Report on Gaps in Research Regarding the Impact of Electrical Generation and Transmission on the Wisconsin Environment

Environmental Research Program

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Kestral Management Services, LLC

Environmental Research Program

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Executive Summary

Wisconsin's Focus on Energy Environmental Research Program undertook a "gap analysis" to determine where there is a lack of knowledge about the environmental impacts of utility generation and transmission of electricity. The findings of this analysis will help the Environmental Research Forum and the Wisconsin Department of Administration's Division of Energy decide where research is needed and where funding by the Environmental Research Program would be appropriate, given that not all research gaps identified lie within the scope of the Forum's goals and responsibilities.

To perform the analysis the Environmental Research Program team identified individuals with expertise covering existing research on the environmental impacts of electricity generation and transmission. The Team then interviewed these individuals to elicit their opinions on what gaps remain in existing research. Once the gaps were identified in a draft report, a review panel evaluated the draft report and suggested changes, where needed.

Although the research needs identified did not always fall cleanly into exclusive categories, the research gaps were grouped into eight general categories:

- Mercury-related issues
- Non-mercury air toxics and other air emission issues
- Solid waste issues
- Climate change
- Environmental impacts of renewable electricity sources
- Water quality impacts
- Transmission line impacts
- Other research issues

In total, 165 knowledge gaps were identified. By far the most gaps were identified for the "mercury-related" category. This was followed by the "non-mercury air toxics and other air emission issues" category.

Introduction

The Focus on Energy Environmental Research Program was created to help Wisconsin gain a more comprehensive understanding of the environmental impacts of electric generation and transmission in Wisconsin. The Environmental Research Forum was appointed to recommend to the Wisconsin Department of Administration's (DOA) Division of Energy which research projects should be funded.

The Program undertook a "gap analysis" to determine where there is a lack of knowledge about the environmental impacts of utility generation and transmission of electricity. The analysis looks at the existing body of research and identifies areas of study where additional work needs to be done.

The ultimate purpose of this study is to help the Environmental Research Forum and the Wisconsin Department of Administration's Division of Energy decide where research would be valuable and where funding is needed.

Method

The Environmental Research Program team identified institutions and individuals with expertise covering existing research on the environmental impacts of electricity generation and transmission. The team then interviewed those individuals to elicit their opinions on what gaps remain in existing research.

The interview questionnaire was open-ended to encourage idea generation and to assure that impacts of the full range of energy-related facilities were considered. Appendix A contains the questionnaire used for this purpose.

The team also asked for referrals to other sources of knowledge and expertise. These included both individuals and reference documents that would be helpful. The team continued to interview knowledgeable individuals until all leads were exhausted. Attachment B lists all parties interviewed.

Once the research gaps were identified in a draft report, a review panel evaluated the draft report and suggested changes, where needed.

Research Gaps Identified

The interview process led to a wide range of comments. Some involved very detailed and specific research project ideas, while others addressed general policy and technology issues and concepts. Results of the interviews are presented below.

Where a gap is clearly stated, no additional explanation is included. The listing of gaps is organized into the following categories used by the interviewees in their responses:

I. Mercury-related issues

II. Non-mercury air toxics and other air emissions

III. Solid waste issues

IV. Climate change

V. Environmental impacts of renewable electricity sources

VI. Water quality impacts

VII. Transmission line impacts

VIII. Other research issues

There is a high degree of interrelationship among categories and among the suggested research gap topics within these categories.

I. Mercury-Related Issues

The mercury research gaps are categorized using the US EPA Strategies for Mercury Research Report as follows:

A. Human health effects and exposure

B. Ecological effects and exposure

C. Transport, transformation and fate

D. Mercury emitted from coal-fired combustion

E. Mercury emitted from other sources

A. Human Health Effects and Exposure

The acute effect of methyl mercury on human health and fetal development has been documented and studied on several levels. The National Academy of Sciences (NAS) report (2000) reviewed the available human health studies and affirmed the EPA mercury reference dose of 0 .1-ug/kg body weight per day, as a scientifically justified level to protect human health. There are,

however, potentially more subtle chronic effects of long-term exposure to methyl mercury that may need further research.

Suggested Research

1. Study the impact of low-level exposures to methyl mercury in humans. (The impact of high-level exposures to methyl mercury is reasonably well understood.)
2. Determine if mercury ingestion increases susceptibility to Type II diabetes.
3. Evaluate the feasibility of replicating the Finnish study linking cardiovascular disease to mercury exposure through ingestion of fish.[1]
4. Determine mercury-related health ramifications of eating fish from Wisconsin lakes. What health effects can we expect to see in those eating given amounts of fish from Wisconsin lakes?
5. Study the current mercury body burden in Wisconsin anglers and populations of concern (e.g., pregnant women, children and women of children-bearing age).
6. Determine the applicability to Wisconsin of recent studies in Alabama that showed surprisingly high levels of mercury in the hair and blood of residents eating locally caught fish.[2]
7. Evaluate the effectiveness of the fish consumption advisory system in Wisconsin in terms of preventing mercury exposure. What could be done to improve this system?

B. Ecological Effects and Exposure

Recent scientific progress has led to an improved understanding of mercury fate and transport in the environment and its toxicity to a wide range of wildlife. The focus of this research has been on the consumption of fish containing methyl mercury by avian species. The EPA report on Mercury Research Strategies states that current procedures for calculating wildlife criterion for mercury are based on an extremely limited toxicity data set. There is a need for controlled laboratory studies of methyl mercury effects in wildlife species.

Suggested Research

8. Answer the remaining questions about the impact of mercury on the common loon since the loon is an excellent bio-indicator of the effects of mercury.
    a. Continue the loon mercury study to validate predictions of the existing toxico-kinetic model.
    b. Establish an accurate relationship between mercury intake and blood mercury exposure.

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[1] Jukka T. Salonen et.al., "Intake of Mercury From Fish, Lipid Perodoxidation, and the Risk of Myocardial Infarction and Coronary, Cardiovascular, and Any Death in Eastern Finnish Men", *Circulation*. 1995;91:645-655

[2] Ben Raines, "Hair Tests Indicate High Mercury Levels", *Mobile Register*. September 30, 1991

c. Collect additional tissue partitioning data and gather supplemental information concerning the effect of mercury exposure on the immune function and physiology of loon chicks.

d. Determine the impact of mercury on loon hatching success.

9. Study the reproductive effects of methyl mercury and bioaccumulation in fish and other species.

10. Determine how mercury and selenium interact toxicologically.

    a. Identify the mechanisms where this takes place.

    b. Determine reproductive impacts.

    c. Determine whether these two heavy metals interact when ingested by animal or human species.

    d. Evaluate primate study data that suggest that selenium does not protect against mercury toxicity, compared to the theorized protection for whales and fish.

11. Establish the link between mercury dose (from airborne deposition) and response, as measured by fate, sediment mechanics, fish and impact on the food chain.

    a. Determine the routes and the effects of exposure and the important endpoints from exposure.

    b. Determine the parts of the food chain that are most important to understand with regard to mercury exposure.

    c. Ascertain the source of the methyl mercury in fish tissue; i.e., how it is related to the inorganic mercury deposited by precipitation?

    d. Monitor the tracer studies being conducted in the Experimental Lakes Area. These should improve understanding of mercury transformations in aquatic systems.

12. Account for the differences in the bioaccumulation of mercury in Wisconsin fish from different lakes. Why do fish of the same size in two different lakes have significantly different amounts of mercury in their tissues?

    a. Review the Dartmouth research finding that fish in more oligotrophic lakes tend to build up greater levels of methyl mercury, than do the same size fish in more eutrophic lakes.[3]

    b. Monitor the Dartmouth research attempting to verify these findings in a suite of four northeastern U.S. lakes.

    c. Determine if the linkage of algal concentration to fish mercury levels also occurs in Wisconsin lakes.

