BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION

In the Matter of the Application by Otter Tail Power Company on behalf of the Big Stone II Co-owners for an Energy Conversion Facility Siting Permit for the Construction of the Big Stone II Project	))))	**Case No EL05-022**

Direct Testimony of
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On Behalf of
Minnesotans for An Energy-Efficient Economy
Izaak Walton League of America – Midwest Office
Union of Concerned Scientists
Minnesota Center for Environmental Advocacy

May 19, 2006

I. PROFESSIONAL QUALIFICATIONS AND SUMMARY

Q. Please state your name for the record.

A. My name is Ezra D. Hausman

Q. Where are you employed?

A. I am a Senior Associate with Synapse Energy Economics of Cambridge, Massachusetts

Q. Please describe your formal education.

A. I hold a PhD. in Atmospheric Science from Harvard University, a master's degree in applied physics from Harvard University, a master's degree in water resource engineering from Tufts University, and a Bachelor of Arts degree from Wesleyan University.

Q. Please describe "atmospheric science."

A. Briefly, atmospheric science is the study of the chemistry, circulation and heat transfer processes of the atmosphere. It encompasses the study of how the atmosphere interacts with the ocean and land surface through processes of chemistry, moisture exchange, and energy transfers. These processes are central to what we think of as the "climate" of the Earth and, in concert with oceanic processes, they control the distribution of surface temperature and patterns of precipitation on the planet.

Another way to look at this is as follows: A certain amount of energy reaches the surface of the Earth, as sunlight, every day. At equilibrium, the same amount of energy must be vented back to space, on average. Atmospheric science is the science of all of those chemical, physical and dynamical processes which work together to move that energy to the top of the atmosphere and release it back into space.

Q. Please describe your experience in the field of atmospheric science.

A. For my doctoral research at Harvard University, I built a dynamic computer model of the ocean-atmosphere system to explore how a number of observed changes in atmospheric chemistry, ocean circulation and ocean surface temperature at the end of the last glaciation ("ice age") can be used to explain certain aspects of the warming of the planet at that time. I demonstrated, among other things, that the increase in atmospheric Carbon Dioxide (CO_2) at that time was both a result of and a strong positive feedback for the concurrent warming of the planet.

After graduation, I worked with researchers at Columbia University to develop private sector applications of climate forecast science. This led to an initiative called the Global Risk Prediction Network, Inc. for which I served as Vice President in 1997-1998. Specific projects included serving as Principal Investigator for a statistical assessment of grain yield predictability in several crop regions around the world based on global climate indicators and for a statistical assessment of road salt demand predictability in the United States based on global climate indicators. I also prepared a preliminary design of a climate and climate forecast information website tailored to the interests of the business community.

Q. Please describe your work since 1998.

A. Since 1998 I have been primarily focused on electricity market issues, turning my numerical modeling and analysis skills to issues of electricity market structure, electric industry restructuring, asset valuation and price forecasting, and environmental regulations in the electric industry. In July of 2005, I joined Synapse Energy Economics of Cambridge, Massachusetts, to continue this work but with more of a focus on the environmental, long-term planning and consumer protection aspects of the industry. This has given me an opportunity to apply my combined expertise, in atmospheric science and in the electric industry, to some of the most important issues facing the industry and, indeed, our society.

Q. Have you attached a copy of your current resume to this testimony?

A. Yes, I have, as Exhibit JI-2-A

Q. Please provide a summary of the main points of your testimony.

A. Human induced climate change is a grave and increasing threat to the environment and to human societies around the globe. Its early effects, which are already observable and documented in the scientific literature, are consistent with those predicted by computer models of the global climate, and these same models predict much more severe effects to come. Indeed, we are on a path that, if unchanged, is likely to bring about a climate well outside the range of anything ever experienced by our species, with the potential for severe and irreversible changes that will forever alter our environment, our economies and our way of life.

While some level of climate change is already a fact, computer models tell us that we can still avoid the most dangerous impacts by limiting the further buildup of CO_2 in the atmosphere. Perhaps the most important way to achieve this is by limiting the burning of fossil fuels in the decades ahead. In contrast, if the Big Stone Unit II is built, it would inject enormous amounts of CO_2 into the atmosphere for decades to come and would contribute to the dangerous atmospheric buildup of this gas. Thus, the proposed unit would exacerbate a problem that is likely to cause dramatic environmental and economic harm to societies around the globe, including to the communities in South Dakota.

