/hr and smaller will still be dictated by the states. Across the Northeast, these emission limits greatly vary from 0.1 lbs/MMBtu (heat input) in Connecticut to 0.6 lbs/MMBtu (heat input) in New York. In Vermont and several other states, emission limits vary depending on best available control technology among other factors.

Because they tend to be subject to less regulation than larger-scale boilers, there are few data on the actual emissions of smaller ICI boilers. However, a study of boilers in New England provides examples demonstrating how average PM emission levels vary depending on boiler size and the type of control technology use:

- Standard boiler with use of a cyclone or multicyclone: 0.2 lbs PM/MMBtu (heat input);
- Advanced boiler design and use of a high-efficiency multi-cyclone: 0.1 lbs PM/MMBtu to 0.2 lbs PM/MMBtu (heat input); and
- Good boiler design and use of an electrostatic precipitator (ESP), fabric filter or baghouse: below 0.02 lbs PM/MMBtu (heat input). European data suggest that advanced boiler design alone may be able to achieve PM emissions below 0.1 lbs/MMBtu

Air dispersion models are also used during the permit process to ensure that pollutant emissions—estimated on the basis of parameters in the permit, such as emission limits and stack height, and taking into account meteorological and topographical conditions in the area—will not exceed the ambient air quality standard. As Dr. Dockery described, the NAAQS for PM includes both a 24-hr and an annual standard. Thus, permit modeling does not address impacts of $PM_{2.5}$ over the short term (e.g., several hours).

With the exception of New Hampshire and possibly New Jersey,[43] air dispersion modeling analyses are not required for many small or medium-sized wood-burning units proposed for Northeast states. For example in Vermont, air dispersion models are required only if emissions are estimated to exceed 10 tons per year of a given pollutant. Typically, NOx is the pollutant that triggers the modeling requirement. Facilities using up to 9,000 tons per year of green wood usually fall below the threshold of 10 tons per year of NOx (equivalent to 630,000 gallons of number 2 fuel oil) that would trigger air dispersion modeling. Most small facilities can avoid the modeling requirement by limiting their annual fuel usage. In Vermont, even the largest high schools with wood boilers were not required to use air dispersion models to estimate concentrations of pollutants in the ambient air near the school and at a distance from it. Despite this regulatory gap, there have been a few institutional wood-boiler systems in Vermont that conducted air dispersion modeling studies. These studies confirmed that the project met the NAAQS without the need for more stringent emission controls.

Conclusions

There are several opportunities for ensuring greater public health protection from biomass boiler emissions.

[43] In New Hampshire, air dispersion modeling is required for any unit with a heat capacity greater than 2 MMBtu/hr (heat input). In New Jersey, air dispersion models are required for any unit greater than 1 MMBtu/hr (heat input) if located in an area of substantial public concern.

- Emissions of pollutants from wood fueled combustion systems vary widely. Policies need to include monitoring or other requirements that ensure that a given unit emits what is promised based on the manufacturer's specifications.
- Air permits are based on regulatory thresholds that vary across the Northeast states. As a consequence, institutional units in some Northeast states will not require a permit. Moreover, new systems may be designed (sized) to avoid exceeding a regulatory threshold. Consistently stringent permit requirements across Northeast states could provide greater assurance that the emissions from boilers will pose fewer risks to health when compared to the current regulatory structure.
- The majority of ICI boiler permits may not require air dispersion modeling. The main exception is in New Hampshire where air dispersion modeling is required for any unit over 2 MMBtu/hr (heat input). Even where modeling is a component of the permit process, it is designed to determine whether or not the facility will exceed the NAAQS which as noted earlier do not address s short term impacts of $PM_{2.5}$ impacts (i.e. high emission events lasting less than 24 hrs).

Symposium Participant Questions and Comments

Comment: In Norway, wood biomass heating systems minimize emissions by including two boilers—one smaller than the other—and running the most appropriately sized boiler for specific heating requirements. As a consequence, each boiler is run at full load, maximizing efficiency and optimizing combustion conditions. Which boiler is used depends on the heating needs of the building.

Comment: In many northern European countries, facilities are required to undergo an environmental management system-style review prior to installation, with a requirement for third party sign-off. The review includes proper boiler sizing, fuel quality, and assurances regarding a consistent fuel supply as well as assurances that the facility has the capacity to properly run the boiler. In addition, the regulatory systems in these countries cover all units, with requirements for boilers as small as less than 1 MMBtu/hr all the way up to the very large electric generating systems. They also include fuel specifications. European regulations stringently limit a range of emissions. As a consequence, in Switzerland for example, electrostatic precipitators—one of the most effective control technologies for fine particulate pollution—must be installed on any unit over 1.7 MMBtu/hr. Small boiler operators in the U.S. often tune the system to minimize emissions for CO—typically the emission standard they have the most difficulty meeting. Tuning the system for CO may result in higher PM emissions. In contrast, regulations for a broader suite of pollutants in Northern Europe means that boiler operators there cannot tune the boiler for a single pollutant.

Question: *In Vermont, was there an evaluation of asthma rates in any of the schools before and after the installation of the wood biomass boilers?*
Response: No. The Vermont Department of Health generally does not currently have routine access to school-level asthma data and did not undertake a separate survey to evaluate rates.

Comment: We need to emphasize the issue about lack of ambient air pollution monitors. This issue has been raised a couple times in this Symposium. In most areas where these ICI boilers are operating, there are no ambient pollution monitoring stations and so we lack data regarding regional impact. Most of the U.S. is in "unknown" attainment simply because we lack the monitoring infrastructure to understand background pollution levels on the scale needed.

Energy and Emissions Performance of Commercial Wood Boilers
Ellen Burkhard, New York State Energy Research and Development Authority

NYSERDA has a Biomass Heating Research and Development program that is working with manufacturers and research institutions in New York to develop and evaluate advanced biomass combustion technologies. This R&D program aims to promote the commercial availability of more efficient and lower emitting units. Dr. Burkhard's presentation described recent studies supported by NYSERDA that have evaluated advanced commercial/institutional biomass heating technologies.

Emissions Evaluation of a Traditional Wood-Chip Stoker Boiler and Oil Boiler Used at a Vermont School

The first study, conducted by the Northeast States for Coordinated Air Use Management (NESCAUM) evaluated emissions from a wood-chip stoker boiler located at a school in Vermont, as well as emissions from the oil boiler used for back-up heating at the school. The comparative fuel/technology design of this study was of interest to NYSERDA because in rural locations, the heating fuel that tends to be displaced by wood biomass is heating oil. Consequently, NYSERDA benchmarks emission rates and combustion efficiencies for biomass against the fuel/technology being displaced—heating oil. Currently, only three or four schools in New York currently heat with wood-boilers, but proliferation of the use of wood biomass to heat schools is likely. NYSERDA was interested in evaluating the combustion performance of current biomass heating technologies used at schools to better understand the potential for the units to contribute to local pollution by $PM_{2.5}$, which is already high in some areas of New York. Moreover, since New York recently spent more than $5 million to retrofit diesel buses with the express purpose of reducing onsite emissions and associated $PM_{2.5}$ levels, NYSERDA is concerned about the installation of boilers that may undermine progress in reducing harmful exposures to children.

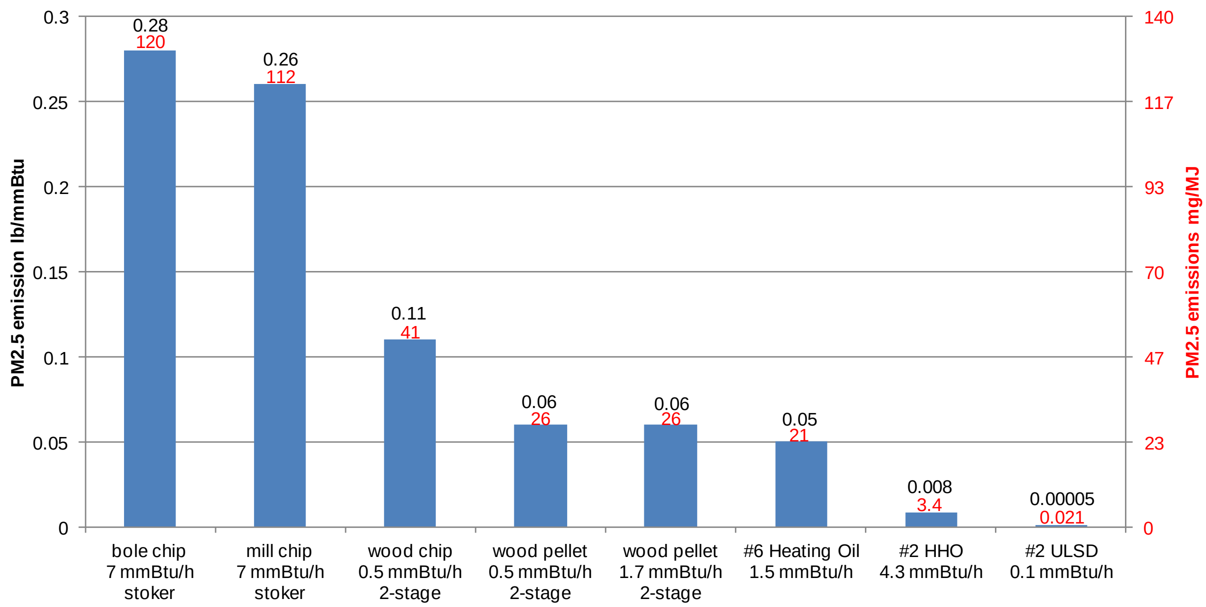
The 7 MMBtu/hr Vermont school stoker boiler tested by NESCAUM used "green" mill chips (debarked wood chips from milling residue) or bole chips (with bark) with approximately 40% moisture content and was able to achieve combustion efficiencies of 75 - 81% at full load. The 4.3 MMBtu/hr traditional oil heat boiler onsite had a combustion efficiency of approximately 80% and used #2 oil. The average PM emission rates for the various fuel/boiler technologies were as follows (see Figure 4):[44]

- Bole chips used in the 7 MMBtu/hr stoker boiler: 0.28 lbs/MMBtu
- Mill chips used in the 7 MMBtu/hr stoker boiler: 0.26 lbs/MMBtu
- #2 oil used in the 4.3 MMBtu/hr oil boiler: 0.008 lbs/MMBtu

[44] Based on unpublished data previously presented at the 2010 Northeast Regional Meeting of the American Chemical Society.

Thus, emissions of fine particulate from the wood biomass boiler used at the Vermont school are orders of magnitude higher than from the fuel oil being displaced.