13. Conduct more wildlife mercury monitoring, especially on fur-bearing animals.

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[3] Pickhardt et.al., "Algal blooms reduce the uptake of toxic methylmercury in freshwater food webs", *PNAS.* 2002;99:4419-4423

a. Determine baseline levels.

b. Determine current and historic levels of mercury in various test species.

c. Study what each species food-chain niche tells us about the contaminant and its movement.

C. Transport, Transformation and Fate

Methyl mercury is the primary agent of exposure to both humans and wildlife and it is critical to understanding the relationship between methyl mercury in fish, levels of ambient mercury in the environment and emissions from all sources. Research and monitoring needs have been identified that follow the pathways of exposure from emissions to fish uptake. These include the atmospheric transport, transformation and fate processes; deposition of mercury from the atmosphere to aquatic environments; fate, transport and transformation processes in aquatic environments; and monitoring of spatial and temporal patterns of mercury in fish.

Suggested Research

14. Continue the existing mercury deposition monitoring in Wisconsin (suggested by multiple mercury researchers and others). The current mercury monitoring network will run out of funding starting 2003. The Environmental Research Forum has recommended to the Division of Energy that Focus on Energy monies be spent for this purpose.

15. Quantify land emissions (e.g., from landfills) of mercury. In addition, there is a similar research need for data on coal combustion waste landfills. Monitor ongoing research of the evasion of mercury, especially from different coal-fired ash types. Determine additional research needs.[4]

16. Conduct mercury event sampling and speciation. A number of deposition sites collect weekly samples; however, event sampling is needed to determine the originating source area of the deposited mercury. This information is extremely critical for air transport modeling.

    - Determine the adequacy of the daily sample collections for event sampling by the National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN) Devil's Lake site. Monthly methyl mercury measurements are conducted at this site.

17. Quantify dry-fall of mercury. Mercury associated with air particles (dry-fall) is estimated to be a major part of the deposition in some areas (e.g., urban environment and, to a lesser extent, in rural areas). There is no good data on this.

    - Determine the adequacy of University of Wisconsin researcher's recent EPA funding to establish a dry-fall sampling station at or near Devil's Lake to fill this gap.

18. Establish a mercury air monitoring "Super Site" to obtain ambient, vapor-phase mercury levels, speciated vapor-phase sampling in dry fall-out, in rain-out and in snowfall. This

[4] Current research is quite substantial according to Ken Ladwig (EPRI), personal communication.

refers to the lack of dry fall-out data and the lack of speciated data for wet and dry deposition and ambient concentrations of vapor-phase mercury.

- Determine if the information to be collected at the Devil's Lake site by UW-Madison researchers through an EPA grant is adequate to fill this gap.

19. Perform mercury source characterizations for improved emission estimates and measurements on mercury and other persistently bio-accumulative toxics (PBTs). We have poor data about how much mercury is emitted from what specific sources of emissions and equally poor data on other persistent bioaccumulative toxics.

20. Improve modeling of mercury transport, deposition and bioaccumulation

21. Establish an urban mercury deposition site. An urban wet and dry mercury deposition site is needed to yield more complete monitoring information for the state.

    a. Use site to create urban baseline against which to evaluate the success of any future mercury control legislation.

    b. Site in or near (downwind of) an urban area where waste (hospital, municipal, etc.) is incinerated. Waste incineration is another important source of airborne mercury. The issue is sorting out the sources of mercury that actually get into precipitation and subsequently deposited in Wisconsin watersheds.

22. Study if and how lichens located near power plants could be used as indicators of potential bioaccumulation of mercury, other heavy metals and sulfur. The use of lichens as a means of monitoring time-integrated ambient conditions has been applied in the past in Europe. They could be the subject of useful research on the locations, types, amounts and analysis/display of sampling data to address both routes of exposure and fate and transport.

23. Estimate to what degree Wisconsin lakes would recover if mercury deposition were reduced.

    a. Estimate how long recovery would take, by lake type.

    b. Estimate how quickly and to what extent the bioaccumulation of mercury in fish and other aquatic organisms would decrease in Wisconsin lakes?

24. Methyl mercury has been found attached to algal particles in the water column of Lake Superior. Study why methyl mercury is found in Lake Superior, given that methylation is not occurring in the lake's sediments.

    - Determine the role of the dimethyl mercury production in peat bogs of northern Minnesota that volatilize and convert to methyl mercury. Does this occur on a large enough scale to account for the methyl mercury levels found in Lake Superior?

25. Study the factors causing Wisconsin's elevated rates of mercury deposition relative to other places.[5]
26. Determine how much mercury deposition in Wisconsin originates from locations out-of-state and from which sources in those locations.
27. Determine if specific Wisconsin atmospheric mechanics (temperature, etc.) have an effect on mercury transport and deposition chemistry.[6]
28. Study what happens to mercury that is deposited in the soil root zone. Is this mercury accumulating in plants? Is it volatilizing into the air?
29. Investigate ways of preventing or ameliorating methylation.
30. Test Wisconsin lakes over multiple years for longer-term mercury trends.
31. Design a statistically valid sampling program for mercury in fish using an approach that allows for a trend analysis of data from year to year.[7]
32. Acquire a better understanding of the role of benthic organisms on mercury in sediments. We need a better understanding of how bacteria that live in lake sediments cause methylation of mercury to occur.
33. Determine sulfate dependency for methylation. To what degree is the mercury methylation process dependent on the presence of sulfate in the sediments?
34. Gain a better understanding of the role wetlands play in mercury cycling and the methylation process.
35. Determine mercury bioavailability in lake sediments. Depending on the precise form of mercury in lake sediments, the mercury may or may not be in a form that can be ingested by organisms living in the sediments. Unless this can happen, the process of bioaccumulation throughout the food chain cannot occur.
36. Better understand how methyl mercury is formed abiotically and if this can occur in Wisconsin. Determine the applicability of recent evidence from the Florida Everglades

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[5] Wisconsin had five active NADP/MDN sites in calendar year 2001. Mercury deposition fluxes at the three northern-most MDN sites were 7.7 - 8.0 micrograms per square meter and in south-central and southern Wisconsin the fluxes were 12.3 - 13.0 micrograms per square meter. By comparison, the fluxes at the seven MDN sites in Pennsylvania were 4.9, 6.8, 7.4, 8.3, 8.5, 9.5 and 11.4 micrograms per square meter. Annual 2001 sulfate deposition fluxes in Wisconsin ranged from 9 to 16 kilograms per hectare, while in Pennsylvania the sulfate fluxes ranged from 15 to 21 kilograms per hectare. Except for one station, Pennsylvania's sulfate fluxes were all higher than Wisconsin's sulfate fluxes, whereas Pennsylvania's mercury fluxes were generally the same or lower than Wisconsin's mercury fluxes. Sulfate and mercury emissions in Wisconsin are lower than in Pennsylvania. What's driving these differences in deposition fluxes? How does the form of mercury emitted affect them? By the distance to source? By atmospheric transformation processes? Are there important sources of mercury that have been missed in Wisconsin?

[6] With regard to bullets 26 and 27: Coupled high resolution atmosphere mesocale and atmospheric chemistry models are now available that allow for detailed assessments of the atmospheric dynamics associated with the transport, diffusion and deposition of chemicals, including mercury.

[7] The Candy Schrank-led project, funded by the Environmental Research Forum, is designed to fill this gap.

that methyl mercury can be formed without the participation of bacteria. It is not clear whether this can occur in Wisconsin's more temperate climate.

