BEFORE THE
PUBLIC SERVICE COMMISSION OF WISCONSIN

Application of Wisconsin Electric Power Company for a Certificate of Authority to Construct and Place in Operation a 50 MW Biomass-Fueled Cogeneration Facility to be Located in the Village of Rothschild in Marathon County, Wisconsin	Docket No. 6630-CE-305

DIRECT TESTIMONY OF DAVID L. MACINTOSH, Sc.D. ON BEHALF OF D.C. EVEREST AREA SCHOOL DISTRICT

Q. Dr. MacIntosh, what is your professional address and position?

A. I am a Principal Scientist and Associate Director of Advanced Analytics and Building Science, at Environmental Health & Engineering, Inc., located at 117 Fourth Avenue, Needham, MA 02494.

Q. Please describe your educational and professional experience.

A. I have a B.S. in Decision Sciences and a M.S. in Environmental Science from Indiana University, and a Sc.D. in Environmental Health from the Harvard University School of Public Health.

As a Principal Scientist and Associate Director of the Advanced Analytics and Building Sciences Division at Environmental Health & Engineering, Inc. (EH&E), I lead exposure, health impact, and sustainability analyses for commercial, government, and not-for-profit organizations. My recent activity has focused on ambient air quality, heavy metals, naturally occurring radioactive materials, and contaminants in construction materials. I manage a group of 17 scientists, industrial hygienists, and engineers who specialize in characterizing and diagnosing the complex relationships among ambient conditions, human activities, and building systems that influence the environmental quality of the built environment. The majority of work in my division is performed under contract to the U.S. Consumer Product Safety Commission, U.S. Environmental Protection Agency, Commonwealth of Massachusetts, and various school systems, colleges, and universities.

In addition to my position with EH&E, I am an Adjunct Associate Professor of Environmental Health at the Harvard School of Public Health and Instructor of Environmental Management at the Harvard Extension School. I teach courses in human exposure assessment and environmental management to graduate and undergraduate students. Prior to joining EH&E, I was a tenured faculty member at the University of Georgia during which time I performed research on human exposure to chemical hazards in community and occupational settings; taught undergraduate and graduate courses on environmental chemistry, air quality, and hazardous waste management; and provided service to businesses, government agencies, and non-governmental organizations in Georgia, the United States, and internationally.

I am active in numerous professional venues in the field of environmental health science. I am a frequent author of scientific papers on human exposure to and health risks of environmental contaminants that are published in peer-reviewed scientific journals or presented at scientific meetings. I am also a technical advisor to the WHO International Program for Chemical Safety and have been an *ad hoc* member of the FIFRA Science Advisory Panel to the U.S. Environmental Protection Agency (EPA) for assessments of genetically modified foods, chromated copper arsenate, and chemical pesticides. I recently completed an external peer review of the Human Exposure and Atmospheric Sciences Division in the EPA National Exposure Research Laboratory and a human health risk assessment toolkit for the World Health Organization. In addition, I am a member of the Technical Advisory Panel for the Gulf Coast Children's Health Study being directed by the U.S. Centers for Disease Control and Prevention (CDC).

My professional qualifications are more fully set out in my curriculum vitae, a copy is attached as Exhibit 14.8.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to present information on potential air quality and health impacts to students, faculty, and staff of schools in the D.C. Everest Area School District, Weston, WI of air pollutant emissions associated with the proposed 50 MW Biomass-Fueled Cogeneration Facility to be located in Rothschild, WI.

Q. What materials did you review in the process of completing this work?

A. Some of the key literature that I reviewed includes the Environmental Assessment of the 50 MW Biomass-Fired Cogeneration Facility prepared by the Wisconsin Public Service Commission (PSC 2010), the Construction and Operation Application for the Biomass-Fueled Cogeneration Facility prepared by Wisconsin Electric Power Company (Wisconsin Electric 2010), and the Air Quality Impact Assessment prepared by RTP Environmental Associates on behalf of WE Energies (RTP 2010). All of the materials that I reviewed in conjunction with this assessment are referenced throughout this testimony and the complete citations are listed at the end of this testimony.