FIGURE 4. Emission Evaluation Results from NYSERDA Sponsored Research: PM2.5 Emissions (Heat Input)



(Source NYSERDA)

Third-Party Evaluations of Two Commercial-Sized Advanced Two-Stage Wood Pellet Combustion Systems

NYSERDA recently supported Clarkson University and a certified stack-test company to evaluate the emission rates and combustion performance of several commercial-sized advanced combustion boilers:

- 0.5 MMBtu/hr 2-stage boiler imported from Austria burning wood chips with 30% moisture content
- 0.5 MMBtu/hr 2-stage boiler imported from Austria burning wood pellets
- 1.7 MMBtu/hr 2-stage boiler newly manufactured in New York, which burns wood pellets

Wood pellets are a more processed and refined fuel than wood chips. This additional processing results in fuel characteristics that increase the combustion efficiency, such as uniformity of size of the pellets, low (5%) moisture content and a very low ash content. Over the last 5 - 6 years, the wood pellet industry has expanded in New York, with over $30 million invested in three large plants and a few smaller facilities as well—a trend that is likely similar in other Northeast states.

While traditional wood combustion technologies such as stoker boilers directly combust the wood, advanced biomass combustion uses a two-staged system. In a two-staged combustion system, wood is heated in an oxygen-depleted primary combustion chamber to drive off volatile gases from the solid fuel (gasification process). The gases are then burned in a second chamber where oxygen-rich air is mixed with the gaseous fuel. This two-stage technology results in higher combustion efficiencies and more complete combustion than direct-fired combustion technologies.

Results of Clarkson University's third party evaluation revealed (see Figure 4):[45]

- The advanced two-stage combustion systems burning either wood pellets or wood chips had dramatically lower emissions than the Vermont school stoker boiler tested by NESCAUM that burned bole chips or mill chips.
- $PM_{2.5}$ emissions from the advanced wood combustion systems burning pellets had lower emissions than the two-staged advanced wood combustion systems burning wood chips (0.6 MMBtu/hr versus 0.11 MMBtu/hr). Neither of the advanced two-stage systems tested were able to achieve $PM_{2.5}$ emissions below the 0.054 limit set by both Germany and Switzerland.

Despite achieving lower $PM_{2.5}$ levels compared to conventional stoker boilers, the two-stage wood combustion units still emit levels that are dramatically higher than emissions from #6 fuel oil, #2 home heating oil, and ultra-low sulfur home heating oil (see Figure 4). In 2012, ultra-low sulfur heating oil will become available in New York, which will enable wider adoption of condensing boiler technologies. Condensing boilers recapture heat that would otherwise go up the stack to increase overall efficiency by approximately 10%. These units will have an emissions profile similar to natural gas.

The two-stage wood combustion units can achieve lower $PM_{2.5}$ emission levels with the installation of particle emission control technologies. A laboratory study conducted by Clarkson University showed that ESPs are highly efficient at removing alkali salts, the type of particles predominately released by advanced combustion units (see: Dr. Kocbach Bølling's presentation above). They also remove PM, with efficiencies greater than 95%. Currently, ESPs for small boilers are costly—often multiple times the cost of the boiler itself. However, the European market is beginning to commercialize ESPs for the small boiler market with an ability to achieve 60 - 90% PM removal efficiencies. As of 2014, regulations in Germany and Switzerland will promote and expand the market for the use of ESPs on small wood combustion boilers. In addition, new technologies are on the horizon, such as economizers. This technology is also a condensing technology and decreases emissions as a result of increased waste heat utilization and by producing a condensate which captures particulates.

Composition and Size Distribution of Particles Emitted from Advanced Combustion Biomass Technologies

Clarkson University also tested the composition of the $PM_{2.5}$ emitted from the 0.5 MMBtu/hr two-stage Austrian boiler. Findings were similar to those reported by Dr. Kocbach Bølling in her presentation. Because the two-stage boiler technology achieves more complete combustion, the composition of the

[45] Chandrasekaran SR, Laing JR, Holsen TM, et al. Emission characterization and efficiency measurements of high-efficiency wood boilers, *Energy and Fuels.* 2011;5(11):5015–5021.

fine particles are primarily inorganic salts and low in organic carbon and soot. Dr. Kocbach Bølling's review concluded that this particle composition profile is less toxic than particles emitted by boilers with less complete and less efficient combustion, such as stoker boilers.

The size distribution of the particles emitted from the advanced two-stage combustion units reflects the size expected of combustion particles. When the combustion chamber is at steady state, the size of the particles emitted is mostly ultra-fine or nano-sized particles, with some accumulation mode particles (See Table 1 for size reference). When the performance of the combustion is not at steady state (i.e., start-up/shut down periods or is not being used at high load) the particle size distribution changes. For example, during start-up, the more particles fall into the accumulation mode size whereas during shut down, more ultra fine particles occur.[46]

TABLE 1: Size Comparison of Air Pollution Particles

Particle Type	Size
Coarse Particles	Less than 10 microns
Fine Particles	Less than 2.5 microns
Accumulation Mode Particles	~0.075 microns to 2.5 microns
Ultra-Fine Particles	Less than 0.1 microns
Nanoscale Particles	0.0025 to 0.02 microns

Conclusions

In addition to advancing understanding of emissions from wood-burning heating systems, NYSERDA has used results from its biomass R&D program to help incentivize the use of lower emitting wood combustion technologies. For example, in order for a commercial biomass boiler project to be eligible for recent "stimulus funding," the proposal was required to specify a boiler combustion efficiency of at least 83%—a level of efficiency which would translate into reduced emissions. Funding was subsequently provided to five biomass boilers meeting this standard, three of which are being used at schools.

In summary, results from NYSERDA's R&D program demonstrate that advanced wood boilers can achieve:

- the same efficiency as oil-fired boilers;
- lower $PM_{2.5}$ emissions than direct-fired wood chip combustion technology, with particles composed primarily of inorganic salts; and
- PM2.5 levels that are similar to oil-fired boilers if post combustion control with ESPs are used.

Symposium Participant Questions and Comments

Question: *Several presentations highlighted information about the efficiencies of various wood combustion boilers. It seems that the pathway towards lower PM emissions lies with the use of wood pellets. What is the emissions profile for a pellet manufacturing plant? What are the environmental,*

[46] Chandrasekaran SR, Laing JR, Holsen TM, et al. Emission characterization and efficiency measurements of high-efficiency wood boilers, *Energy and Fuels.* 2011;5(11):5015–5021.

health and safety implications of transforming green wood into pellets? Are we shifting the risks away from boiler operations towards the pellet industry?

Response: Approximately 15 - 20 % of the energy used in a pellet plant generates heat to dry the pellets. However, it is true that pellets have a "preloaded" environmental impact given the emissions required to produce and energy required to dry the pellets. It is worth examining whether pellets result in a net gain from both an energy and emissions perspectives, considering impacts across the biomass energy system from production to use.

Response: There are a wide range of pellet manufacturing facilities. The newer pellet plants have more stringent emission controls and are using more efficient manufacturing processes.

Response: It is true that using pellets, especially for smaller-scale units, is an easy way to lower PM emissions compared to using wood chips. Wood chip boilers with advanced emission control technology makes sense for many facilities, especially given the lower cost of wood chips compared to pellets.

Response: The problem with wood chips is the moisture content. When used in biomass boiler systems, much of the initial energy in the system is used to drive off the moisture in the wood chips and as a consequence, combustion efficiencies are compromised and emissions are higher. We need to consider feasible and economical approaches to pre-drying the wood chips. If the market evolves to use condensing economizers as Dr. Burkhard discussed, the heat collected can be used to dry the chips.

Question: *For all sources of energy, there are costs and benefits. It matters how the risks are managed and minimized. In schools, the primary factors driving decisions to install a wood boiler seem to be fuel costs and support for local industry and jobs. What are the affordable interventions for schools to reduce emissions in this context?*

Response: Part of the solution is making advanced combustion technologies more available and affordable. Not only are the emissions greatly reduced, but they appear to be less toxic than emissions from conventional combustion systems.

Response: For existing buildings, some states provide technical assistance services for schools and businesses to identify opportunities to improve combustion efficiency and performance (and thus reduce emissions) of a given boiler. Some schools in Vermont will use their back-up oil-fired boiler until the weather is sufficiently cold such that they can run their wood boiler on high-load, for example, rather than using it on the shoulder season when it would burn less consistently and therefore less efficiently. Another important step is to make drier chips available. Using drier chips than those that are routinely available will decrease emissions.

Response: Options to retrofit existing units to improve performance are limited. There need to be more information and incentives to encourage installation of new advanced combustion systems. As Mr. Snook's presentation showed, the highest costs of a wood boiler project are in the equipment and its installation. Use of a more advanced boiler or emission control device is only a fraction of the total cost of the project–costs that will pay for themselves given the greater efficiencies they offer.

Response: In New York, the state's Department of Education generally supports a large fraction of the capital costs associated with a new wood biomass heating system, while the school pays for ongoing fuel expenses (which tend to be lower with wood fuels). As a consequence, a full life-cycle economic analysis is not always relevant to the school, as they do not bear the majority of the initial capital expenses.

Estimating Public Health Impacts: Air Receptor Modeling & Measurement
Phil Hopke, Clarkson University

Dr. Hopke's presentation reviewed exposure assessment methods relevant to wood biomass energy projects, in particular air dispersion and receptor modeling. He also discussed recent research assessing exposure to PM based on these methods from recent research in Rochester, NY.

Modeling is used to understand the concentrations of woodsmoke or other biomass burning particles to which people are exposed. Two types of models are used:

- Air dispersion modeling, which estimates the transport of specific pollutants using meteorological data and other factors that affect the dispersion of pollutants to estimate pollutant concentrations in specific locations.
- Receptor modeling, which attempts to identify the original source of a pollutant given measurements of concentrations of pollutants at a particular location.

EPA's AERMOD: Potentially Underestimating the Building Downwash Effect

The current local-scale air dispersion model approved for estimating the concentrations of biomass combustion-related pollutants is EPA's AERMOD. EPA has identified problems in models generated for facilities with short stacks. The pre-2011 versions of AERMOD did not adequately account for the "downwash effect", in which the pollutant plume is brought to the ground near the source. As a consequence, modeling to estimate concentrations of pollutants near facilities with shorter stacks, such as schools, may have underestimated ground-level concentrations of the pollutants in the immediate vicinity.

Any air dispersion modeling using AERMOD prior to April 2011 may have underestimated the building downwash effect and should be revisited. State regulatory agencies should ensure that facilities conducting air dispersion modeling for permit purposes are using the updated AERMOD so that the potential for building downwash is appropriately calculated.

Receptor Modeling for Woodsmoke in Rochester, NY

Receptor models use the distinct patterns of pollutant particle composition emitted by different sources to estimate percentages of particle pollution that comes from each source type.