37. Support the mercury stable isotope studies at the Experimental Lakes Area (ELA) in Canada.[8]

38. Determine soil retention of mercury. Of the mercury that occurs naturally in the soil or that has been deposited from the atmosphere, how much is kept within the soil matrix and for how long?

39. Determine soil evasion of mercury. Determine how much mercury volatilizes into the air from the soil.

40. Determine methyl mercury production in soil.

41. Gain an understanding of how much methyl mercury in the bioavailable form is produced in various Wisconsin soils.

42. Study bioavailability of mercury in soil runoff. Of the mercury that is attached to soil particles in storm water runoff, how much is in the methylated form that makes it bioavailable?

43. Determine mercury yield coefficients from land use types.[9]

44. Map the footprint of mercury emitters in Wisconsin. How much stays in Wisconsin? Establish the deposition footprint for all significant Wisconsin emitters. This is important for determining how much of the mercury deposition that occurs in Wisconsin stems from Wisconsin sources.

45. Better understand the physics of volatilization of mercury that has been deposited in both wet and dry forms.

46. Develop improved mercury budgets (e.g., including the chlor-alkali plant, cement manufacturers and incinerators, in addition to utility sources).

47. Develop a comprehensive budget of all significant mercury sources and estimates of the amount of mercury they emit to the ambient atmosphere.

    - Expand the monitoring network for mercury and acid deposition. By establishing more monitoring sites that sample for both mercury and acid deposition, Wisconsin will be able to draw conclusions more precisely about the nature of both kinds of deposition and the changes in both over time.

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[8] Funding support for this program is important because it enables actual controlled experiments to be run in lakes that have been set aside for this research. Significant research findings are already emerging from this program, but there is at present no funding identified for 2003 to purchase the mercury isotopes that are critical to these experiments. If this work were brought to a stop, valuable future knowledge would probably be lost. As an example, the results to-date suggest that only recently deposited mercury is available for methylation, whereas the older deposited mercury appears to be unavailable for methylation. Van Bowersox (NADP) adds that this program has shown how much mercury deposited on the surrounding watershed actually gets into a lake on a yearly basis. These experiments offer a unique opportunity to learn more about mercury cycling.

[9] Although the Experimental Lakes Area program has developed yield coefficients for natural (undeveloped) watersheds, there is a need to develop such coefficients for developed watersheds such as agricultural and urban, so that conclusions can be drawn about how much mercury can be expected to reach lakes surrounded by such watersheds, should deposition be controlled in the future.

48. Evaluate the vertical flux of mercury at various locations and over various surfaces in Wisconsin to take into account how much mercury is re-volatilized from the surface. Flux measurements provide the net amount of mercury that is deposited versus that which stays on the surface.

D. Mercury Emitted from Coal-Fired Combustion Sources

Mercury emitted from waste combustion systems is being substantially reduced as EPA regulations take effect. However, standards for electric utilities and other commercial and industrial boilers have not yet been set. There are several major questions about the chemistry of mercury in coal-fired combustion units and flue-gases. The Environmental Research Forum does not count items in this area among its immediate research priorities.

Suggested Research

49. Define cloud and plume mercury chemistry with reaction rates. The transformation that takes place while the mercury is in the plume down-wind of an emission source is not well understood. It is also unclear how cloud chemistry can transform mercury and affect mercury deposition patterns.

50. Conduct source-related mercury sampling at power plant locations.

    a. Determine how much mercury is emitted from each Wisconsin power plant and determine the speciation of that mercury.

    b. Include a mass-balance across the facility, not just air emissions. Include a sampling of all solid and liquid waste streams as well.

51. Determine to what extent different coals result in different mercury deposition footprints or different speciation within those footprints.

    - Determine how different coals burned in specific Wisconsin power plants would change the total amount of mercury deposited, the form (speciation) of the mercury deposited and the footprint of that deposition by each such plant.

52. Determine if mercury is more bio-available in the presence of certain other chemicals in flue gases and in the combustion process. Is mercury rendered more bio-available in the presence of certain chemicals, both during combustion and in the flue gases that are produced by the combustion of coal in coal-fired boilers? If so, such boilers could be targeted for mercury reduction prior to other boilers.

53. Investigate if mercury control provides other environmental or energy benefits. Do side benefits occur either to the environment or to energy efficiency due to controlling mercury emissions from coal-fired boilers?

54. Investigate the feasibility, cost and environmental and energy benefit of technologies other than conventional coal-fired boilers for anticipated new electrical generation in Wisconsin such as integrated gasification combined cycle plants. IGCC units have proven cost effective elsewhere and can reduce mercury emissions by 99 percent.

E. Mercury Emitted from Other Sources

Wisconsin has one of 12 remaining chlor-alkali plants in the country. This plant, located at Port Edwards on the Wisconsin River, is the largest source of mercury in the state. The plant manufactures chlorine and caustic soda and uses large quantities of mercury in its manufacturing processes. EPA has assigned a single mercury emission number for all chlor-alkali plants, with no regard to size or amount of mercury utilized. Recently, EPA funded a study of mercury emissions from a chlor-alkali plant in Georgia. This is an area that requires more research. In addition, chlor-alkali sites in Maine and North Carolina have been found to have significant quantities of mercury-laden wastes stored on-site with considerable contamination of local soils and waterways. The release of mercury through media other than air also needs investigation for the Port Edwards plant.

Suggested Research

55. Document mercury speciation at the Wisconsin Chlor-Alkali plant.

    - Determine the mercury emission rates and the various chemical species of mercury within the fugitive emissions. Since these different mercury species have varied impacts on the environment, it is important to know in what forms and in what percentages mercury emissions occur from this large source.

II. Non-Mercury Air Toxics and other Air Emission Issues

A. Human Health and Welfare

Human health concerns have been expressed with respect to a variety of air emissions effects (other than mercury emissions) associated with the generation of electricity. The U.S. Environmental Protection Agency (EPA) has adopted National Ambient Air Quality Standards (NAAQS) for a number of air pollutants, including ozone and fine particles ($PM_{2.5}$). Although these standards are not yet in place, EPA estimates that almost 82 million people live in 333 counties that are likely not to meet the NAAQS for ozone and almost 120 million people live in 173 counties that will not meet the NAAQS for $PM_{2.5}$. (Note there are 99 counties that would not meet both the NAAQS for ozone *and* $PM_{2.5}$.) SO_2 and NO_X emissions from coal-fired power plants are important precursors for these pollutants.

Suggested Research

1. Study what health and welfare impacts occur as a result of fine particulate emissions from coal-fired plants.

2. Conduct an analysis of emissions trading of SO_2 and the extent to which it has led to a net increase or net decrease in emissions within the Wisconsin airshed. Although SO_2 emissions have decreased substantially on a national scale, it is not known if emissions in Wisconsin's airshed have similarly declined under the trading regime.

3. Characterize the relationship of toxic air emissions to eventual human health impacts.

    a. Make use of the emissions inventory data to help with this.

b. Consider ozone formation and the role of NO_X versus VOCs where the state is largely forested with hardwoods, as they may generate VOCs at a scale that contributes to the creation of tropospheric ozone.

4. Determine the extent to which rates of cancer, asthma and birth defects are related to the proximity of coal-fired power plants.

5. Study the detailed chemical makeup of particulate emissions to understand the relationship of coal-fired emissions to human health. Although we do know that this is very location-specific, little is known about this relationship.

6. Gain a better understanding of the transport of fine particulates to better understand the human health and welfare implications of these emissions. Fine particles are known to play a critical role in the uptake and transport, the wet- and dry-deposition processes and the paths of exposure and uptake mechanisms in plants and animals. But the dynamics and effects of transport are not fully understood.