Q. In addition to the document review, what else did you do to form the opinions that you are presenting today?

A. I conducted a walk through inspection of Rothschild Elementary and portions of D.C. Everest Junior High and D.C. Everest Senior High. In addition, I obtained supplemental information from Dr. Kristine Gilmore, Superintendent of D.C. Everest Area School District, and Jeff Belott, Supervisor of Maintenance Operations for D.C. Everest Area School District, who accompanied me during these inspections. While in the Rothschild area, I also observed several other buildings in the D.C. Everest area, including Domtar Rothschild Mill, Wausau Airport, Central Wisconsin Airport, and Weston Power Plant.

Q Can you describe the operations for the proposed 50 MW biomass-fueled cogeneration power plant?

A. The proposed cogeneration facility is proposed to have an electric generating capacity of 50 megawatts (MW) and to also generate steam for the Domtar Rothschild paper mill (WEPCO 2010). Materials that I reviewed indicate that the facility will include a circulating fluidized bed (CFB) boiler, an extraction steam turbine generator; cooling towers; natural-gas fired auxiliary boilers (to supply process steam for the mill if the biomass boiler is out of service or if full electric capability is required); boiler water treatment; fuel receiving, processing, storage, and conveying systems; generator step-up transformers' associated control systems; and other improvements. The CFB boiler is described as being fueled with woody biomass, principally in the form of logging residue, with natural gas provided for start-up and flame stabilization purposes.

Q. Have you reviewed emissions rates of air pollutants from the facility as described by Wisconsin Electric?

A. Yes. I am aware of two sets of emission rates for nitrogen oxides, carbon monoxide, sulfur dioxide, particulate matter (all forms), and volatile organic compounds that have been reported for the facility in documents prepared by Wisconsin Electric.

Q. What is the distinction between the two sets of emissions data that you reviewed?

A. One set of emissions data is described as "Expected Annual Emissions (ton per year)", which I understand to be emissions estimated for utilization of the facility that is anticipated at this time. The other set of emissions data is described as "Potential to Emit (ton per year)", which I understand to be emissions estimated if the facility were to operate at maximum capacity. The total potential emission rate is approximately 3.5 times greater than the total expected emission rate.

Q. Does that mean that Wisconsin Electric is seeking a permit that would allow the facility to release more air pollutants in the future than it plans to emit at this time?

A. Yes, that appears to be the situation.

Q. Are the "expected annual emissions" equal to the current annual emissions from the Domtar paper mill?

A. No. Wisconsin Electric reports that total expected emissions of nitrogen oxides, carbon monoxide, sulfur dioxide, particulate matter (all forms), and volatile organic compounds are 30% less than total current emissions from the Domtar mill. This reduction is due to the plan to shut down the natural gas-fired boilers being used at the Domtar mill currently and replace that source of heat with the proposed biomass-fired boiler equipped with certain emissions control technologies.

Q. You mentioned five different types of air pollutants that comprise the total emissions contemplated for this facility. Are emissions of each type expected to be lower under the planned utilization compared to current emissions from the mill?

A. Expected emissions of four of five of the pollutants are reported to be lower than current emission rates. However, reports from Wisconsin Electric show that expected emissions of particulate matter are more than double (2.3 times greater than) current levels, and potential emissions of particulate matter are nearly 10 times greater than current levels.

Q. What is the significance, if any, of an increase in particulate matter emissions and a decrease of emissions for other air pollutants in terms of potential air quality impacts?

A. When considered on equal footing, such as amount of pollutant per volume of air, and at the concentrations typical of outdoor air, both particulate matter less than 10 micrometers (PM_{10}) and particulate matter less than 2.5 micrometers ($PM_{2.5}$) are more potent human health hazards than the other air pollutants evaluated in the emissions analysis that was conducted by Wisconsin Electric. So, while the total amount of emissions is expected to decline, the toxicological potency of total emissions may be the same or higher for the proposed facility because of the expected increase in emissions of particulate matter.

Q. Does the WE Energies air quality impact analysis account for the increase in emissions of a more potent air pollutant?

A. Not explicitly, although methods appropriate for doing so, typically termed health impact analyses, have been developed by the U.S. Environmental Protection Agency and others.