Recent use of receptor modeling to investigate sources of PM pollution identified a new method for distinguishing sources of woodsmoke from other combustion sources, such as vehicle exhaust. The method uses an aethalometer to measure light absorption of particulate matter at two wavelengths: 880 nm and 370 nm. Since the organic aerosol component of particulate matter emissions from wood combustion enhance light absorption at 370 nm relative to 880 nm, the difference between the two wavelengths—called Delta C—is used as an indicator signal specific to woodsmoke.

Research exploring the specificity of Delta C as a marker of woodsmoke has demonstrated that Delta C values peak in the winter and correlate well with levels of levoglucosan, a validated marker of woodsmoke. Use of delta C in a recent receptor model of PM pollution in Rochester, NY estimated that woodsmoke contributed approximately 17% of the $PM_{2.5}$ in the air in winter, and a total of 7% of the amount of $PM_{2.5}$ over the course of one year. Both these estimates are similar to data in New York State's emissions inventory. [47]

Mobile measurements using an aethalometer were taken throughout the east side of Rochester.[48] For one particular location, there was a substantial increase in particle concentration in the winter compared to the summer months. The Delta C peak in this area corresponded to a $PM_{2.5}$ increase of 6 ug/m^3. [NOTE: this location was described in the presentation as a grammar school that uses a wood biomass boiler. Following the Symposium, the school reported to New York State Department of Environmental Protection that it does not use a wood boiler. The source of the increased woodsmoke pollution in that location remains an unanswered question.]

Conclusions

- Use of AERMOD to conduct air dispersion modeling prior to April 2011 may have underestimated the building downwash effect, resulting in underestimations of pollutant concentrations in the vicinity of wood boilers used in institutions with short stacks.
- Use of receptor modeling has shown that woodsmoke in winter represents a significant source of $PM_{2.5}$.
- Exposures to $PM_{2.5}$ in woodsmoke can be significantly higher in localized areas than they are across the entire community or region.

Symposium Participant Questions and Comments

Question: *How much error was introduced into results using AERMOD due to the default assumptions used by AERMOD regarding building downwash?*
Response: Previous versions of AERMOD eliminated the downwash parameter when the stack height was 2.5 times greater than the height of the building. The model failed to include another parameter that is key to ensuring that downwash does not occur: that the stack must be at least 65 meters tall. In an unpublished analysis for a school-sized institutional boiler in the western region of the country, results from AERMOD estimated that impact from the wood burning unit that was less than 10 MMBTU/hr in size was approximately 3 ug/m^3. When the stack height in the analysis was reduced by 2 inches to include downwash emissions, the potential impact increased to 33 ug/m^3. These results cannot be generalized to all facilities given that parameters used in estimates of pollutant dispersion are specific to a given facility. However, it is worth pursuing a similar assessment for multiple facilities in different types of locations to better illuminate the impact of the flaw in the pre-2011 version of AERMOD.
Response: If the stack height was greater than the stack height delineated as good engineering practice (GEP), the change in the AERMOD downwash parameter could change the modeling predictions. If the

[47]Wang Y, Hopke PK, Xia X, et al. Source apportionment of airborne particulate matter using inorganic and organic species as tracers*, Atmos Environ*. 2012;55:525-532.
[48] Wang Y, Hopke PK, Utell, MJ. Urban-scale spatial-temporal variability of black carbon and winter residential wood combustion particles, *Aerosol Air Qual Res.* 2011;11:473–481.

actual stack height is lower than GEP, the change in AERMOD likely will not make a difference in the estimated impact.

Response: While it is has been commonly understood that GEP can address downwash issues, air tunnel simulations show that building configuration also plays a keep part in dispersion of pollution and thus stacks that are 2.5 times higher than the building do not ensure downwash protection. In addition, AERMOD was originally designed to estimate emission impacts from large stationary sources with very tall stacks. The downwash parameter was essentially turned off because the effect was not an issue for stack heights above 65 meters, such as those at large facilities. We don't know whether or not AERMOD estimates track with real-time experiences of smaller facilities, such as schools because the data have not been collected.

Discussant: *Lisa Rector, Northeast States for Coordinated Air Use Management*

A major data gap is an understanding of emissions from boilers as they are actually operating. As several presenters described, emissions from biomass combustion systems can vary significantly based on four factors: fuel type; fuel quality; boiler and emission control technology; and operating conditions. However, the standard emissions tests used for air regulation (60 minutes measuring PM and CO) are simply a snap-shot in time, typically conducted under best operating conditions, such as when the boiler is at full load and when the best quality fuel is used. However, many boilers—especially those at the institutional scale—are oversized, and thus routinely operate at low loads. In addition, fuel quality can vary, and can be of poorer quality than the fuel used during the emissions test. Thus, existing emissions data for ICI boilers are mainly from those boilers that have been tested when the emissions are likely the lowest. Moreover, the emission control technologies of smaller boilers vary, (i.e., a cyclone versus an ESP for emissions control); they depend on state emissions regulations, which are inconsistent.

How a state chooses to regulate will also significantly impact the type of combustion unit installed. For example, the PM emission limit in NY is set at 0.6 lbs/MMBtu (heat input). This is a static standard that has been in place for years. In contrast, states such as Rhode Island and Vermont set emission limits based on a best available control technology requirement, which becomes more stringent as technology improves.

In addition to promoting the installation of advanced boiler technology and use of the most effective emission control technologies, we also need to address the issue of fuel type. Though the use of wood pellets results in lower emissions, the vast majority of units in operation use wood chips. There needs to be more guidance for facilities using wood chips regarding how to operate and maintain the boiler to minimize emissions.

A major concern is that the market often expands to where the regulatory requirements are minimal. Given: (a) the lack of focus on boilers under 10 MMBtu/hr (heat input) in EPA's new boiler rules, (b) the lack of regulatory authority by some states for small boilers, such as the size being installed in some schools, and (c) legal allowances in some states for high amounts of PM to be emitted from small boilers, few disincentives are in place for institutional scale boilers to adopt the most advanced and clean technology.

Discussant: *Mark Utell, University of Rochester Medical Center*

It is important to expand beyond what the body of research implies for susceptible populations to also address impacts on the general population. Several presentations this morning addressed health effects of air pollution in general and more specifically of woodsmoke pollution. The health effects observed in these research studies, such as premature mortality and respiratory and cardiovascular morbidity effects, were observed primarily in susceptible populations. Yet, there is growing evidence that one of the mechanisms responsible for an increased risk of cardiovascular outcomes associated with PM pollution is accelerated atherosclerosis. If PM pollution accelerates atherosclerosis, then the health of the general population will be impacted.

Not only do children spend more time outside, but like adults, when they exercise they experience increased deposition of particles including ultra-fine particles. As Dr. Kocbach Bølling described, ultra-fine particles (particles under 100 nm) dominate particulate pollution in woodsmoke. Research at the University of Rochester Medical center has demonstrated that ultra-fine particles are deposited to a greater degree than fine particles; and with exercise, deposition approaches 80%. Deposition of ultra-fine particles is even greater in asthmatics at rest and again increases when exercising. If there is woodsmoke pollution in the school yard when children are playing and exercising outside, the deposition of ultra-fine particles can be very high.

Recent research also conducted by the University of Rochester Medical Center in collaboration with Clarkson University has examined the effect of ultra-fine particulate pollution on a high risk population: patients enrolled in a cardiac rehabilitation program as a result of a cardiac event. When these patients were exercising, changes in heart rate variability, cardiac repolarization effects and higher levels of systemic inflammation were correlated with higher levels of ultra-fine particulate pollution. As Dr. Kocbach Bølling discussed, the bulk of toxicology research on woodsmoke focuses primarily on respiratory effects, yet it is important to keep in mind potential impacts on the cardiovascular system as well.

Symposium Participant Questions and Comments

Question: *Concerning inflammatory effects on the lungs, the issue of tolerance emerges: the increasing tolerance of someone as they experience subsequent exposures. Has the issue of tolerance to air pollutants been investigated?*
Response: Much of the air pollution research on tolerance focuses on the gases, such as ozone and NOx. For example, if you are exposed to several high ozone days, response to ozone exposure the latter days is lessened. I am not aware of research that has examined tolerance to PM of any size; because of the nature of particulate matter (varying sizes and composition), research on tolerance to PM would be harder to reproduce compared to research on tolerance to the gaseous pollutants.
Response: In research focused on women exposed to biomass smoke from cooking over open flames as well as wildland fires, there is a "healthy cook" "healthy worker" effect, reflecting that people who cannot not tolerate the short-term respiratory irritation effects of woodsmoke stop doing such work. Those that remain in the study may therefore be particularly capable of tolerating respiratory irritation effects from pollutants in woodsmoke.

Question: *I agree with the comment about needing to investigate and address risks among the general population from air pollution, not just susceptible populations. Among the non-susceptible population, exercise patterns seem to be changing in the Northeast—adults are exercising more while children are becoming a bit more sedentary. Has there been any research assessing where adults are routinely exercising (walking, biking, running) in relation to air pollution?*
Response: In general, days of high PM levels occur during the winter when most exercising is done inside.
Response: We lack knowledge about air pollution levels in the majority of communities because of the limited number of central air monitoring stations currently available.
Response: A similar question that is often asked is whether or not it is worse for your health to exercise outside on a road versus not. There have been several studies examining these tradeoffs, which have concluded that the benefits of exercise outweigh any detrimental impact from breathing polluted air. With that said, it is best to avoid exercising during periods of high traffic and thus higher pollution.

Section 4. Panel Discussion

The panel included representatives from a health advocacy organization, the biomass industry, and those state agencies—health, environment, energy and education—whose policies and programs on biomass energy have implications for public health. This was the first time that this range of organizations—public and private, and multiple state agencies—had gathered to exchange their perspectives on this topic.

The panelists' remarks addressed three questions: (a) What role does their organization play with respect to the public health aspects of biomass energy? (b) What constraints do they confront in addressing public health as they make decisions about biomass energy, including political, legislative as well as resource challenges? (c) What are promising programmatic and policy opportunities for elevating public health more consistently and systemically in biomass energy decisions? Highlights from each panelist's comments are described below.

Suzanne Condon, Bureau of Environmental Health, Massachusetts Department of Public Health

The Massachusetts Department of Public Health (MDPH) has both an informal and formal role in addressing public health issues associated with wood biomass combustion. The informal role is responding to community concerns regarding environmental exposures from a current or proposed facility that may affect or has affected local residents. The Bureau of Environmental Health (BEH) at MDPH routinely responds to these requests by providing epidemiologic and toxicologic health assessments. The more formal role involves biomass energy projects that come before the Massachusetts Environmental Policy Act (MEPA) office of the Massachusetts Executive Office of Environmental Affairs (EOEA). In this context, BEH may be asked by EOEA to provide expertise regarding the potential public health impacts of a new technology. BEH may also review environmental notification forms filed by prospective facilities as part of the MEPA process, and through the formal public comment process we can suggest a more thorough evaluation of the project if there are potential public health concerns.