B. Toxic and Regional Haze Emissions Issues

Welfare concerns include reduced visibility due to regional haze in National Parks and Wilderness Areas, as well as in urban areas. In 1999, the EPA promulgated regional haze regulations, which establish a goal of "natural visibility conditions" (i.e., no visible manmade air pollution) in 156 of the larger federal parks and wilderness areas by 2050. States are currently working together through five Regional Planning Organizations to develop and implement multi-state strategies to reduce emissions of visibility-impairing fine particle pollution. SO_2 emissions from power plants are the dominant cause of this pollution in the eastern half of the U.S.

Suggested Research

7. Discern from in-stack samples the size distribution, chemical composition and visual characteristics of particles (2.5 and 1 micrometer size) in power plant plumes to:

   a. develop a power plant emissions signature for receptor modeling;

   b. characterize size distribution of particles for deposition modeling;

   c. characterize chemical composition for deposition modeling; and

   d. develop visual characteristics of elemental carbon to distinguish carbon from power plants versus other sources, such as diesel emissions.

8. Evaluate the risk associated with exposure to all metals at monitoring locations to determine the relative risk from power plants.

   a. From in-stack samples, characterize the size distribution and chemical composition of various metals in power plant plumes.

   b. From ambient samples, characterize the size distribution and chemical constituents of the metals at various monitoring sites.

   c. Use receptor modeling to predict the presence of metals from power plants at monitoring sites.

9. From in-stack sampling, characterize $PM_{2.5}$ emissions to improve chemical and deposition modeling.

10. Characterize PM_1 concentrations (contribution from metals, role of elemental carbon, etc.) and determine the contribution from power plants.

11. Analyze wet deposition samples (from mercury or acid deposition samplers) for toxic metals content.

    - Supplement analysis of wet deposition samples with analysis of surface water, fish or agricultural crops to determine metals concentration in order to assess whether any of these metals pose a human or environmental risk at their current concentrations.

12. Evaluate nitrogen (ammonium nitrate, etc.) deposition, using both deposition monitoring and water quality monitoring to estimate the effect of atmospheric nitrogen loading on eutrophication, algae blooms or other adverse effects on water bodies in Wisconsin.

13. Use a Eulerian grid model to determine the culpability of Wisconsin power plants for nitrogen loading coming from atmospheric deposition.

14. Study the degree of influence of coal-fired power plant emissions on asthma and other diseases compared to the effects of dietary and other non-utility emission pathways for potential exposure. Changes in the electric industry should be based on the best science available, but the contributing causes of asthma are many. Given the macro-scale of current knowledge it is not possible to select the most effective control measures without a better understanding of all the contributing factors.

15. Perform more monitoring of air toxics (other than mercury), such as arsenic or chromium, to determine what public health concerns may arise from these kinds of deposition. This is related to the need to treat particulates as more than just a category of pollutants that is either smaller than 10 micrometers or smaller than 2.5 micrometers. We do not generally break down the chemical structure of the particulates we measure and it is in the particulates that we will find metallic air toxics such as arsenic and chromium.

16. Monitor acid gases (HF and HCl) from power plants and evaluate their potential impact on public health and the environment. Acid gases make up the bulk of hazardous air pollution from coal-fired plants.

17. Determine what health effects occur as a result of radioactivity emitted by coal.

    - Determine how radioactivity affects the suitability of ash as an agricultural soil amendment, building material, or in other known applications.

C. Sources of Deposition

One of the major areas of uncertainty regarding the environmental impact of power plant emissions is deposition sources and their locations.

Suggested Research

18. Determine how much of the deposition of NO_X, SO_2, particulate matter and ozone occurring in and downwind of Wisconsin is attributable to Wisconsin coal-fired power plants.

    a. Determine how much comes from other Wisconsin industrial facilities (e.g., paper mills).

    b. Determine how much comes from motor vehicles.

    c. Determine how much comes from out-of-state sources.

19. Determine how much of the ambient concentration of metals and other hazardous air pollutants is attributable to Wisconsin coal-fired power plants. What do the ambient levels of these pollutants mean in terms of human exposure and public health risk?

20. Acquire a better understanding of the sources of atmospheric oxides of nitrogen (NO_X), because sulfate in the atmosphere (SO_4) is decreasing and NO_X is becoming a proportionally bigger source of acidification.[10]

21. Perform ambient monitoring and source characterization of dioxin emissions in order to understand deposition types and rates.

22. Determine the fate of toxic air emissions. How far do these emissions travel?

    - Characterize and map the sources, their contributions to the air mass, the resulting ambient and transient conditions and the eventual forms and fate at the point of release to land-based and water-based resources.[11]

D. Monitoring for Multiple Pollutants

Historic data series are limited to relatively few pollutants: Complete understanding of the environmental effects of the electric power industry would require a more robust baseline of information.

Suggested Research

23. Conduct long term atmospheric and deposition monitoring for emissions of multiple air pollutants. Develop a multi-year period of record for a number of air pollutants using the

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[10] Much of the emphasis on acid deposition has been on the deposition of sulfates. Sulfate concentrations have decreased in air and precipitation over the last decade, which is consistent with Title IV of the 1990 Clean Air Act Amendments, which lowered sulfur dioxide emissions allowances beginning in 1995. Nitrate concentrations have remained relatively unchanged, however, and so the ratio of sulfate to nitrate has decreased. Nitrate deposition has grown in importance, relative to sulfate, as a cause of acidic deposition throughout the eastern U.S.

[11] Warren Heilman (USDA) added the following regarding this issue: This is an extremely complicated question and is a major research gap right now. The amount of toxic pollutants in the atmosphere, where these pollutants are transported, the chemical transformations that occur in the atmosphere, the amount of deposition taking place and the ultimate impact on land-based and water-based resources are all inherently tied to the local and regional variability of the atmosphere and the "character" of the landscape. The prevalence of land-water heterogeneities in the Great Lakes region and the rapidly changing landscape due to social and economic drivers of landscape change in the region complicate the problem because land-water-atmosphere interactions impact emissions, transport, chemistry and deposition. Getting a handle on how the future landscape will affect pollutant patterns in the region is even more critical.

same monitoring network. Use these data to study how multiple air pollutants act together from human health and other perspectives.

- Review the efforts currently underway to collect a wide variety of air quality and meteorological data at an "urban-rural" pair of monitoring sites in Milwaukee and Mayville, WI.

24. Conduct monitoring for Hydrogen Flouride and Hydrogen Chloride near power plants.

E. Combustion/Emission Relationships

By studying different coal combustion processes, one can determine what effect those processes have on power plant emissions. The Environmental Research Forum does not count the item in this area among its immediate research priorities.

Suggested Research

25. Study how to control combustion to reduce air toxic emissions. Determine what alternative methods of coal combustion result in reductions in air toxic emissions. Determine which specific air toxics are reduced by different coal combustion technologies. Review EPA and other research to determine the adequacy and applicability of current work.

F. Deposition Impacts

Deposition and impact information is now much more available than 20 years ago. However, there are still areas where more research is needed, particularly on the impacts of certain types of deposition.

Suggested Research

26. Determine the impact of the deposition of various air toxics on Lake Michigan. What are the concentrations of toxics in the lake? What impacts on lake sediments occur? What impacts are there on fish?