Q. How does the WE Energies air quality impact analysis assess impacts of the individual air pollutants?

A. WE Energies used a mathematical model to predict the concentration of those air pollutants at numerous locations off-site. The predicted concentrations were first compared to various benchmarks including Significant Impact Level (SIL) increments and Prevention of Significant Deterioration (PSD) increments.

Q. How did the modeling results compare to the benchmark PSD and SIL increments?

A. Maximum predicted concentrations were below the corresponding PSD increments for each pollutant, but above the SIL increments for nitrogen dioxide, sulfur dioxide, PM_{10}, $PM_{2.5}$ and lead. As a result of exceeding the SIL increments for some pollutants, Wisconsin Electric was required to conduct a cumulative analysis in which emissions from other nearby sources are modeled in addition to emissions from the proposed source. In turn, the predicted cumulative air quality impacts were added to estimates of background concentrations, and the sum was compared to National Ambient Air Quality Standards (NAAQS) for the respective air pollutants.

Q. How do the predicted cumulative air quality impacts compare to the National Ambient Air Quality Standards?

A. In general the predicted air quality impacts plus background are below the NAAQS. The results for $PM_{2.5}$, however, are an exception. For $PM_{2.5}$ the sum (34.2 $\mu g/m^3$) of predicted cumulative impacts (8.6 $\mu g/m^3$) and background (25.6 $\mu g/m^3$) for a 24-hour period is reported to be 98% of the NAAQS for 24-hour average $PM_{2.5}$ concentrations (35 $\mu g/m^3$).

Q. How robust are predictions of air quality impacts of air pollutant emissions from a point source using models such as those run in this analysis?

A. Predictions from air quality models such as the one used in Wisconsin Electric's modeling analysis are generally accepted to be accurate to within a factor of two of actual impacts. As a result, actual impacts could be greater than those predicted and may exceed the NAAQS from time to time.

Q. Are air modeling results also influenced by the meteorological data input to the mathematical model?

A. Yes, meteorological information input to an air quality model does influence the output. In this case, WE Energies used five years of hourly observations from the weather station located at Wausau Airport (AUW) and approximately 3.5 miles north of the proposed facility. According to materials that I reviewed, the Wisconsin Department of Natural Resources (WDNR) recommended use of the Wausau airport data.

Q. Could other meteorological data have been used instead?

A. Yes, meteorological observations from the Central Wisconsin Airport (CWA) approximately 9 miles south of the proposed facility could have been used in addition to or instead of the Wausau airport data.

Q. Is there any reason to use the Central Wisconsin airport data?

A. There are at least three reasons to explore the potential for different results from a second airport that is also nearby the proposed source. First, the predicted 24-hour $PM_{2.5}$ impact plus estimated background levels of $PM_{2.5}$ are reported to be within 2% of the NAAQS. Moreover, a residential community is immediately adjacent to and generally in the prevailing downwind direction from the proposed facility, where some of the highest impacts can be reasonably expected to occur. Second, the presence of Rib Mountain approximately due west of Wausau airport, but northwest of the proposed facility, may limit the representativeness of meteorological conditions at Wausau airport for the proposed location. Third, my cursory examination of seasonal wind direction for the two airports suggests a greater frequency of southwesterly winds at CWA than AUW which would transport emissions from the facility in the general direction of a D.C. Everest elementary school and junior high school. Given those circumstances, a sensitivity analysis to characterize the range of predicted concentrations produced from additional reasonable data would be an appropriate course of action.

Q. What is the source of the background concentration of $PM_{2.5}$ and other air pollutants used in the modeling analysis?

A. According to the documents that I reviewed, the background concentrations were based on guidance from WDNR. The specific background concentrations that were used in the analysis are described by WDNR as being appropriate for areas with 'low' background as opposed to 'high' background. Citing a WDNR September 15, 2008 memo, WE Energies air quality impact analysis refers to the background values used as for areas with "low population and industrial activity". I was not, however, able to find that terminology in the WDNR memo WE Energies cited.