It is clear from reviews of the relevant science that there is cause for concern about health impacts from pollutants in biomass combustion emissions—particularly for the elderly, young people, and people with pre-existing illnesses, such as asthma or cardiovascular disease. In these susceptible populations, health impacts have been associated with lower levels of air pollution than those expected among the general public. As has become clear from the debates on biomass energy installations in multiple communities, residents generally want to know how the proposed project will impact their health. They are interested in cumulative environmental exposures and in current and likely trends in the burden of disease in their community. However, air permitting processes generally do not include analyses of the implications of a given proposed facility on the health of a specific local population.

A useful tool for protecting public health in facility proposals is the Massachusetts equivalent of the National Environmental Policy Act (NEPA). As originally written, NEPA and its state equivalents were not only focused on environmental protection and preservation, but also on health. For example, Section 4321 of NEPA states, "The purposes of this Act are…to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man…"

Moreover, Section 4331 states:

> *In order to carry out the policy…it is the continuing responsibility of the Federal Government to…assure for all Americans safe, healthful, productive, and esthetically and culturally pleasing surroundings; attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences…*

Yet historically, federal and state environmental policy processes have relied on national ambient air quality standards (NAAQs) as a proxy for likely health impacts. The question becomes how can health data become better integrated into the environmental policy act process?

One promising approach for incorporating health data into such environmental regulatory processes is the use of Health Impact Assessment (HIA), a tool for objectively assessing the potential health effects of a project or policy *before* it is built or implemented. HIAs complement traditional risk calculations (which estimate likely changes in concentrations of particular pollutants in ambient air) made during siting and regulatory permit processes by considering the potential impacts of exposures on community health statistics and health indicators, such as disease outcomes and income and employment. The purpose of an HIA is to help bring public health issues to the attention of decision makers prior to decisions, so that solutions can be designed into the plan. HIAs are not "project killers." They can facilitate project approvals by identifying red flags and a range of solutions early in the proposal process. They can then be incorporated into revised plans. Moreover, HIAs can help avoid costly lawsuits after a regulatory decision is made.

HIAs use a structured framework that helps stakeholder identify priority concerns and discuss practical recommendations for mitigating problems.[49] The mitigation recommendations could include operational plan modifications such as specifying the route diesel vehicles must take on their way to the facility in order to reduce potential exposures to particulate matter. If environmental exposure concerns cannot be mitigated, other aspects of a given project can serve to improve health such as providing sidewalks and lighting to promote walking. Other initiatives might provide direct support for community health

[49] HIA is a 6-stage process that includes: (1) screening (whether an HIA is needed and likely to be useful to a specific decision-making process); (2) scoping (once it is determined that an HIA should move forward, a plan for the HIA is developed in consultation with stakeholders); (3) assessment (the baseline health of the affected communities is assessed as well as the potential impacts of the decision under question); (4) recommendations (practical solutions that can be implemented within the political, economic or technical limitations of the project or policy being assessed are recommended); (5) reporting (results of the HIA are provided to the affected stakeholders and decision-makers); and (6) monitoring and evaluation (results of the HIA are monitored and evaluated to better understand changes in the health or health risk factors in the population based on the implementation of the final policy, program or project).

benefit programs. HIAs provide an opportunity for projects that might otherwise increase health risks to not only reduce/eliminate risks but also to advance health with steps endorsed by the community.

Bill Irwin, Radiological and Toxicological Science Program, Vermont Department of Health

Environmental protection has long been considered a surrogate for protecting health. To some degree, environmental regulations protect public health, but not always adequately. Recognizing this limitation, Vermont has recently directly incorporated health concerns and the use of health impact assessment (called "public health assessment" in Vermont) in two important state-wide policies: Vermont's Comprehensive Energy Plan and its Health Reform bill.

Despite the potential impacts of wood combustion on public health, the Vermont Department of Health was not engaged historically in permitting or policy decisions associated with energy projects. In the spring of 2011, the state's new Public Service Department Commissioner asked the Department of Health to review the state's draft Comprehensive Energy Plan to ensure that health was appropriately considered and integrated into the Plan. The Department of Health recommended incorporating health impact assessments. The final Comprehensive Energy Plan now includes an appendix on public health assessment (Vermont purposely left out the word "impact" in order to better differentiate public health assessment from environmental impact statements.) Public health assessments describe the site of the proposed project, the routes of exposure, the populations exposed, and the means to promote health improvement. Whether the proposed project is a wind turbine, a hydroelectric project, or wood biomass energy project, the use of public health assessments will help ensure that the project does not undermine, but rather advances human health while it pursues other societal benefits.

Health care reform has been a recent focus in Vermont. There is significant agreement among the executive and legislative branches as well as among Vermont's public health officials that significant societal savings can accrue from better-managed health care. As a consequence, Vermont's health reform bill now includes recommendations that new projects funded by the state undergo a public health assessment. Underlying these provisions is an understanding that health-protective measures need not hinder the economic benefits or resource efficiencies of a proposed project, especially when taking into account the cost savings associated with preventing early deaths and disease. Projects subject to a public health assessment would include not only energy facilities and systems, but also community planning and transportation projects, among others. The Health Department is working to enhance the specificity of its health data for use in community-level assessments.

As a mountainous state, Vermont has topographical and meteorological conditions that may increase exposure to harmful pollutants, as discussed in earlier presentations. Many of Vermont's schools are located in vulnerable areas, such as river valleys that experience winter temperature inversions that can trap polluted air, and include populations of children that are more susceptible to health risks because of poor health status. By conducting public health assessments as part of the review of energy projects proposed for these areas, steps to protect health can be incorporated into the design of a project.

Effective regulatory enforcement is also important. Once a project is approved, there needs to be effective enforcement of regulations to ensure that the most vulnerable are indeed being protected.

Barbara Morin, Office of Air Resources, Rhode Island Department of Environmental Management

The Office of Air Resources at the Rhode Island Department of Management is responsible for issuing permits to facilities that are sources of air emissions, and enforcing air quality rules. The most effective tool used by the Office of Air Resources to minimize risks to public health from emission sources, including ICI wood boilers, is the air permitting process. Rhode Island's threshold for regulating boilers is among the lowest in the Northeast: any boiler greater than 1 MMBtu/hr (heat input) is required to have an air permit before construction. As a consequence, Rhode Island requires air permits for small facilities that are not required in the majority of Northeast states. In addition, because Rhode Island's air toxics regulation sets low thresholds for requiring impact/air dispersion modeling for a number of pollutants, emissions from nearly all air sources are modeled, including the three ICI wood biomass units permitted in Rhode Island: two in schools, and the other at a hospital.

Rhode Island uses a Best Available Control Technology (BACT) approach when it issues an air permit. Staff conducts a review of the newest, best available technology to control emissions (both "end of pipe" emission control technology as well as boiler design) at the time of the permit application. The review includes an analysis of the economic feasibility of BACT for boilers in different size ranges; a technology that is financially viable for a large facility may not be feasible for a smaller one. The Office of Air Resources sets limits for emissions of PM, metals and other pollutants based on the findings of this review.

The BACT review process supports continual improvement in emission reductions. For example, a facility that received an air permit in 2011 was required to use an electrostatic precipitator (ESP) to control its emissions, whereas a similar facility that received an air permit in 2007 was required to use a multi-cyclone—a less effective particle collection device.

One constraint in the existing air quality regulatory structure is that the permit process cannot affect a facility's choice of fuels or location. While a facility may have the opportunity to use less polluting fuels, fuel choices have no bearing on the permit process as long as the emission limits are met. In addition, impacts of emissions may be more problematic in one community than in another, yet the permit process cannot direct where the source is located unless the emissions are expected to result in violations of ambient air quality standards.

Another limitation in the air quality permit process is that for small sources, there are minimal requirements for public engagement. Permit applications for major emission sources—for example, large electricity generating units—often stimulate more and earlier participation by the public because of the scale of the projects, the number of people potentially affected, and opportunities for comment that are built into the process. In contrast, there may be little or no media attention and minimal community organizing around permit applications for smaller facilities. Typically, the public as well as the health department become engaged in debate about smaller facilities only after the permits are issued and the facility is operating. At this stage, concerns are more difficult to address.

Mark Torpey, New York State Energy Research and Development Authority

NYSERDA is a public benefit organization, not a regulatory agency. It manages public benefit funds to help New York meet its energy goals: reducing energy consumption, promoting the use of renewable energy sources, and protecting the environment.

Biomass is just one of NYSERDA's program areas. Within the biomass program, there are three focus areas. First, as Dr. Burkhard noted in her presentation, NYSERDA has a major focus on advancing high-efficiency, low-emitting thermal heating technologies, including hybrid fuel technologies. Second, NYSERDA is responsible for administering New York State's Renewable Portfolio Standard (RPS). The standard established a mandate that by 2015, 30% of the state's power generation will come from renewable fuels. Several biomass plants—either co-firing with biomass or using 100% biomass fuel—have received renewable energy credits. Third, NYSERDA has a liquid fuels program which supports research to advance the conversion of biomass solid fuels, such as maple wood chips, into liquid fuels.

There are two key challenges that NYSERDA faces in its programs. First, it is always difficult to effectively optimize and apportion NYSERDA's limited public benefit funding for the three biomass programs. Considerations in these budgeting decisions include current and future uses of biomass as a feedstock as well as research evidence and gaps regarding environmental and public health impacts. Second, New York, like other states, has limited capacity for the long-term monitoring needed to assess environmental and public health impacts associated with air pollution. In the Adirondacks, a monitoring program has been in place for 30 years, and has generated extensive data on acid deposition and changes in phytoplankton and zooplankton levels, as well as fish populations, in 52 lakes in the region. The majority of other regions in the state do not have this kind of capacity for long-term monitoring. Additional capacity is needed to better understand the impacts of biomass combustion.

A key opportunity for addressing the health impacts associated with biomass combustion is the development of a roadmap to guide policy and technological investment, for which NYSERDA has issued a solicitation. The solicitation prioritizes an assessment of public health impacts and solutions for public health protection. Other states, such as Massachusetts, are undertaking similar initiatives; this opens the door for shared learning and regional collaboration.