27. Increase the number of ozone monitoring stations in Wisconsin, especially in the south, in order to study tree growth across the ozone gradient, and to determine what impact ozone appears to have on tree productivity.[12]

[12] According to forestry expert Teague Pritchard (WDNR), there is little evidence of adverse acute impact on trees from air pollution, except in the southeast part of the state where ozone readings can get quite high at times. However, there is little data on the chronic impacts of trees in Wisconsin from both ozone and other air pollutants. A study is going on now near Rhinelander (the Forest-Atmosphere Carbon Transfer and Storage (FACTS-II) Project) in which trees in the open are subjected to varying degrees of chronic air pollution from both carbon dioxide and ozone, as well as acute exposure to these pollutants. This study has found that, while ozone pollution impacts may be strongest in southeastern Wisconsin, episodic high surface ozone concentrations can occur in northern Wisconsin and the upper peninsula of Michigan. The impact of these episodic events on sensitive tree species in the region, including northern Wisconsin, the upper peninsula of Michigan and northern lower Michigan is not known. Both the FACTS-II Project and ongoing-coupled atmospheric-photochemistry modeling efforts are providing new insights into the prevalence of these episodic events and the real impact on sensitive tree species. The results of the modeling effort so far reinforce the suggestion that the number of ozone monitoring stations throughout Wisconsin should be increased.

28. Determine the ecological impacts from the emission of pollutants from Wisconsin coal-fired plants (e.g., acid deposition from HCl, HF, SO_2 and NO_X emissions). Study changes in soil chemistry. Evaluate the impacts on economically important timber species.

29. Conduct more detailed monitoring of soil solution chemistry, especially with regard to whether trees may be incapable of handling nitrate loadings. More work must be done to investigate soil solution chemistry to better understand how tree growth, health, winter hardiness and succession may be affected by atmospheric deposition.

30. Relate the impact of emissions reductions to deposition and to ecological recovery in order to project the level and rate of recovery that is achievable at various emission and deposition levels.[13]

31. Determine the degree to which Wisconsin soil and groundwater are becoming contaminated with zinc due to acid precipitation dissolving the zinc from zinc-coated steel.

G. Emission Speciation

The specific types (species) of air emissions from a coal-fired power plant are a function of the type of combustion process used by the plant.

Suggested Research

32. Analyze how specific power plant combustion technologies affect the speciation of heavy metals and VOCs. Information about particulate emissions from power plants is usually about particulates as a category, rather than about the specific chemical makeup of the particulates. By paying attention to the chemical makeup, determine which power plants the particulates come from.

33. Collect data on the emissions and potential public health impact of other air toxics such as dioxins/furans, radionuclides, acid gases and metal species other than mercury.

H. Transformation of Gas Precursors to Particulates

Suggested Research

34. Determine how the gas precursors (NH_3, SO_2, NO_X) of particulates in Wisconsin become particulate and ozone concentrations. How are the gaseous emissions of NH_3, SO_2 and NO_X transformed into particulate and ozone concentrations and deposition?

    a. What is the relative impact of these emissions on public health (e.g., ozone and fine particles) and welfare (e.g., visibility impairment) in the eastern half of the U.S.?

[13] Some of this work has been done in the Northeastern US using the model PnET. The results are reported in BioScience 51(3) 180-198.

III. Solid Waste Issues

Most solid waste issues identified are concerned with the management of coal ash from electrical generation. Two other areas of interest include disposal of creosote-treated utility poles and potential issues of using sewage sludge as a boiler fuel.

Suggested Research

1. Determine the impact on the beneficial reuse of fly ash if mercury or NO_X controls are mandated. Will these controls change the chemistry of utility ash? It is possible that the beneficial reuse of fly ash, particularly for cement/concrete making, would suffer if controls were mandated. This assumes that the present mercury control technology, which is used prior to the precipitator at power plants, would be employed. However, it is not clear that other uses could not be substituted for the concrete/cement use. Until more is known about the full range of possible beneficial uses of fly ash and the concentration of mercury and carbon in the fly ash, this question cannot be answered with certainty.

2. Determine the fate of mercury in coal combustion waste. State and federal rules are being developed to reduce air emissions of mercury. This will increase the concentration of mercury in the residuals. What is the extent of mercury re-volatilization from ash landfills and from beneficial uses of combustion waste (e.g., cement manufacturing, agricultural amendment, road base, etc.)? Will the use of activated carbon for mercury control increase the leachability of mercury from combustion waste?

3. Ascertain which constituents in ash would prohibit or aid the land application of coal ash. What constituents would make it more desirable to use ash for land application purposes if added to utility ash in greater concentrations? What constituents would make it more difficult to land apply utility ash if present in greater concentrations?

4. Determine the impacts on clay and other liners in monofills from ash disposal leachates. What is the effect on the liners of monofills, from the leachate that results from coal ash? Does this leachate affect the life of monofill liners?[14]

5. Analyze the long-term environmental impact of both existing and new coal ash disposal sites. Evaluate the safeguards state law now requires and determine if there are gaps in these requirements.[15]

6. Conduct research into the actual environmental risks posed by high volume uses of coal ash.

7. Determine the potential environmental barriers to redevelopment of retired coal-fired power plant sites.

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[14] Ken Ladwig (EPRI) indicated that the effects of ash leachate on various liners have been looked at in the past by EPRI and that there appear to be no significant questions remaining.

[15] Contamination of ground and surface waters from the disposal of coal combustion waste (either in landfills or lagoons) has been documented across the country. In Wisconsin, the E.J. Stoneman Ash Pond is a documented "damage case" resulting from disposal of coal ash, demineralizer regenerent and waste water treatment wastes. This site has been remediated. (See Report to Congress on Wastes from the Combustion of Fossil Fuels, U.S. EPA, March 1999).

8. Determine the impact of leachate from mercury removal system sludge on sewage treatment plants. Plant operators are doing a lot to remove mercury and may not look kindly on this leachate.

9. Determine the hazards associated with the disposal of creosote-treated utility poles.

10. Analyze the potential for future sludge incineration as an energy source, in light of the frequent finding of traces of pharmaceuticals in the soil and groundwater. If current practices (for reuse as a soil amendment or for disposal in a landfill) are reduced, will incineration as a fuel source become an attractive solution for managing sludges? If so, what atmospheric emissions might become important considerations?

IV. Climate Change

The impact of potential climate change and ways to address it raised several issues and possible research areas.

A. Environmental Impacts of Climate Change

Suggested Research

1. Determine which Wisconsin animals and plants will find their habitats migrating from their current ranges due to global warming.

2. Develop credible scenarios for the magnitude and rate of climate change at the state level. This kind of analysis is beginning to be feasible, as modelers are developing ways to look at ever smaller grid cells in doing climate projections at the regional level.

3. Determine which resources (e.g., lakes, rivers, agricultural land, forests, ecosystems, human health, recreation, etc.) or activities are potentially at risk from climate change. Explain why.

4. Determine which resources or activities might be better off in the climate change scenarios identified.

5. Assess the potential costs to Wisconsin if substantial climate change occurs.

6. Assess the potential benefits to Wisconsin if substantial climate change occurs.

B. Carbon Sequestration

Suggested Research

7. Determine the carbon sequestration potential for all land use types in Wisconsin. This would be very useful to understand if there is movement toward reduction in either the absolute amount or rate of increase of greenhouse gases.

8. Study the effect of ozone pollution on carbon sequestration.

9. Determine if global warming could turn carbon sinks into carbon sources.

10. Study how carbon is sequestered into the terrestrial biosphere and its longevity through various land management schemes.

11. Determine the kinds of buffering impacts forests have, including their ability to mitigate CO_2 impacts. Forests may buffer acidic precipitation and they sequester carbon by taking in carbon dioxide and emitting oxygen. These buffering impacts have not been examined closely.

12. Develop a greater understanding of how above-ground management affects soil storage of CO_2, and develop strategies that maximize soil storage.

13. Look for geological formations in Wisconsin that could serve as subsurface storage reservoirs for CO_2 captured from fossil fuel power plants.

    a. Estimate their storage capacity.

    b. Determine their location relative to power plants.

14. Investigate the role of other novel sequestration concepts (e.g., mineral CO_2 capture) in Wisconsin.

C. Greenhouse Gas Inventories

Suggested Research

15. Develop baseline information on carbon dioxide (CO_2) in Wisconsin.

16. Develop an inventory of other greenhouse gas emissions in Wisconsin (e.g., methane, nitrous oxide and chlorofluorocarbons).