Q. What are the high and low background area concentrations for $PM_{2.5}$ recommended by WDNR?

A. The low background area concentrations for $PM_{2.5}$ are reported in the WE Energies air quality impact analysis to be an annual average of 8.7 ug/m^3 and a 24-hour average of 25.6 ug/m^3. According to communications with WDNR, the high background area concentrations for $PM_{2.5}$ are an annual average of 10.2 ug/m^3 and a 24-hour average of 28.9 ug/m^3.

Q. What rationale was used by WDNR to designate Rothschild as a 'low' background area?

A. WDNR reports using two criteria – population, then population density. First, cities and villages with a population greater than 25,000 are designated as high background areas. The second criterion is for cities and villages that have populations less than 25,000 but are adjacent to cities with populations greater than 25,000. Cities and villages with population density at least 50% of the larger adjacent city or village are also designated as high background areas. All other cities and villages are reported to be designated as low background areas by WDNR.

Based on the WDNR memo issued on September 15, 2008 titled "Regional Background Concentration", Rothschild is considered a low background region. Wausau city is considered to be a high background area because the population of the city is greater than 25,000 residents. Schofield, which is the community that has a northern border with Wausau and a southern border with Rothschild is designated a high background area, presumably because of its population density. Data that I gathered indicates Schofield has a population density that is greater than half of the population density in Wausau. Rothschild does not appear to be immediately adjacent to Wausau and the information that I gather indicates that its population density is less than half of the population density in Wausau. I presume these are the reasons why Rothschild is designated as a low background area by WDNR.

Q. Are any schools in the D.C. Everest Area School District in close proximity to Schofield and hence might have similar background levels of air pollutants?

A. Rothschild Elementary is about one-half mile south of the nearest Schofield border. The D.C. Everest Senior High is situated similarly. The D.C. Everest Junior High is approximately 100 yards from the Schofield border. In addition, those schools are also proximate to the Domtar mill and the site of the proposed biomass boiler. It is interesting to note that the D.C. Everest Area School District includes the community of Schofield as well.

Q. Are you aware of schools in close proximity to the site of the proposed biomass-fired cogeneration facility?

A. Yes. Rothschild Elementary is located approximately one-third of a mile from the nearest border of the mill and approximately two-thirds of a mile from the location of the proposed biomass facility. D.C. Everest Junior High is approximately 1.3 miles from the proposed location of the boiler. Additionally St. Mark's Catholic School is located about one-half mile from the plant site.

Q Are any of these schools susceptible to elevated $PM_{2.5}$ exposure as a result of emissions from the proposed facility?

A. Rothschild Elementary is located on a hill about approximately two-thirds of a mile northeast of the proposed facility. As shown in Exhibit 14.9, the current mill is in direct sight of the school, with the playground and field behind the school in closest proximity to the site of the proposed facility. I noted burnt and vinegar-like odors during my inspection of both the exterior and interior of the school. I understand those odors to be characteristic of the mill according to information provided by my hosts and also to be characteristic of pulping processes. This information indicates that emissions from the mill area can be transported to the elementary school. In addition, I observed exhaust stacks of the current mill from the roof of the Junior High, indicating that the Junior High is also in direct line of sight of the proposed facility. Based on my experience and training, I know that emissions from the mill area can also be transported to the Junior High. Both schools are frequently downwind from the mill and the proposed facility based on the meteorological data that I have reviewed.

Q: Will students and staff of the schools be exposed to air pollutant emissions from the proposed facility while inside the buildings?

A: While in these buildings, children and staff will be exposed to outdoor fine particles that have migrated indoors, including particles and other air pollutants released from the proposed facility. I understand from representatives of the D.C. Everest Area School District that the Rothschild Elementary building is open from 6am – 6pm during which time it is occupied by various combinations of staff and students. During the school year, a typical child and staff member will spend 25-30% of their day inside the school buildings. Children who participate in the Extended Day program may be inside the school both earlier and later than the normal school hours. I was informed that Rothschild Elementary is also the site of programs for children during the summer when school is not in session.

Q: How do particles in outdoor air enter a building?

A: The amount of outdoor particles that enter indoors is determined by several factors, including: the amount of outdoor air that enters the building (i.e., the air exchange rate), the particle penetration factor (i.e., the extent to which outdoor particles penetrate building exteriors), and the filtration capacity of systems that mechanically introduce outdoor air into a building or recirculate indoor air.