An additional opportunity is pursuing greater consistency among the carrot and stick renewable energy policies related to biomass fuel. In the Renewable Portfolio Standard program, for example, credits are granted to biomass power plants based on receiving a Forest Stewardship Council certification for the fuel source. However, in the Regional Greenhouse Gas Initiative (RGGI), biomass plants are penalized unless there is a 100 year conservation easement on the land from which the biomass fuel is harvested. As a consequence, a biomass power plant can receive RPS credits and also be penalized for the same operations under RGGI. There is an opportunity in the coming year(s) to insert public health into the discussion as consistency across these and other policies is pursued.

Ed Murdough, Bureau of School Approval and Facility Management, New Hampshire Department of Education

In New Hampshire, as in most states, the Department of Education shares with local municipalities the costs of new school construction or major renovation of existing schools. The department also has an incentive program that provides additional financial support for the construction of "high-performance" or "green" school buildings. This is the Department of Education program that most often handles wood biomass heating projects in New Hampshire's schools. The Department of Education also participates in "New Hampshire Partners for Healthy Schools," a collaboration among state agencies and non-governmental organizations that grew out of the state's asthma program. While wood biomass heating in schools has not emerged as a primary topic of concern for this group, it is within the purview of the collaboration, the goal of which is to address environmental health issues in schools, including indoor air quality.

Currently, five public schools in New Hampshire have either wood chip or wood pellet heating systems, and several wood boilers operate at private schools. The first wood biomass heating system in a New Hampshire public school went online in 2005. Wood boilers are slated for installation at several other public schools in the next two years. With a grant from the US Department of Agriculture, the New Hampshire Department of Education has conducted feasibility studies at many schools across the state to explore shifting to wood biomass heating. The largest operating unit in a New Hampshire school is a 6.7 MMBtu/hr (heat input) wood chip boiler in the Merrimack Valley School District, located in the city of Concord. Also in Concord, a district heating system burns wood biomass to generate steam that heats several state office buildings and schools in the city.

Wood chip heating systems require space. For example, the Merrimack Valley wood biomass system—which heats both a middle and a high school—has two bunkers for wood chip storage, each of which can hold two 40-foot tractor trailer loads. In the peak of the heating season, there is one delivery per week. In addition to the bunker, space is required for truck delivery. As a consequence, it is not physically feasible for many schools to install such a system, particularly in urban settings. Moreover, concerns about population density and adding to existing pollution tend to be greater in cities. Thus, wood biomass heating systems are unlikely to be proposed in most urban schools.

While this Symposium has focused on the public health concerns of wood biomass heating in schools, energy and health are just two components of sustainability that drive design choices in high-performance school buildings. All New England states and New York participate in the Collaborative for High Performance Schools (CHPS), a benchmarking system that seeks to optimize the attributes of a high-performance school. In addition to health and energy efficiency, the CHPS system includes criteria such as indoor environmental quality, building siting, materials selection, and water efficiency.[50] This often means that the benefits of any one attribute are not fully maximized for a given school building.

The primary incentive driving schools to exchange their old oil boiler for a new wood biomass boiler is financial. In the case of CHPS, more often than not the cost savings from increased energy efficiency and lower fuel costs is so substantial that they also offset higher costs of other CHPS strategies, such as choice of building materials. Yet the benefits of using wood heat are not just financial and not just experienced by the school itself. Additional sustainability benefits include support for local employment in the wood chip and pellet industries, as well as reduced public health impacts of extraction, refinement and transportation of oil.

However, several concerns have been raised regarding the use of wood biomass to heat New Hampshire schools. The primary concern is the availability of wood fuel. As more and more wood biomass heat and power systems come online, there is a fear that fuel supply may become limited. With a constrained supply, wood fuel costs may rise dramatically. While supply has not been an issue to date, this remains a question despite various studies to examine this topic in the Northeast. A second concern is the reliability of the boilers themselves in achieving the efficiencies and pollutant emission levels stated in the boiler manufacturer's specifications. Wood biomass systems require facility managers to maintain many more moving parts than traditional oil or gas boilers and routine maintenance and tuning are critical for optimal performance.

The final concern is the capacity of the regulatory structure to ensure that emissions from ICI biomass units do not harm public health. Though New Hampshire's regulations are among the most stringent—requiring that air dispersion modeling be done as part of the permitting process, even for small wood boilers—its capacity to enforce existing regulations is limited. Even the most stringent regulations are effectively meaningless if there is no capacity to enforce them, and New Hampshire has experienced drastic cuts in state agency resources.

Lani Graham, Maine Medical Association

Maine is a heavily forested state, and its state and local economies are heavily dependent on this natural resource. The current government administration in Maine supports wood biomass energy and is opposed to new regulations that affect businesses. Because of these and other factors that drive Maine's current politics, it will be an uphill struggle to elevate the issue of public health impacts of non-residential wood biomass combustion.

The Maine Medical Association (MMA) represents approximately 3,500 physicians in Maine. MMA is a dues-paying organization, which means that the Association is responsive to the interest of its membership. While the membership's primary interest is physician wages and working conditions, issues affecting public health in Maine are also a concern. MMA's active public health committee is the primary mechanism by which rank and file members become engaged in specific public health issues.

[50] For a complete list of the standards see: www.chps.net

The committee can develop resolutions, which if agreed to by the membership, become MMA policy, triggering allocation of resources, including advocacy by leadership and by legislative lobbying staff. Independent of MMA policy positions, member physicians are often willing to support communities with health concerns by providing testimony at local and state hearings. Yet to date, the issue of public health impacts from non-residential wood combustion is not on the radar of the vast majority of MMA members.

There are two primary constraints that limit physicians' engagement in public health issues. First, MMA members work on public health issues as volunteers, limiting the amount of time and level of effort they are willing to invest. Second, the continually changing expectations and demands placed on physicians as a result of health reform initiatives limit physician attention and action, whether the issue is air pollution, obesity, tobacco use, or toxics. Time allowed in the exam room to respond to patient concerns is decreasing, not increasing. In addition, the knowledge needed to practice patient-level health care is increasing exponentially, which constrains physicians' time to learn about and engage in broader public health debates.

If physicians are to spend their volunteer time on this issue, they will need to feel that they are making a difference in improving and protecting the public's health. Whether working through a state medical association chapter or in other ways, a number of strategies could help raise awareness among physicians about the impacts of ICI or EGU wood combustion. These include developing clear, one-page summaries of the health impacts of concern as well as hosting forums to present the relevant scientific evidence. Whatever the strategy, it is important to elevate issues that are of primary interest to physicians, such as the impact on children. In addition, because physicians are keenly interested in the health of their individual patients, patient-level prevention strategies will be of particular interest. For example, physicians would be interested in learning about the results of the intervention study Dr. Brauer discussed, which demonstrated that HEPA air filters reduce indoor levels of airborne particulates from woodsmoke, and decrease respiratory symptoms.

Charlie Niebling, New England Wood Pellet and Biomass Thermal Energy Council

New England Wood Pellet is a wood pellet manufacturing company headquartered in Jaffrey, New Hampshire, with manufacturing plants in New Hampshire and New York. It promotes advanced wood combustion, and believes that wood pellets can play a role in supporting regional sustainability.

Through its products, its technology and its actions, the advanced wood combustion industry seeks to demonstrate that there is a better way to use wood to make heat that is less polluting and more efficient. This technology is "not your grandfather's wood boiler." An important challenge is to showcase technological advances that respond to concerns about air emissions and public health impacts.

There are a number of values about wood combustion shared throughout the region that present opportunities. The first is energy independence. The Northeast is far more dependent on petroleum for transportation, for industrial uses and for heat than other regions in the country. Together, the New England states and New York consume the vast majority of heating oil and propane used for industrial, commercial and residential heat. The region exports over $15 billion for these fuels, paying entities outside regional and national borders, with consequences for the economic health of the region and for our nation's security.

A second shared value is sustainable economic development, especially in rural regions in Maine, Vermont, New Hampshire, western Massachusetts, much of the state of New York, and even parts of Connecticut. When the fuel dollars stay in this region, they support a significant number of jobs that would otherwise go elsewhere. A third value is efficiency: wresting as much useable energy as possible out of a given fuel. A fourth value is minimizing environmental impacts of energy extraction and use in ways that are responsible and responsive to the environment, including practicing sustainable forestry and maintaining clean air. Finally, a fifth shared value is public acceptance.

The expansion of any energy resource, renewable or otherwise, that does not carefully balance shared values, will fail in the long run. Companies that came together to form the Biomass Thermal Energy Council recognize that a successful future for biomass fuel depends on leadership by the advanced combustion industry in embracing shared values, including concerns about public health impacts.

We are currently in the phase of early market adoption of the most advanced combustion technologies. They have high capital costs that make it difficult for individuals and organizations to consider adopting this technology, even when low operating costs result in an attractive return on investment. Anything that increases capital costs, especially in the early stages of a new technology deployment, can make it difficult if not impossible to achieve the economies of scale which in turn lower costs.

Yet, current federal and state energy policies favor and incentivize the least efficient uses of biomass. Whether at the level of federal tax policy or state Renewable Portfolio Standards (RPS) programs, there is virtually no incentive structure to promote and support the most efficient uses of biomass, in particular the production of heat through direct combustion. Moreover, the thermal biomass industry competes in the marketplace with coal, natural gas, and oil, which are supported by a complex web of incentives and other policies. The policy environment is unintentionally hindering the transition of a wood energy economy away from inefficient uses to more efficient uses.

In addition, the current regulatory structure is archaic. Despite evolution over time, it has its origins in a post-WWII America focused on coal and oil and has yet to embrace what the biomass thermal industry can offer. Indeed, the regulatory structure can be punitive to advanced wood combustion technologies. For example, air permit fees are based on the tons of total criteria air pollutants that are emitted, yet there is no differentiation between the types of pollutants, despite differences in public health and environmental impacts.

Perceptions of biomass have been largely influenced by the thick blankets of smoke in the hilly regions of rural New England on winter mornings, or the often excessive smoke emitted by outdoor wood boilers. The Biomass Thermal Energy Council is advancing vastly different technologies than those responsible for such woodsmoke pollution. Help is needed to communicate this to the skeptics.

There are opportunities for advancing the dual goals of public health protection and clean, renewable energy. First, we need to move away from our current technology-biased energy policy to a more outcomes-focused approach where clean air, job growth and sustainable forests are the benchmarks. If we create energy policies that reward efficiency, we will achieve these outcomes. Secondly, we need to restructure permit fees so that heavy fees are levied on the most harmful emissions, to empower the project applicant to determine the most cost-effective way of reducing emissions. We need to avoid regulations that pick winners and losers among the range of technology options.

Next, we need to support continuous improvement in biomass thermal technologies with the kinds of incentives and support that made possible the tremendous growth in the use of wood for heating in Europe over the last fifteen years. No industry can go from zero to one-hundred in 2.5 seconds, and policies should not impose such high barriers that all progress grinds to a halt.