17. Develop a Wisconsin-specific carbon budgeting system. This could prove particularly useful if there is movement toward greenhouse gas reductions. Such systems are complex and a strategy for Wisconsin could be very specific to the mix of industry and vegetation types in the state.

18. Estimate the life cycle greenhouse gas emissions from the transmission of electricity in Wisconsin. Different aspects of transmission lines, such as transmission line power losses, affect the total amount of power delivered and, thus, greenhouse gas emissions, for Wisconsin. Looking at the life cycle results of different transmission configurations could indicate improved future electricity delivery strategies.

D. Adaptation Strategies

Suggested Research

19. Determine to what degree alternative bio-energy sources (e.g., poplar tree plantations, switchgrass) help to displace fossil fuel combustion and reduce greenhouse gas emissions in new electrical power generation strategies.

20. Investigate the possibility of retrofitting coal plants to scrub CO_2 from large coal plants by means of mono-ethanolamine.

21. Investigate the potential for steam reformation in Wisconsin power plants. A process known as the integrated gasifier combined cycle (IGCC) separates CO_2 formation from the process of heat generation.[16]
22. Determine the potential costs and benefits of adaptation programs that might be implemented to avoid climate change damages. Are there "no regrets" adaptation strategies that should be considered now?
23. Estimate the potential carbon reduction that can be achieved by a greenhouse gas market.
24. Estimate the potential costs of avoiding a build-up in atmospheric greenhouse gases—internationally, nationally and at the state level.
25. Evaluate the potential benefits of programs that reduce the accumulation of greenhouse gases in the atmosphere.
26. Decide if acting independently to require emissions abatement makes sense for Wisconsin.
27. Determine if more emphasis should be given to the other greenhouse gases defined in the Kyoto Protocol.

V. Environmental Impact of Renewable Electricity Sources

The production of energy from renewable sources can avoid some of the environmental impacts of conventional generation. Nevertheless, much remains to be learned about the impacts of the various renewable energy types.

A. Hydropower Dams

Hydropower dams have significant impacts on aquatic species living in the rivers such dams span.

Suggested Research

1. Study the characteristics of Wisconsin warm water fisheries' passage at dams.
2. Determine the level of entrainment of fish on water intake structures at hydropower dams. How many fish are trapped by being pulled into water intake structures at these dams?
3. Determine what controls the range of travel for Wisconsin warm water fisheries. To what degree do hydropower dams control the range of travel for Wisconsin warm water fisheries?
4. Study the fish mortality rate at hydropower dams in Wisconsin.
5. Study the impact of hydropower dams on the viability and range of rare mussel species.

[16] IGCC could lead to "zero emissions from coal" according to Robert Williams, head of energy-systems analysis at Princeton.

B. Wind Generator Impacts

The environmental impact of wind generators is primarily sociological. The very novelty of wind power invokes controversy among neighbors and communities surrounding a prospective site. At issue are conflicting perceptions of turbine noise levels, visual impact, and changing property values. The perception endures that wind turbines kill a lot of birds despite substantial existing research to the contrary. Solid evidence of these issues is useful, but perhaps more essential is to fill the gaps in knowledge about adaptation to a new energy technololgy.

Suggested Research

Bird and Bat Impacts

6. Estimate the bat population to determine the significance of bat/wind generator collisions.

7. Estimate the impact of Lake Superior and Michigan wind generator locations on bat and bird collisions. Compare the likely impact of wind electricity generators constructed on the shoreline versus offshore in Lakes Michigan and Superior.

Perception Issues with Wind Generators

8. Study wind turbine noise issues. How annoying is the noise created by wind machines? Wind generators create a certain amount of noise, which has not been taken fully into account in determining the environmental impacts associated with wind machines. How do people living near wind machines react to the noise? Do bigger wind machines produce less noise because of their slower propeller speeds?

9. Investigate wind turbine visual issues. What is the visual impact of windmills? What do most individuals feel about the visual impact of wind machines? Are they seen as positive or negative? Do these features create a greater negative visual impact if grouped together in a wind farm configuration?

10. Investigate television interference caused by wind generators. This issue could be studied to see if this perceived impact is actually occurring due to wind generator operation.

11. Analyze organized protests against the siting of wind machines on agricultural land. What is the impact of land developers' concerns about potential devaluation of potential sub-division land?

12. Analyze the impact of wind farm siting on surrounding property values.

C. Other Renewable Energy Issues

Other issues are considered important because of the potential value of renewable energy sources as a means of reducing the environmental impacts of the electric energy industry.

Suggested Research

13. Compare nuclear, coal-fired, gas-fired and renewable electricity generation options in terms of the environmental impacts of each to see what is the best fuel resource mix from an environmental perspective.

14. Estimate the impact of large-scale farming of biomass energy crops on soil, erosion and habitat.

15. Evaluate the impact of increased traffic on local roads if the use of such biomass crops as switchgrass or fast growing wood crops were to dramatically increase.

16. Study the feasibility of co-firing switch grass with coal to decrease NO_X and particulate emissions. Earlier tests using switch grass found that it burned very cleanly. It would be useful to determine more explicitly what proportion of switch grass can be co-fired with coal to result in the optimum NO_X and particulate reduction while maintaining sufficient power production.

17. Develop an accurate inventory of the amount of scrap wood available (e.g., from dunnage, pallets, sawdust) to determine the potential for biomass-fired electricity generation. The last inventory of wood residue was conducted in 1992.

VI. Water Quality Impacts

The research gaps identified related to water quality come from two categories: the impact acid deposition and the thermal impact of cooling water on surface water.

A. Acid Deposition Impacts

Acid deposition in Wisconsin has been studied intensively over the past twenty-plus years. Much is now known about the impacts of acid deposition in Wisconsin. However, some questions still remain.

Suggested Research

1. Determine the extent to which watersheds (lakes in particular) have responded to the measured lower acid precipitation. To what degree has the lower acidity of precipitation been reflected in higher pH in sensitive lakes and to what extent have the fisheries and other biological indicators shown a return to a less acidic lake water regime?

2. Confirm leaching losses of nutrients into soil water from soils in northern Wisconsin. Determine whether acid deposition is responsible. There are natural, microbially mitigated processes involved in the soil nutrient cycle and considerable organic nitrogen in most soils. Is acidic deposition driving losses? What is the role of natural processes and forest aggradation?

B. Power Plant Cooling Water Impacts

Many power plants tap streams and other water bodies for cooling water and discharge significant amounts of warm water back to the source.

Suggested Research

3. Determine the changes in temperature due to cooling water discharges from coal-fired power plants into Wisconsin receiving waters. This would be a valuable input into the question of whether thermal standards should be developed for power plant cooling water discharges.
4. Evaluate the impact of biocides and other cooling water additives emanating from Wisconsin coal-fired power plants on receiving water quality.
5. Determine the impact of cooling water discharges from the Valley Power Plant in Milwaukee on combined sewer overflows.

VII. Transmission Line Impacts

The following environmental issues surrounding transmission lines were noted as areas needing research.