Q: What are the major determinants of air exchange rate in the schools?

A: Air exchange rate is largely determined by whether windows are open or closed and whether the mechanical ventilation systems are delivering outdoor air into the school. I observed at least two open windows at Rothschild Elementary during my inspection (Exhibit 14.10) even though the temperature outside was approximately 55 degrees

Fahrenheit and there was light to moderate precipitation. The Environmental Assessment prepared by WDNR notes that at least one school proximate to the proposed facility, Rothschild Elementary, has no central air conditioning and opens windows to cool the building. I also observed that the unit ventilators that provide mechanical ventilation to classrooms of the schools (Exhibit 14.11) were operating and delivering outdoor air into the classrooms. In addition, I observed that exhaust systems in the schools were operating as intended, which also facilitates air exchange in the buildings. During my inspection of Rothschild Elementary, I noted that the majority of classrooms and the outdoor air intakes for the unit ventilators of those rooms face west toward the proposed facility. (Exhibit 14.12)

Q. Earlier in your testimony you mentioned that certain types of pre-existing illness are known to make people more susceptible to adverse effects of air pollution and particulate matter especially. Are you aware of any information on the prevalence of those illnesses among the D.C. Everest school population?

A: I reviewed a report on the number of children with asthma in D.C. Everest schools that was provided by Dr. Gilmore. The report indicates that at least 25 children (7.4%) in Rothschild Elementary and 69 children (13.2%) in the Junior High have asthma. I understand that the data in this report are based upon the number of children who have registered asthma medication or other related care with school nurses. These data may not include children with asthma who do not anticipate receiving treatment at school.

Q. What would be the effect on the air quality modeling analysis results of using the high background area concentration for $PM_{2.5}$ rather than low?

A. Referring to Table 2.18-10 of the Technical Support Document provided by Wisconsin Electric, the cumulative impact of the proposed facility, mill, and other nearby sources on upper end 24-hour average $PM_{2.5}$ concentrations was predicted to be 8.6 ug/m^3. Summing that value with the high background concentration from WDNR of 28.9 ug/m^3 yields a total concentration of 37.5 ug/m^3. That concentration is greater than the 24-hour average NAAQS for $PM_{2.5}$ of 35 ug/m^3. A similar conclusion is obtained using the predicted concentrations shown in Table 2.18-9 of the WE Energies air quality impact analysis, in which the highest modeled 24-hour average concentration of $PM_{2.5}$ is reported to be 7.6 ug/m^3. Combined with the high background area concentration from WDNR of 28.9 ug/m^3, the total $PM_{2.5}$ concentration would be 36.5 ug/m^3.

Q. Are you aware of any other information that would be helpful for evaluating background concentrations of air pollutants in the vicinity of D.C. Everest schools?

A. Measured concentrations of $PM_{2.5}$ in areas reasonably representative of Rothschild would also be helpful for characterizing background in the vicinity of the proposed biomass boiler and mill. WDNR gathers $PM_{2.5}$ concentrations from monitoring sites in Wood County and Taylor County, Wisconsin. Those data are available from the U.S. Environmental Protection Agency (EPA). The EPA records state that the monitoring objective for both of these sites is to characterize population exposure. The site in Wood County is within Wisconsin Rapids city center, across the Wisconsin River and approximately 1 mile south of a paper mill. The monitoring site in Taylor County is located in a rural area where the primary land use is agricultural. According to my calculations, the annual average $PM_{2.5}$ concentration at the Wood County (1999 – 2003) and Taylor County (2003 – 2008) sites are 10.7 ug/m^3 and 8.3 ug/m^3, respectively.

Similarly, the average of the 98th percentile 24-hour average $PM_{2.5}$ concentrations in Wood County (1999 – 2003) and Taylor County (2003 – 2008) is 30.9 ug/m^3 and 26.9 ug/m^3, respectively.

Q. Are the sites in Wood County and Taylor County designated by WDNR as high background areas or low background areas?

A: Both locations are designated as low background areas according to communications with WDNR.