Next, we need to keep in mind the comparative risks when balancing the important objectives of public health protection with all of the other shared values associated with renewable energy policies in the Northeast. Lastly, if a government agency or foundation is willing to support a design contest for the cleanest wood biomass combustion technology with a significant financial reward for the winners, the innovations that will likely emerge will be ground-breaking.

Summary

Many of the panelists suggested opportunities for advancing public health protections in the context of wood biomass combustion. Highlights include:

- federal and state environmental policies requiring assessments of the health implications of proposed projects;
- HIA as a tool for engaging the public and ensuring that health considerations are taken into account at the early stages of a project;
- the development of roadmaps to set goals and drive short and long-term planning for policy changes that promote technological innovation to achieve them;
- the importance of physician educational materials and identifying patient interventions to reduce health risks from woodsmoke exposure that can benefit an individual as well as a population;
- a shift to policies that drive continual improvement and that are focused on outcomes like clean air, job growth and sustainable forests, rather than focused on specific technologies; and
- initiatives (such as a design contest) to advance market-ready clean combustion design innovations.

Section 5. Roundtable Discussions and Plenary: Promising Policy and Program Tools for Coordinated Regional Action

Following the panel discussion, participants gathered in six small roundtable groups to discuss actions that hold promise for protecting public health from ICI and EGU wood burning. Key informant interviews in advance of the Symposium had identified six broad areas for action. Each roundtable was charged with focusing on one of these areas, identifying priority program or policy changes, and specifying action steps to advance the priorities.

Each group's recommendations are summarized below. In addition, an electronic survey following the Symposium invited participants to prioritize the action steps made by all six roundtables. Results of this survey are summarized in Section 6.

Topic #1: Encouraging Cleanest-Burning Combustion Technologies.

Charge to Roundtable 1: Consider what priority policy and/or program changes are needed to encourage the development and installation of ICI wood combustion technologies and fuel combinations that are as clean or cleaner (i.e., do not increase near-source exposure) than the fuels/combustion technology being replaced.

Roundtable 1 Priority Program or Policy Changes and Specific Action Steps

1. **Develop a best practices guide for optimizing biomass heating combustion efficiency and performance.** The guide should review state-of-the-art high-efficiency biomass heating system design, including the use of thermal storage to manage low load conditions as well as technologies that integrate biomass combustion with the use of solar or clean-burning oil/gas technologies. The guide should also review best-performing emission control technologies and practices for ensuring high combustion efficiencies and lower emission levels.
2. **Establish regional specifications for wood biomass fuel and appliance standards.** These regional specifications should include efficiency and emission standards as well as consistent ratings for fuel, including ash and moisture content (pellets and chips) used for biomass heating. Real field performance data on a broad range of appliance and fuel types is needed to establish these standards.
3. **Provide incentives or financing programs to off-set the up-front costs of new wood biomass heating projects.** Federal tax credits available for other renewable fuel technologies should be extended to biomass heating technology. Additional options could include performance-based incentives, such as a state's renewable portfolio standards or analogous programs, innovative financing programs, such as third-party ownership or a loan-loss reserve fund, as well as capacity rebates for high-efficiency biomass combustion units or those using integrated solar-thermal units.

4. **Research and develop low-cost advanced emission control technologies.** This research is not limited to add-on emission control devices, but should also include novel combustion technology design.

Topic #2: Regulatory Programs, Policies and Tools for ICI Wood Combustion

Charge to Roundtable 2: Identify opportunities for regulatory tools (e.g., emissions testing and modeling, permit thresholds, emission limits, BACT requirements, and others) to: a) fill current gaps in control of emissions from ICI wood combustion technologies; and b) promote cleanest-burning technologies**.**

Roundtable 2 Priority Program or Policy Changes and Specific Action Steps

All priority regulatory solutions identified require additional regional engagement across states in the Northeast to further refine and develop.

1. **Establish a certification process and a recertification/review process for wood biomass combustion systems.** Regular certification should be required of all systems—there would be no unit size threshold. This certification process is important for all ICI/EGU boilers, not just those using wood fuel.
2. **Establish a boiler performance rating system to support setting emission limits that drive continuous improvement.** The system should be based on identifying and comparing emissions from current combustion technologies to rate the best performing technologies—the top 10% of units. The ratings would be the basis for setting emission standards. Continued use of the rating system should support evolving emission standards as combustion technology becomes cleaner burning.
3. **Establish and enforce a fuel specification standard.** This standard would be needed for biomass fuels as well as all the broader range of heating/combustion fuels (e.g. oil).
4. **Streamline regulatory requirements.** The number of regulatory requirements for biomass boilers (e.g., air permits, ASME requirements) should be examined and streamlined where appropriate.
5. **Charge facilities a fee based on all pollutants emitted to promote the use of advanced technologies that can lower emissions.** Fees should be used to develop more robust and comprehensive programs for monitoring and analyzing emissions data.

Topic #3: Guidance and Educational Materials

Charge to Roundtable 3: Consider what kinds of tools, materials and content are needed for decision makers (such as school boards and facilities managers), to elevate health considerations in the installation and management of institutional/commercial boilers. This would include information about health hazards and opportunities for reducing exposure to pollutants.

Roundtable 3 Priority Program or Policy Changes and Specific Action Steps

1. **Require that ICI boiler operators receive formal operations training.** Training should include health impact information. Non-regulatory opportunities to enhance biomass boiler operator training may include expanding training programs offered by vendors and manufacturer associations as well as non-profit organizations engaged in educational outreach to facility managers and school boards.
2. **Establish and coordinate a regional informational clearinghouse on public health risks of wood biomass combustion.** The entity establishing this clearinghouse should develop and/or adapt existing fact sheets and other publications that provide comprehensive information about the risks (e.g., health, especially in susceptible and vulnerable populations) and benefits (e.g., supporting local economies, reducing energy costs, etc.) associated with wood biomass energy. The clearinghouse should include a glossary of terms that are important for understanding wood biomass energy and air regulations as well as terms relevant to understanding and evaluating public health risks.
3. **Require that facility proponents address the public's concerns regarding health impacts during air permit processes (conducting a health impact assessment, for example).** Educational material can be developed to help the public become better informed regarding key questions to ask in the evaluation of health impacts during the permit process as well as during the monitoring of existing facilities' emissions and operating characteristics.

Topic #4: Filling Policy-Relevant Research Gaps

Charge to Roundtable 4: What scientific gaps are essential to fill as health considerations become more prominent in decision-making about non-residential wood combustion? What opportunities are there for conducting research to fill these gaps in a timeframe that is useful to policy makers?

Roundtable 4 Priority Program or Policy Changes and Specific Action Steps

1. **Design and conduct an efficient study of the health effects (or biological markers) to address whether children are being harmed by woodsmoke emissions in their schools.** School absenteeism due to conditions associated with woodsmoke exposure, such as asthma, would be a feasible endpoint to pursue.
2. **Design and conduct an exposure study that fully describes the PM and non-PM emissions from a state-of-the art advanced combustion ICI wood biomass unit.** Exposure assessment studies are needed to clarify if the current risk management methods based on characterization of stack emissions is sufficient to protect public health. In addition to PM, these exposure assessments need to characterize exposure associated with the broader array of pollutants from wood biomass combustion, including VOCs, PAHs, dioxins, and heavy metals.
3. **Design and conduct a qualitative research study to evaluate the level and sources of public knowledge regarding non-residential wood biomass emissions.** Greater knowledge is needed to understand the extent to which the general public understands the potential public health risks associated with wood biomass combustion emissions.

Topic #5: Public Health Engagement in Energy Decision-Making

Charge to Roundtable 5: Consider what policy/program changes and tools will help facilitate increased public health engagement in energy decision-making, with particular reference to non-residential wood combustion.

Roundtable 5 Priority Program or Policy Changes and Specific Action Steps

1. **Formally integrate health into energy planning processes.** This integration could be facilitated by conducting health impact assessments (HIAs) for proposed energy projects as well as for state-wide energy planning. All stakeholders should be engaged early in the design and execution of the HIA.
2. **Establish a regional working group to integrate public health into energy decision-making.** This working group should include a range of state agencies as well as non-governmental organizations and industry stakeholders.
3. **Develop HIA standards.** Standardization of health impact assessment methods appropriate for the broad range of energy projects, from a proposed boiler in an elementary school to a 30 MW electric generating plant, is needed. Key components of HIA that require standardization include: assessing baseline health conditions in the community or communities of concern, addressing environmental justice, examining the health risks and health benefits, and assessing the economic/financial health costs and/or savings. Standards should also include engaging stakeholders early in the HIA process. A key first step should be to develop a working definition of health impact assessment (as distinguished from ATSDR's public health assessment or risk assessment, for example).
4. **Establish an information clearinghouse.** This clearinghouse could house model language for integrating public health into state energy plans (e.g. specific HIA methods required) as well as existing state policies and legislation relevant for evaluating public health during the siting of energy facilities, such as thresholds for conducting risk assessment review and permitting. Best industry practices as well as protocols and guidelines to address public health concerns that are not addressed under current regulatory practice could also be included.

Topic #6: Public Health and Large-Scale Wood Biomass Combustion

Charge to Roundtable 6: Consider what policy and program changes are needed to fill knowledge gaps and address public health concerns associated with large-scale wood biomass combustion.

Roundtable 6 Priority Program or Policy Changes and Specific Action Steps

1. **Require an HIA when evaluating air permit applications.** This requirement could be instituted through state regulations either as part of a state's analogous National Environmental Protection Act program and/or as dictated by a state's energy plan. Requiring an HIA will help improve the siting and operations of large-scale wood-burning units as well as address public concerns about health impacts, especially in areas that are already polluted.
2. **Improve the process used by states in the Northeast region to regulate biomass combustion, including addressing inconsistencies and sharing information.** Organizations such as the

Northeast States for Coordinated Air Use Management (NESCAUM) could help increase consistency among the varying regulations associated with wood biomass combustion units in Northeast states. It could coordinate a clearinghouse of information to enhance communication about regulatory models and policies.

3. **Improve understanding of the emission rates and ambient air impacts of air toxics associated with large-scale biomass combustion, given variability in operating and load characteristics, fuel types, and meteorological and topographical conditions.** Data are needed to better characterize emissions under a range of operating conditions (such as during start-up and shut-down) and fuel compositions. The analyses should address a broader range of toxic pollutants common in woodsmoke than just criteria air pollutants. Because ambient air impacts are affected by source characteristics (e.g., stack height, exit temperature and velocity) as well as meteorological and topographical characteristics, air dispersion analyses are needed for those smaller combustion units that often fall below regulatory thresholds requiring impact analyses.
4. **Require wood biomass combustion units that burn construction and demolition wood debris to be regulated as waste incinerators.** Incineration programs are better equipped to provide the increased regulatory scrutiny that is needed during the permit process for new facilities and during regulatory enforcement activities of existing facilities.