Suggested Research

1. Study the effects of transmission line corridors on the overall forest resource. Do transmission lines influence species diversity? Do invasive plants more easily grow and predominate where transmission lines cut through forests? Does animal habitat change significantly?
2. Monitor bird populations before and after transmission lines are constructed where lines will cross areas known to function as flyways or attractive avian habitat. This would aid in understanding the effect of lines on bird movement and mortality.
3. Compare the impacts of different treatments (i.e., mechanical versus chemical) for right-of-way maintenance on different plant species. Building a transmission line necessarily requires maintenance on the right-of-way to keep it from becoming overgrown. Some of this maintenance is done mechanically and some is done chemically. What are the overall impacts of these two approaches on different plant species growing in or adjacent to the right-of-way?[17]
4. Determine the impact of habitat fragmentation on plants and animals due to transmission line locations and corridor maintenance. Does this create adverse impacts on plants or animals living in or adjacent to the transmission corridor?
5. Study seasonal variation in construction-related impacts. When building transmission line corridors through wetlands, are environmental impacts less severe when construction is done in winter? This question is related to the fact that most wetland plants are dormant

[17] According to Kathy Zuelsdorff, (PSCW) there is quite a large volume of available research literature covering this topic, so this does not appear to be a significant research gap

or at least undergoing reduced biological activity during the winter. Therefore, winter construction may be less damaging to wetland.

6. Study the role of transmission line corridors in animal movement. Do animals use transmission corridors to travel from one area to another or will the corridors serve more as barriers to such travel.[18]

7. Determine the impacts of transmission lines on rare species. By fragmenting the ecosystem in which rare plant and animal species live, what is the resulting impact on rare species?[19]

8. Study how aesthetics are best taken into consideration in transmission line planning.

9. Study processes for determining whether to route new transmission lines close to people (e.g., along roadsides) as opposed to more hidden locations where wildlife, wetlands and woodlands are affected to a greater degree.

10. Determine if there are other rare species or host plants (in addition to Karner blue butterfly) that could benefit if transmission line right of ways are managed to provide appropriate habitat. For example, in certain areas of the state transmission line corridors are being managed to encourage the growth of lupine, the sole larval food of the Karner blue, as a means to maintain or increase local populations. Are there other rare species or host plants for rare species that could thrive in transmission corridors if maintenance techniques and timing are managed in a certain way?

11. Compare the use of timber matting to access pole sites versus low-pressure track vehicles during transmission line construction. How do they impact the degree and speed of wetland vegetation recovery?

VIII. Other Research Issues of Note

The remaining research issues did not fit well within the research areas listed above.

Suggested Research

1. Identify the environmental impacts of dry cask storage of spent fuel rods at Wisconsin nuclear power plants.

2. Compare the noise implications of coal-fired generating plants versus those of distributed generation. While coal-fired central generating plants create significant noise, how does this compare on an aggregate basis to replacing such generation with many small power generating plants, located close to the demand for electricity, that are fired with either natural gas or diesel fuel?

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[18] Research suggests that large animals may use the corridors for travel but that the ROW clearing may serve as a barrier to small animals or those sensitive to changes in microclimates (e.g., salamanders or other amphibians).

[19] Kathy Zuelsdorff (PSCW) suggests that this question is too broad. She indicates that adverse impacts on rare plants could be due to 1) habitat loss or fragmentation; 2) frequent/routine disturbance causing general habitat degradation and/or invasion of exotic species or 3) ROW maintenance techniques and timing (i.e., herbicide use or mechanical cutting).

3. Compare the visual (aesthetic) impact of power plants and their stacks. How does this compare to the visual impact of the smaller but more frequent distributed generation stations?
4. Identify options for replacing existing transformer oils with those that have lower environmental impacts – either in their production or in terms of spills.
5. Analyze the effect of the electricity infrastructure on urban sprawl and human migration.
6. Analyze the impact of rail transport of coal through Wisconsin (e.g., fugitive dust through communities en route).

Conclusion

The gap analysis interview process yielded a robust set of observations and interest in environmental effects associated with Wisconsin's utility electricity generation and transmission. The interview process led to a wide range of comments, a broad span of subjects and a diverse level of detail.

There is a high degree of agreement among interviewees regarding the importance of gaining more understanding of mercury and its effects. Although this list of questions should not be considered to be exhaustive, the interviews revealed a great deal about how much has yet to be discovered in this area.

The gap analysis should help the Environmental Research Forum to recommend what the next round of projects for the next round of funding under the research program.

Appendix A: Gap Analysis Questionnaire

. Date: _____Time: _____

Name of Kestrel Associate:
_____

Name of Contact: _____ Title:
_____

Organization:
_____

Telephone Number:
_____

Gap Analysis Questionnaire (use back of sheet, for additional entries)

As staff to the Wisconsin Focus on Energy Environmental Research Administrator, we are charged with the mission of determining what research gaps exist in terms of the environmental impacts caused by electricity generation and transmission.

We would like to learn from you what research gaps you feel exist. We will submit this information to the Wisconsin Environmental Research Forum so that it can help the Department of Administration's Division of Energy to decide how to allocate roughly $1 million per year over the next 3 years for research designed to close these gaps.

1) What research gaps can you think of regarding the environmental impacts due to:

- Gas or coal-burning electricity generation? (Hints: Impacts on lakes, rivers, trees, soil, agriculture, property)

- Nuclear generation of electricity?

- Utility-owned wind generation of electricity?

- Hydropower electricity generation?

- Biomass electricity generation (e.g., landfill gas- or wood-fired generating units)?

- Electric power transmission lines (siting, construction, etc.)?

2) Do you know of anyone else who might have a useful perspective or information on these questions?

Who? How can we contact them?

May we mention your name? Who else?

3) Do you recommend any literature?

Appendix B: Contacts Made for Gap Analysis

Wisconsin Department of Natural Resources

George Albright – Chief, Environmental Analysis & Liaison Section, Bureau of Integrated Science Services
Craig Anderson – Natural Heritage Inventory Program Botanist, Bureau of Endangered Resources
Sue Bangert –Director, Bureau of Solid Waste Management
Gerald Bartelt – Chief, Wildlife & Forestry Section, Bureau of Integrated Science Services
Catherine Bleser – Environmental Analysis & Review Specialist, Bureau of Endangered Resources
Larry Bruss – Chief, Ozone Section, Bureau of Air Management
Paul Delong –Director, Bureau of Forestry
Lloyd Eagan –Director, Bureau of Air Management
Mark Giesfeldt – Director, Bureau of Remediation and Redevelopment
Tom Hauge – Director, Bureau of Wildlife Management
Robert Hay – Cold-Blooded Species Program Manager, Bureau of Endangered Resources
John Heinrich – Industrial Process Focus Systems Manager, Bureau of Air Management
Signe Holtz –Director, Bureau of Endangered Resources
Ed Jepsen – Engineer, Environmental Studies Section, Bureau of Air Management
Tom Karman – Stationary Source Control Strategy Engineer, Ozone Section, Bureau of Air Management
Doug Knauer – Chief, Environmental Contaminants Research Section, Bureau of Integrated Science Services
Paul Koziar – Waste Management Specialist, Bureau of Solid Waste Management
Terry Mace – Resource Analysis Specialist, Forestry Program Support Section, Bureau of Forestry
Robert Martini – Federal Energy Regulatory Commission Environmental Analysis & Review Specialist
George Meyer –Special Assistant to the Secretary
Mike Meyer – Environmental Contaminants Research Section, Bureau of Integrated Science Services
Teague Pritchard – Forestry Planner, Forestry Program Support Section, Bureau of Forestry
Jamie Schlangen – Environmental Review Coordinator, Bureau of Endangered Resources
Duane Schuettpelz – Chief, Wastewater Permits & Pretreatment Section, Bureau of Watershed Management
Al Shea –Director, Bureau of Watershed Management
Tom Sheffy – Chief, Monitoring Section, Bureau of Air Management
Bill Smith – Natural Heritage Inventory Program Zoologist, Bureau of Endangered Resources
Steve Ugoretz – Energy team Leader, Environmental Analysis & review Specialist, Bureau of Integrated Science Services
Rich Wedepohl – Chief, Dam Safety & Floodplain & Shoreline Management, Bureau of Watershed Management

Darryl Zastrow – Chief, Forestry Sciences Section, Bureau of Forestry

Wisconsin Department of Administration
Don Wichert – Chief, Energy Resources Section, Division of Energy

Wisconsin Public Service Commission
Bill Fannucchi, Senior Environmental Analyst

Wisconsin Department of Health & Family Services
Henry Anderson, M.D.