Q: What would be the effect on the air quality modeling analysis results of using results from Wood County and Taylor County as an estimate of background concentrations in Rothschild?

A: Use of the Wood County data noted above as background for Rothschild would yield 24-hour average $PM_{2.5}$ concentrations above the NAAQS according to the local source-related impacts shown in Table 2.18-9 and Table 2.18-10 of the WE Energies air quality impact analysis. Use of the Taylor County data as background for Rothschild would yield 24-hour average $PM_{2.5}$ concentrations just above the NAAQS for the cumulative analysis reported by WE Energies (Table 2.18-10) and just below the NAAQS based on the significant impact modeling results shown in Table 2.18-9 of the WE Energies report. It is important to note these are preliminary estimates based on the available modeling and monitoring data. A more refined and thorough analysis of both the modeling and measurement data would need to be conducted to reach a definitive conclusion about the influence of measured background concentrations on projected air quality impacts of the facility proposed for Rothschild.

Q. In general what impact on human health can result from approaching, even exceeding, NAAQS as suggested by the modeling you have reviewed?

A. I would expect an increased risk of cardiovascular and respiratory problems, including asthma attacks, especially in vulnerable populations.

Q. Are there economic impacts for counties that violate the NAAQS?

A. Potentially yes. Any new emission source or major modification of an existing source proximate to the proposed facility may be required to install the best available control equipment and find offsets for the new emissions. Companies looking to expand may avoid communities designated as non-attainment areas to avoid the costs of additional control equipment and emission offsets.

Q. Have studies shown that there are health risks associated with exposure to particulate matter?

A. The most recent $PM_{2.5}$ Criteria Document (EPA 2004a) contains over 2,000 pages of documentation regarding exposures to and health risks from $PM_{2.5}$. This includes not only epidemiological evidence, but also extensive toxicological evidence. While it is impractical to summarize the entirety of the information reported within this document, it is important to recognize that the cardiovascular and respiratory effects observed in human populations have been observed in laboratory studies of humans and animals as well. My opinions about the health effects of particle matter are consistent with the key insights summarized in the Integrative Synthesis (Chapter 9) of the EPA Criteria Document for Particulate Matter. Quoting from the Integrative Synthesis chapter:

"Considering the evidence from the full body of epidemiologic studies using various PM indicators, the available findings demonstrate well that human health outcomes are associated with ambient PM."

"The results for U.S. and Canadian studies are generally consistent with those presented in Chapter 8 based on all available epidemiologic studies world wide. These results indicate that there is substantial strength in the epidemiological evidence for association between PM_{10} and $PM_{2.5}$ and mortality, especially for total and cardiovascular mortality, but also for respiratory mortality."

"Important new evidence is available from toxicologic studies that builds support for plausibility of associations between particles, especially fine particles (or constituents) with physiological endpoints indicative of increased risk of ischemic heart disease, development or exacerbation of atherosclerosis or changes in cardiac rhythm."

"Toxicological studies have provided evidence that supports plausible biological pathways for respiratory effects of fine particles."

Q: What health benefits have been identified with lower exposure to particulate matter?

Highly regarded scientific studies in the United States and elsewhere have shown that lower exposure to fine particles reduces the risk of serious respiratory and cardiovascular events, asthma attacks, and lengthens the average lifespan. These health benefits have been observed at concentrations of particulate matter that are below the current NAAQS. The benefits of lower exposure will be greatest for people who are most vulnerable to the effects of fine particle pollution, including children, the elderly, and others with asthma, diabetes, and heart conditions.

Q. The modeling reported by WE Energies indicates that the 24-hr average and annual average NAAQS for $PM_{2.5}$ will not be exceeded. Does that mean that we would not expect to see health effects resulting from $PM_{2.5}$ and PM_{10} exposure in the Rothschild area?

A. No. Although the NAAQS is health-based, the standards for PM_{10} and $PM_{2.5}$ are not intended to be a threshold below which health effects are not observed or do not occur. In fact, the EPA (EPA 1997) states explicitly that the Act does not require the Administrator to establish a primary NAAQS at a zero-risk level.