Section 6. Conclusion: Synthesis and Future Directions

Recommendations to Guide Future Work

Dr. Hoppin concluded the day's program with observations about the accomplishments of the meeting and opportunities for elevating health in decision-making about wood biomass and for protecting public health. This section summarizes her remarks, and subsequent work by the Lowell Center to synthesize the results of the Symposium.

Common Goal and Guiding Principles

Dr. Hoppin noted that the Symposium presentations and discussions reflect a common goal of the stakeholders who participated: healthy renewable energy. Across the broad array of disciplines, organizations and sectors represented, she observed a "sense of the Symposium": that policies and programs promoting wood biomass energy should prioritize the protection of public health. Recognizing that the debate about wood biomass as a source of renewable energy has focused on its impact on local economies, dependence on fossil fuels, forest health and carbon neutrality, Symposium participants urged that public health be systematically considered in biomass decisions, along with these other important societal goals.

Drawing on the day's discussions, the Lowell Center identified **four principles to guide work that supports the goal of healthy renewable energy**. ***First, it is important to fill relevant data gaps, but there is sufficient scientific information to proceed with common-sense actions to reduce exposures to woodsmoke.*** The Symposium presentations and discussion enhanced a collective understanding of the known risks to human health from wood combustion. They also identified gaps in the relevant science. One significant gap is that no study to date has evaluated the impacts of exposure to woodsmoke on high-risk populations, such as school children, taking into account the variability in emissions that can occur during normal boiler operations. Better information about likely impacts of localized pollution on susceptible populations will be helpful for decisions about boiler installations, as well as for policy decisions (for example, the promotion of wood biomass combustion to provide heat in schools). Studies are also needed to evaluate peak exposures, rather than average exposures, to ascertain risks of exacerbating asthma and other health effects. Yet, eliminating incentives for boilers that do not meet the highest emission standards should not wait for research results.

Too often in environmental health debates, gaps in scientific knowledge become excuses for not moving forward with common-sense efforts to reduce risk. Symposium participants recommended both filling policy-relevant research gaps and taking action—by advancing the use of the cleanest burning technologies for example—before the gaps are filled. A premise of the Lowell Center is that systems of production and consumption are not only root causes of pollution but also part of the solution. Dr. Hoppin applauded the group for integrating efforts to better understand the problem with finding solutions.

Second, though there may be disagreement about the pace of change that is needed or feasible, the principle of continual improvement is important: all policies should drive continual improvement in technologies to achieve greater combustion efficiencies and lower emissions of pollutants.

Third, the need for regional coordination on these issues surfaced throughout the day, and was formally reflected in several recommendations. In particular, innovation can be undermined or encouraged by differences in state policies and programs. Several organizations represented at the Symposium—for example, the Northeast States for Coordinated Air Use Management (NESCAUM), the Asthma Regional Council of New England, the American Lung Association, and the regional offices of EPA, DHHS and the U.S. Forest Service—have important roles to play in coordinating initiatives to advance healthy renewable energy in the Northeast. Coordination among agencies within states and across the Northeast region is needed to maximize the effectiveness and efficiency of regulations, programs and other tools that protect public health and advance cleanest-burning technologies.

Fourth, it is important to consider the health and environmental impacts of wood biomass technologies across the life cycle—upstream as well as downstream. Upstream decisions may have significant implications. For example, pellets may burn more cleanly than wood fuel, but the manufacturing process uses more energy and is itself polluting. Moreover, health risks from wood biomass energy are not limited to stack emissions from wood-burning units. Workers who make wood chips and pellets are at risk of both accidental injury and health impacts associated with wood dust, molds and endotoxins. Sustainable forestry practices are essential for carbon sequestration, yet excessive demand for wood could undermine sustainable forestry practices and contribute to climate change, with its devastating health and environmental consequences. On the other hand, improvements in local economies associated with wood biomass activities can carry health benefits. An examination of the full life-cycle supports a more complete consideration of impacts and trade-offs. That said, while a broader understanding of system-level impacts has the potential to reveal solutions that avoid unintended health and environmental consequences, it is important to define a scope that is manageable given available analytical tools, that capitalizes on opportunities for promoting better—if not perfect—practices and that encourages continual improvement.

Dr. Hoppin concluded by thanking all those involved in planning, financially supporting, contributing ideas, and participating in the Symposium. She committed Lowell Center resources to follow up the Symposium. This includes a conducting a survey of participants to further prioritize recommendations and fundraising to support implementation of the recommendations.

Recommendations

From the presentations, panel remarks, roundtables and plenary discussions, the Lowell Center synthesized five broad recommendations, which align with the priority action steps generated by the roundtables, described below.

1. **Constructively engage the public.** Informed people given opportunities to participate fully in planning and decision-making are capable of providing and considering relevant data, weighing

trade-offs, and proposing solutions. Their ideas and ability to build on aligned interests often transcend the constraints of individual agencies. Collaborative work across government agencies can complement the benefits of early and effective engagement by the public.

2. **Prioritize public health in wood biomass decision-making across the Northeast.** Public health implications need to be considered early in the energy planning process, and health goals maximized as part of initiatives to advance other important societal goals, such as energy efficiency, sustainable forestry practices, carbon neutrality, reduced reliance on fossil fuels and economic revitalization.
3. **Promote better understanding and consideration of health impacts on susceptible and vulnerable populations, as well as measures to reduce individual and community exposures.** Wood biomass combustion can result in peak localized exposures that pose risks to susceptible populations in particular. Yet they are not accounted for in air quality permitting. These factors should be taken into account before choices are made about siting, boiler and control technologies, fuel, operator training, and other steps that can improve protection of public health. For example, policy makers might consider a principle that the installation of wood boilers in institutions frequented by susceptible populations—such as schools and hospitals—should proceed only if the boiler emissions will be comparable to or lower than emissions from the cleanest alternative fuels or technologies.
4. **Incentivize and reward only high-efficiency, clean, wood-fired combustion, with consistent standards across the Northeast, focusing not only on technologies but also on outcomes.** With the exception of a few state initiatives, current incentives, both the carrot and stick varieties, do not reward the cutting-edge, healthiest technologies. Rather, they support–or fail to constrain–all ICI and EGU wood combustion technologies with the justification that they do not depend on fossil fuels. The Lowell Center urges decision-makers to consider incentivizing only those wood biomass systems whose emissions are comparable to those of the cleanest alternative fuels and technologies, taking into consideration variability in conditions that affect emissions.
5. **Fill gaps in existing air quality regulation and air quality monitoring capacity. Consider other regulatory measures to protect public health and discourage all but the cleanest-burning wood biomass units.** The Symposium identified a number of ways in which current regulatory practices fail to address pollution from ICI and EGU scale wood combustion. Filling these gaps—which include lack of regulatory scrutiny of smaller ICI units, variable emission limits from state to state, and lack of consideration of localized pollution, among others—and considering additional regulatory measures is important not only for protection of public health but also for the economic viability of the most advanced technologies.

Symposium Evaluation

The Lowell Center and the Symposium Planning Committee had set two goals for this meeting:

1. Exchange information about the state of the science regarding health effects of wood biomass combustion, with a focus on institutional, commercial and industrial-scale use.

2. Discuss policy and program changes that hold promise for protecting public health from non-residential wood combustion.

Participants gave the Symposium top marks in their written evaluations of the Symposium. In follow-up discussions, the Planning Committee concurred that the meeting had met its objectives, providing high-caliber presentations and generating practical action steps with broad support that have the potential both to elevate health in wood biomass decision-making, and to improve public health protection.

Yet beyond a report summarizing the content of a successful meeting, what potential is there for the ideas generated and the relationships built to catalyze changes? What steps can participants and their colleagues take to address scientifically grounded concerns about risks to health from these technologies? Survey respondents expressed strong interest in building on the Symposium and helping to advance its action steps.

Opportunities for Leadership by Key Constituencies

The recommendations and action steps detailed in earlier sections and summarized above reflect cross-constituency discussions to identify changes that multiple interests agree are needed. Though they may not include the most ambitious reforms of policies or programs that some of the constituencies urge, the recommendations and action steps have the potential, both in their content and in their broad-based support, to result in dramatic improvements to public health.

An important next step for government agencies, health professionals, scientists, private companies, and advocates is to identify those recommendations for which their sector's or organization's leadership will be critical. Each institution will find opportunities for action within its purview that are also feasible to incorporate into current activities, even in a resource-constrained environment. The Lowell Center encourages each participant to systematically revisit the results of the Symposium with colleagues who did not attend, and start implementing one or more priority action steps.

Highest Priority Action Steps for Policy and Program Change: Post-Symposium Survey

In each roundtable, participants prioritized action steps, setting aside a long list of good ideas to focus on 3-5 within each broad area for action. The final list of 23 priority changes across 6 roundtable discussions, as summarized in Section 5, is not exhaustive; rather it reflects the participants' best judgment about priorities within a given broad area. All 23 should be considered recommended action steps from the Symposium.

The roundtable process did not allow for participants to prioritize across roundtable topics. To identify the top priorities among all that were proposed, the Lowell Center surveyed participants one week after the Symposium, asking them to choose their top four priorities for policy or program change, and to rank them. [51] Thirty percent of Symposium participants, representing all of the constituencies except for

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[51] The survey was administered via Survey Monkey. It included a 4-point scale (priority 1-priority 4) to collect rankings among the list of 23 roundtable recommended action steps. The survey condensed similar

the heat and power industries, responded to the survey. Nine action steps were identified as top priorities (numbered below).

Health Impact Assessment

Respondents ranked the two recommendations related to Health Impact Assessment (HIA) as the highest priorities. A total of 77% of survey respondents selected at least one of them. Of those who prioritized HIA, 71% prioritized the first recommendation below. Twenty-nine percent of respondents who prioritized HIA gave the highest priority to the second. Among Symposium participants who included one of the HIA-related recommendations among their priorities, 92% ranked them first or second among their four votes.

1. Formally integrate health into energy planning processes by advancing health impact assessment.
2. Develop standardized Health Impact Assessment methods appropriate for the broad range of energy projects.