University of Wisconsin – Madison
Vicki Bier – Department of Mechanical Engineering
James Bockheim – Department of Soil Science
Stephen Born – Department of Urban & Regional Planning
Jonathan Foley – Gaylord Nelson Institute for Environmental Studies; Chair, Center for Sustainability and the Global Environment
Thomas Jeffries – Department of Bacteriology
Erhard Joeres – Chair, Department of Civil Engineering
Marty Kanarek – Department of Preventive Medicine
Gerald Kulcinski – Department of Engineering Physics
Douglas Reinemann – Department of Biological Systems Engineering
Jamie Schauer – Department of Civil Engineering
(All of the UW personnel are professors)

University of Wisconsin – La Crosse
James Wiener – Wisconsin Distinguished Professor, College of Science and Allied Health

Investor-Owned Electric Utilities
Jim Christensen – Alliant Energy
Noel Cutwright – We Energies
Eric Hennen – Dairyland Power Cooperative
David Michaud – We Energies
Ed Newman – Wisconsin Public Service Corporation
Mike Ricciardi – Madison Gas & Electric

Wisconsin Geological & Natural History Survey
Jamey Robertson, Director

Wisconsin Environmental Decade
Keith Reopelle, Program Director

Wisconsin Manufacturers & Commerce
Jeff Schoepke, Environmental Policy Director

Wisconsin Paper Council
Ed Wilusz, Government Relations Director

Wisconsin Utilities Association
Bill Skewes, Executive Director

Citizen Utility Board
Steve Hiniker, Executive Director

Sierra Club
Brett Hulsey, Senior Midwest Representative
Caryl Terrell, Staff Director

Audubon Society
Karen Edder-Hale, Executive Secretary, Madison Chapter

Wisconsin Public Interest Research Group
Kerry Schumann, Director

Center for Clean Air Policy
Governor Anthony Earl – Chairman
Ned Helme – Executive Director

Upper Midwest Gap Analysis Program
David Fitzpatrick, Coordinator

The Health Effects Institute
Debra Kaden, Senior Scientist

United States Geological Survey
David Krabbenhoft, Research Scientist

United States Environmental Protection Agency – Great Lakes National Program Office
Judy Beck, Lakewide Management Plan Coordinator
Gary Gulezian, Director
Todd Nettesheim, Environmental Engineer

New York State Energy Research & Development Authority
Mark Watson

Electric Power Research Institute
Kathy Trudell, Regional Representative

National Atmospheric Deposition Program
Van Bowersox, Coordinator

Earth Institute of Columbia University
Tracey Holloway, Post-Doctoral Fellow

Wisconsin Federation of Cooperatives
David Jenkins, WECA Division Manager

Sixteenth Street Community Health Center (Milwaukee)
Peter McAvoy, Environmental Policy Director

United States Fish & Wildlife Service
Janet Smith, Green Bay Office Field Supervisor

Dartmouth College

Paul Pickhardt and colleagues, a series of publications including a Dartmouth College press release (March 18, 2002, Office of Public Affairs) and the Proceedings of the National Academy of Sciences (published online on March 19, 2002), all of which allude to how algae appear to influence mercury uptake in fish.

Appendix C: Draft Analysis Reviewers

Gap Analysis Reviewers			
Reviewer	**Affiliation**	**Qualifications or Association with Issues**	**Referring Source**
Topical area: **Mercury-Related**			
Jim Hurley	UW-Sea Grant Institute	Mercury issues in WI	Doug Knauer, WDNR
Doug Knauer	WDNR (now retired)	Mercury research expert	Clear choice from ERF meeting experience
Topical area: **Non-Mercury Air Toxics and other Air Emission Issues**			
Martha Keating	Consultant to Clean Air Task Force (formerly with US EPA)	Good on mercury and non-mercury emissions from utilities (not WI-specific)	Jerry Mendl
Rick Haeuber	US EPA	Air emissions expertise (not WI-specific)	Mark Watson
Larry Bruss	WDNR	Good on non-mercury emissions from Wisconsin utilities	Lloyd Eagan
Kathy Lambert	Hubbard Brook Research Foundation	Acid deposition (not WI-specific)	Mark Watson
Topical area: **Visibility/Haze**			
Mike Koerber	LADCO	Great Lakes area visibility expert	Rheal Poirer (Conference of New England Governors and Eastern Canadian Premiers), via Cheryl Rezabek
Larry Bruss	WDNR	Wisconsin visibility expert	Lloyd Eagan
Topical area: **Solid Waste Issues**			

Gap Analysis Reviewers			
Reviewer	**Affiliation**	**Qualifications or Association with Issues**	**Referring Source**
Bill Constantelos	Midwest Energy (formerly with Waste Management and Reg. V EPA)	Solid waste impacts of electricity generation	Peter Wise (Kestrel, former second in command of IL EPA)
John Shennot	WDNR	Energy sector specialist – electricity	Peter Wise
Ken Ladwig	EPRI	Knows solid waste impacts from electricity generation; knows WI context	Dick Bratcher (EPRI Global Climate Manager)
Phil O'Leary	UW- GNIES	Solid waste expert; knows WI context	Pat Eagan
Topical area: **Carbon Sequestration/Green House Gas Emissions**			
Gary Jacobs	Oak Ridge National Laboratory	Carbon sequestration/Greenhouse gas authority	Cheryl Rezabek
Howard Herzog	MIT	Clean Air Task Force uses him for carbon sequestration expertise	Jerry Mendl
Dick Bratcher	EPRI	EPRI Global Climate Manager	Roy Christianson
Erhard Joeres	UW Civil Eng.	Good oversight knowledge of carbon sequestration issues	Pat Eagan
Topical area: **Renewable Electricity Sources**			
Richard Schaten	UW-GNIES	Good perspective on energy and the environment; expertise with renewables	Pat Eagan
Chandra Shah	National Renewable Energy Laboratory	Knowledgeable about the environmental impacts associated with renewable electricity alternatives	Kavita Maini (Envise)
Topical area: **Monitoring**			
Van Bowersox	NADP	Knowledgeable about monitoring needs in the Great Lakes area	Cheryl Rezabek
Topical area: **Forest Atmosphere/Ecosystems**			

Gap Analysis Reviewers			
Reviewer	**Affiliation**	**Qualifications or Association with Issues**	**Referring Source**
Dr. Warren Heilman	USDA Forest Service		Cheryl Rezabek
Topical area: **Landscape Ecology**			
Eric Gustafson	USDA Forest Service		Cheryl Rezabek
Topical area: **Riparian & Aquatic Ecosystems**			
Dr. Randy Kolka	USDA Forest Service		Cheryl Rezabek
Topical area: **Water Quality Impacts**			
Mike McHale	USGS Troy, New York	Good understanding of toxicological aspects of water quality impacts from electric power generation	Mark Watson
Topical area: **Transmission Line Impacts**			
Noel Cutwright	Wisconsin Electric	Transmission line environmental impacts expert	Dick Bratcher
Kathy Zuelsdorff	PSCW	Transmission line environmental impacts expert	Jerry Mendl
Topical area: **Other Research Issues of Note**			
John Shennot	WDNR	Electric energy sector specialist	Peter Wise

Focus on Energy is a public-private partnership offering energy information and services to energy utility customers throughout Wisconsin. The goals of this program are to encourage energy efficiency and use of renewable energy, enhance the environment, and ensure the future supply of energy for Wisconsin.

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