We can look directly at the health evidence to determine whether health effects are anticipated at current levels of exposure. The American Cancer Society cohort study (Pope, et al. 2002) did not find a threshold for $PM_{2.5}$ health effects. Instead, that study found effects for concentrations below 10 micrograms per cubic meter ($\mu g/m^3$) on an annual average basis. More broadly, some time-series studies have examined the possibility of non-linearity in the relationship between particulate matter exposures and mortality (Daniels, et al. 2000; Schwartz, et al. 2002; Dominici, et al. 2003). All concluded that a linear no-threshold model was the best fit to the observed data, explainable by the substantial variability in individual susceptibilities. For example, an analysis of data from the Six Cities Study found an essentially linear relationship between daily mortality and $PM_{2.5}$ concentrations down to 2 $\mu g/m^3$ (Schwartz, et al. 2002).

Thus as summarized in the EPA Particulate Matter Staff Paper (EPA 2005), there is no evident threshold from multi-city time-series studies or cohort studies of PM-related mortality. For this reason, the staff concluded that "it is appropriate to use the linear or log-linear concentration-response models reported in epidemiologic studies in the quantitative risk assessment" (p. 3-59).

The issue of a threshold for PM-mediated health effects has been addressed by the National Academy of Sciences (NAS) as well. In 2000, Congress directed the Agency to ask the NAS to review the methodologies used by the EPA to perform benefit-cost analyses for air quality and to recommend a common methodology to be used in all future analyses by the Agency (U.S. Senate 2000). In its ensuing report (NRC 2002), the National Research Council (the research branch of the NAS) stated "For pollutants such as PM_{10} and $PM_{2.5}$, there is no evidence for any departure of linearity in the observed range of exposure, nor any indication of a threshold."

Q. Are there any emissions related to the facility operation beyond stack emissions?

A. Yes. Wisconsin Electric reports that biomass fuel used to operate the CFB boiler will be trucked into the facility. Heavy-duty vehicles are typically powered by diesel fuel. Diesel exhaust is composed of both gases and particulate matter. In addition to being a respiratory and cardiopulmonary hazard, diesel particulate matter is classified by the EPA as a suspected chemical carcinogen. Based on the information that I reviewed, Wisconsin Electric estimates that the operation of the facility will require 110 trucks delivering biomass on a daily basis (5 days per week, year-round).

Q. Are there ways that the predicted ambient air quality impacts of facility-related air pollutants in the vicinity of D.C. Everest schools could be reduced?

A. Potentially yes. Fundamentals of air pollutant dispersion from a point source tell us that increasing the height of an emission will have the general effect of reducing impacts of emissions for locations near to the source, as is the case for the D.C. Everest schools and the proposed biomass facility. Operation of additional air pollution control equipment such as a flue gas desulfurization system or an electrostatic precipitator could conceivably reduce the amount of emissions which would have a direct benefit for air quality in vicinity of the schools. These are two general approaches. Engineers who specialize in the design of boilers and air pollution control technologies would be able to identify a comprehensive list of options for this specific facility.

Q. Are there ways that the impacts of facility-related air pollutants on indoor air quality of D.C. Everest schools could be reduced?

A. Yes. Mechanical systems that include central air conditioning will reduce children's exposure to fine particles in two ways. First, air filters integrated into the systems can capture a large fraction of the particles that would otherwise pass through the systems. A typical central air filter (e.g., MERV 11) can capture up to 78% of the fine particles that encounter it (ASHRAE 2007). And, central air conditioning will enable schools to be well ventilated while keeping windows closed, thus minimizing one of the largest pathways for unfiltered air to enter the buildings.

In terms of magnitude of the reduction, my own research, as well as that of my colleagues at EH&E and Harvard and the work of other investigators, demonstrate unequivocally the benefits of central forced air systems and filtration for limiting exposure to particulate matter from outdoors. My study of single family residences with central ventilation demonstrates that occupants are exposed to approximately 60% less outdoor fine particles than residents of single family homes without central air conditioning (MacIntosh et al. 2009). Based on the plethora of indoor air quality investigations conducted by EH&E, I know that central forced air systems with filtration in commercial office buildings are also effective at reducing infiltration of particulate matter from outdoors. I would expect a similar result if we were to compare schools with and without central air conditioning. Because children spend a large fraction of their day in school, reducing exposures within the school buildings will reduce their overall exposure to particulate matter. Moreover central air conditioning and filtration limit infiltration of not only particulate matter emitted from the proposed facility and the related truck traffic, but also reduce indoor concentrations of all particulate matter regardless of source.