Other Priority Action Steps

At least one third of survey respondents ranked the following actions steps among their top four priorities, with 50% or more of respondents ranking the first three as their first or second priority:

3. Establish regional specifications for appliances, including efficiency and emission standards.
4. Design and conduct an efficient study of the health effects (or biological markers) to address whether children are being adversely affected by woodsmoke emissions in their schools.
5. Develop a best practices guide for optimizing biomass heating combustion efficiency & performance.
6. Establish regional specification standards for wood biomass fuel (e.g., ash and moisture content etc.).
7. Provide incentives or financing programs to offset the up-front costs of new cleanest-burning wood biomass heating projects.
8. Improve understanding of the emission rates and ambient air impacts of air toxics associated with large-scale wood biomass combustion, given variability in operating and load characteristics, fuel types and meteorological and topographical conditions. (Though the roundtable group making this recommendation was charged with focusing on large-scale biomass facilities, plenary discussion over the course of the day suggested broad support for this recommendation across all scales.)
9. Establish a regional working group to integrate public health into the energy decision-making process.

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recommendations that emerged from more than one roundtable. It also included open-ended response questions to help clarify responses and gauge organizational interest and capacity to advance the specific priorities.

Though the survey reflects the priorities of only 30% of the Symposium participants, the respondents represent almost all of the constituencies who participated in the Symposium. While no industry stakeholders responded, three of the priorities ranked highly by survey respondents were proposed by Roundtable 1 on "Encouraging Cleanest Burning Combustion Technologies," in which most of the industry stakeholders participated.[52] Thus, given the alignment of stakeholder interests and the capacity of each of the survey respondents to engage partners within and outside of their organizations, these recommended action steps likely have particular potential to gain traction.

Conclusion

The reviews of the state of the science by leading researchers at the Symposium clearly established the public health hazards of the proliferation of wood combustion as a source of heat and power. Policy and program changes identified by Symposium participants comprise an agenda for action by a range of constituencies that would fill the research gaps, and take steps now—given inherent uncertainty in the science—to prioritize the protection of public health as wood biomass and other renewable energy initiatives unfold. But beyond the content summarized in this report, the Symposium fostered communication across sectors and disciplines, enabling people who have historically not worked together to connect, identify common ground, and build relationships. In the months since the Symposium, some participating organizations have begun to capitalize on these relationships, exchanging information and strategies. With the publication of this report, the Lowell Center encourages participants and their colleagues to systematically revisit the action steps they have the potential to advance, and to identify opportunities to work together—across agencies, across sectors and across states—to implement recommendations that need action by multiple parties. The Lowell Center looks forward to continuing to collaborate with Northeast partners to advance policies, programs and practices that hold particular promise for elevating health in discussions and action on wood biomass combustion, for protecting public health, and more broadly, for advancing the common vision of healthy renewable energy.

[52] These three included (1) establishing regional specifications for appliances and for fuels; (2) developing a best practices guide; and (3) providing incentives or financing to off-set the up-front costs of new cleanest-burning technologies. See Section 5 for a complete description.

Appendix A: Symposium Attendees

Name	Organization
Judith Abbott	New York State Department of Health
Raymond Albrecht	Raymond J Albrecht LLC
Robyn Alie	Massachusetts Medical Society
George Allen	Northeast States for Coordinated Air Use Management
Norman Anderson	Environmental Public Health Consultant
Claire Barnett	Coalition for Healthier Schools/Healthy Schools Network
Linda Bonanno	New Jersey Department of Environmental Protection
Gordon Boyce	MA Department of Conservation
Anette Kocbach Bølling	Norwegian Institute of Public Health
Michael Brauer	The University of British Columbia
Dwayne Breger	MA Department of Energy Resources
David Brown	Environment and Human Health Inc
Ellen Burkhard	New York State Energy and Research Authority
Tom Butcher	Brookhaven National Lab
Stacey Chacker	Asthma Regional Council/Health Resources in Action
Richard Clapp	University of Massachusetts Lowell
Molly Clark	American Lung Association in Rhode Island
Shanna Cleveland	Conservation Law Foundation
Suzanne Condon	Massachusetts Department of Public Health
Cathy Crumbley	University of Massachusetts Lowell
Lindsay Dearborn	New Hampshire Division of Public Health Services
David Deitz	Massachusetts Medical Society, Committee on Environmental and Occupational Health
Douglas Dockery	Harvard School of Public Health
Beverly Drouin	New Hampshire Department of Health and Human Services
Jay Duffy	Clean Air Council
Michael Dumond	New Hampshire Department of Health and Human Services
David Dungate	ACT Bioenergy, LLC
Lani Graham	Maine Medical Association
Richard Greves	State of Maine Department of Environmental Protection
Heidi Hales	Vermont Department of Environmental Conservation
Rick Handley	Rick Handley & Associates
Eileen Hiney	MA Department of Environmental Protection
Razelle Hoffman-Contois	Vermont Department of Health
Philip Hopke	Clarkson University
Polly Hoppin	University of Massachusetts Lowell
William Irwin	Vermont Department of Health
Molly Jacobs	University of Massachusetts Lowell

Name	Organization
Susy Jones	Northeast Energy Efficiency Partnerships
Katie King	American Lung Association of New England
David Kriebel	University of Massachusetts Lowell
Rebecca Laws	Boston University School of Public Health
Edward Miller	American Lung Association of New England
Terry Miller	U.S. Agriculture Department, Forest Service
Barbara Morin	Rhode Island Department of Environmental Management
Edward Murdough	New Hampshire Department of Education
Carolyn Murray	Dartmouth Medical School
Charlie Niebling	New England Wood Pellet LLC
Lisa Rector	Northeast States for Coordinated Air Use Management
Rob Rizzo	MA Executive Office of Energy and Environmental Affairs
Betsy Rosenfeld	U.S. Department of Health and Human Services, Region 1 (New England)
Rebecca Ryan	American Lung Association, Vermont Chapter
Alison Simcox	US Environmental Protection Agency
Evan Smith	Vermont Department of Health
Mark Smith	MA Department of Environmental Protection
MaryBeth Smuts	US Environmental Protection Agency, Region I
Steve Snook	Vermont Department of Environmental Conservation
Mark Torpey	New York State Energy and Research Authority
Mark Utell	University of Rochester, School of Medicine and Dentistry
Neil Veilleux	Meister Consultants Group
Randi Walker	New York State Department of Environmental Conservation
Steve Walker	New England Wood Pellet LLC
Marc Wolman	MA Department of Environmental Protection
Jeff Yanosky	Penn State College of Medicine

Appendix B: Symposium Agenda

WOOD BIOMASS FOR HEAT & POWER: ADDRESSING PUBLIC HEALTH IMPACTS

November 7, 2011

Massachusetts Medical Society, Waltham MA

MORNING SESSION

Registration 8:00 AM – 8:45 AM

Welcome 8:45 AM – 9:05 AM

- Dr. Polly Hoppin, University of Massachusetts Lowell
- Mr. Terry Miller, US Forest Service
- Ms. Betsy Rosenfeld , US Department Health & Human Services, Region 1

Health Effects of the Use of Wood for Heat and Power in the Northeast (9:05 AM – 12:00 PM)

Session 1: State of the Science: Woodsmoke Emissions and Health (9:05 – 10:15)
Moderator: Dr. Richard Clapp, University of Massachusetts Lowell

- ***Particulate Matter, Air Toxics & Health: The Big Picture.*** Dr. Doug Dockery, Harvard School of Public Health
- ***Biomass Combustion, Exposure and Health Effects.*** **Dr.** Mike Brauer, School of Environmental Health, University of British Columbia
- ***Toxicity of Woodsmoke Particles Generated Under Different Combustion Conditions.*** Dr. Anette Kocbach Bølling, Norwegian Institute of Public Health
- ***Audience Questions and Discussion***

BREAK (10:15 - 10:30)

Session 2: ICI Wood-Burning in the Northeast (10:30 - 12:15)
Moderator: Mr. Norman Anderson, Environmental Health Consultant

- ***Air Emissions and Permitting: ICI Biomass Boilers*** Mr. Steve Snook, VT Department of Environmental Conservation
- ***Energy & Emissions Performance of Commercial Wood Boilers.*** Dr. Ellen Burkhard, New York State Energy Research Development Authority
- ***Estimating Public Health Impacts: Air Receptor Modeling & Measurement.*** Dr. Phil Hopke, Clarkson University
- ***Discussants***
    - Ms. Lisa Rector, Northeast States for Coordinated Air Use Management
    - Dr. Mark Utell, University of Rochester Medical Center
- ***Audience Questions & Discussion***

LUNCH (PROVIDED) (12:15 - 1:15)

WOOD BIOMASS FOR HEAT & POWER: ADDRESSING PUBLIC HEALTH IMPACTS
AFTERNOON SESSION

Policy and Program Opportunities and Recommendations for Reducing Exposure to ICI Wood Combustion Emissions (1:15 PM – 4:30 PM)

Session 3: Moderated Panel; Current Practice and Perspectives from Northeast States (1:15-2:30)
Moderator: Dr. Polly Hoppin, University of Massachusetts Lowell

- Ms. Suzanne Condon, Massachusetts Department of Public Health
- Dr. Bill Irwin, Vermont Department of Health
- Ms. Barbara Morin, Rhode Island Department of Environmental Management
- Mr. Mark Torpey, New York State Energy Research and Development Authority
- Mr. Ed Murdough, New Hampshire Department of Education
- Dr. Lani Graham, Maine Medical Society
- Mr. Charlie Neibling, Chair, Biomass Thermal Energy Council
- ***Audience Questions and Discussion***

BREAK/TRANSITION (2:30-2:45)

Session 4: Roundtable Discussions and Plenary: Promising Policy and Program Tools for Coordinated Regional Action
Moderator: Ms. Molly Jacobs, University of Massachusetts Lowell

Roundtable Discussions: 2:45-4:00

i. Encouraging Cleanest-Burning Technologies
ii. Regulatory Programs, Policies and Tools for ICI Wood Combustion
iii. Guidance and Educational Materials
iv. Filling Important Scientific Gaps
v. Public Health Engagement in Energy Decision-Making
vi. Public Health Protection and Large-Scale Wood Biomass Combustion Units

Plenary Report Back: 4:00-4:30

Symposium Synthesis & Closing Remarks (4:30 – 4:45)

- Dr. Polly Hoppin, University of Massachusetts, Lowell

Adjourn (4:45 PM)

Notice

Wood Biomass for Heat & Power

Addressing Public Health Impacts

SUMMARY OF A 2011 SYMPOSIUM

The Lowell Center for Sustainable Production uses rigorous science, collaborative research and innovative strategies to promote communities, workplaces, and products that are healthy, humane and respectful of natural systems.

The Lowell Center is composed of faculty, staff and graduate students at the University of Massachusetts Lowell who work collaboratively with citizen groups, workers, businesses, institutions and government agencies to build healthy work environments, thriving communities and viable businesses that support a more sustainable world.

This document is available at
www.sustainableproduction.org/WoodBiomass.php

Lowell Center for Sustainable Production
UNIVERSITY OF MASSACHUSETTS LOWELL

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