Q: What else could be done by the D.C. Everest Area School District to manage exposure to particulate matter from the facility for children and staff who are outside Rothschild Elementary and other schools?

A: If school administrators had real-time information on air quality conditions outside of a school, then it would be possible to make decisions to limit time outdoors when air quality conditions were in a range deemed to be a concern for health. The Air Quality Index (AQI) program developed by EPA is an example that could be used in Rothschild if the necessary data were available. In fact WDNR uses the AQI system to make it easier for the public to understand the health signficance of air pollution for monitored levels of particulate matter and other other common air pollutants. Real-time monitoring and reporting of particulate matter concentrations and other air pollutants, is performed routinely at myriad air quality monitoring sites throughout the United States. WDNR operates several real-time $PM_{2.5}$ monitors and reports one-hour average concentrations on an hourly basis throughout the day. These operations demonstrate that real-time monitoring, reporting, and alert systems are eminently feasible. Monitoring in the vicinity of Rothschild Elementary and D.C. Everest Junior High following protocols established by WDNR and EPA has the added benefit of providing a means of verifying attainment of the NAAQS for particulate matter in populated areas near the proposed facility.

Q. Does this conclude your direct testimony?

A. Yes, it does.

(EPA 1997; Daniels et al. 2000; U.S. Senate 2000; NRC 2002; Pope et al. 2002; Schwartz et al. 2002; Dominici et al. 2003; EPA 2004; EPA 2005; ASHRAE 2007; Macintosh et al. 2009)

ASHRAE (2007). Standard 52.2 - 2007; Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. Atlanta, GA, American Society of Heating, Refrigeration, and Air Conditioning Engineers.

Daniels, M. J., F. Dominici, J. M. Samet and S. L. Zeger (2000). "Estimating particulate matter-mortality dose-response curves and threshold levels: an analysis of daily time-series for the 20 largest US cities." Am J Epidemiol **152**(5): 397-406.

Dominici, F., M. Daniels, A. McDermott, S. L. Zeger and J. Samet (2003). Shape of the exposure-response relation and mortality displacement in the NMMAPS database. Health Effects Institute Special Report: Revised Analyses of Time-Series Studies of Air Pollution and Health. Charlestown, MA**:** 91-96.

EPA (1997). Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule. Research Triangle Park, NC, US EPA, Office of Air Quality Planning and Standards.

EPA (2004). Air Quality Criteria for Particulate Matter. Research Triangle Park, NC, National Center for Environmental Assessment, Office of Research and Development.

EPA (2005). Review of the National Ambient Air Quality Standards for Particulate Matter, Policy Assessment of Scientific and Technical Information, OAPQS Staff Paper. Research Triangle Park, NC, Office of Air Quality Planning and Standards USEPA.

Macintosh, D. L., T. Minegishi, M. Kaufman, B. J. Baker, J. G. Allen, J. I. Levy and T. A. Myatt (2009). "The benefits of whole-house in-duct air cleaning in reducing exposures to fine particulate matter of outdoor origin: a modeling analysis." J Expo Sci Environ Epidemiol **20**(2): 213-24.

NRC (2002). Estimating the Public Health Benefits of Proposed Air Pollution Regulations. Washington, D.C., National Research Council.

Pope, C. A., 3rd, R. T. Burnett, M. J. Thun, E. E. Calle, D. Krewski, K. Ito and G. D. Thurston (2002). "Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution." JAMA **287**(9): 1132-41.

Schwartz, J., F. Laden and A. Zanobetti (2002). "The concentration-response relation between PM(2.5) and daily deaths." Environ Health Perspect **110**(10): 1025-9.

U.S. Senate (2000). Department of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Bill, 2001. H.R. 4635. 106th Congress, 2d Session.