Q. What issues in particular will your testimony cover?

A. My testimony will:

- discuss the scientific basics of global climate change (Part II)
- describe some of the authoritative scientific literature on the subject, including that which is written specifically for the use of policymakers, and the state of the scientific consensus on the subject (Part III)

- describe the rise of atmospheric CO2 globally and in the context of the long-term history of atmospheric CO2 (Part IV)
- discuss climate changes that have occurred already (Part V)
- describe what is predicted for the future (Part VI)
- discuss some of the global impacts of climate change (Part VII)
- discuss some likely impacts of climate change on South Dakota (Part VIII)
- put Big Stone II's CO2 emissions in the context of overall emissions (Part IX)
- express my scientific conclusions as they relate to legal standards applicable to this proceeding (Part X)

II. THE SCIENTIFIC BASICS OF GLOBAL CLIMATE CHANGE

Q. Would you explain the "greenhouse effect"?

A. The planet's climate is a function of how much energy it receives from the sun, how much of that energy it retains, and how that energy is distributed throughout the planet (by wind and ocean currents, evaporation, condensation, and other mechanisms). Solar radiation arrives on earth, mainly in the form of visible light. That radiation is absorbed by the surface of the planet, which in turn radiates heat energy upward. Some of that heat is trapped in the lower atmosphere by naturally-occurring gases, analogous to how heat is trapped in a greenhouse by the glass. This is the natural "greenhouse effect" and the heat trapping gases are commonly called "greenhouse gases."

Without the greenhouse effect, the earth would be far too cold to support liquid water, or probably any kind of life. Similarly with too strong of a greenhouse effect, the earth would be considerably warmer and might have no polar ice caps, as has happened in the geologic past. With an even stronger greenhouse effect the earth could become extremely hot and uninhabitable, like the planet Venus. For all of recorded human history, the greenhouse effect has remained within a fairly narrow range that we know today, allowing complex human civilizations to form and develop. During periods of geologic history that had different abundances of greenhouse gases such as CO_2, the earth had a very different climate.

Q. How have humans enhanced the natural greenhouse effect?

A. Human activities have increased the atmospheric concentration of many greenhouse gases, most notably the concentration of CO_2. This increase has come primarily from the burning of fossil fuels (coal, oil, and natural gas), and also from changes in land use such as deforestation. Of the fossil fuels, coal emits the most CO_2 per unit of energy obtained. Today the primary reason for burning coal is for generation of electricity.

Because of the continuous and accelerating recovery and combustion of fossil fuels, the background level of CO_2 in the air has increased by roughly one third since preindustrial times. This means that the planet as a whole does not lose heat to space as efficiently as it otherwise would, so the system as a whole is warming up. This is the phenomenon commonly referred to as "global warming."

Global warming will affect different areas differently, changing the distribution of rainfall, warming many areas but cooling some others, changing the length of growing seasons, and so forth. To emphasize the planet's complex *response* to global warming, scientists have coined the term "global climate change." I personally prefer to use the term "global climate change" in contexts such as this one to emphasize that the impact of the increased atmospheric CO_2 burden will not just be measured in a few warm days, but in disruptions in the very characteristics of climate that define our lives and our livelihoods.

III. SCIENTIFIC LITERATURE ON GLOBAL CLIMATE CHANGE

Q. In your opinion, what is the most comprehensive, reliable, authoritative, and scientifically credible account, relied upon by you and other experts in your field of climate science, regarding global warming, including the causes of global warming and the potential impacts on people and on the natural world?

A. There are a great number of studies published in distinguished, peer-reviewed scientific journals that are relied upon by scientists in developing a full understanding of the many aspects of climate science and climate change. However, perhaps unique to this area of science, there is a single source that has been carefully assembled by the leading researchers in the field to provide a comprehensive, reliable, authoritative, and scientifically credible digest of this body of research. This source is the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC).

Q. What is the IPCC?

A. The IPCC was formed in 1988 by the World Meteorological Organization and the U.N. Environment Programme in response to rising concerns about global climate change. It provides an organizational structure for the work of hundreds of the world's leading researchers in climate science and related sciences. The IPCC does not do scientific research as an organization; rather, it assesses the scientific literature in an extremely methodical and transparent way, publishing consensus reports that reflect the work of scientists from around the world.

Q. Does the IPCC have any official role in advising policymakers?

A. Yes. In 1988 the United Nations General Assembly formally requested that the IPCC provide a comprehensive review and recommendations with respect to "the state of knowledge of the science of climate and climatic change."[1] In 1992, after receiving the IPCC's first assessment of the science, nearly every nation in the world, including the U.S., entered into the United Nations Framework Convention on Climate Change. The signers of the Framework Convention have asked the IPCC to provide full assessments of the state of climate science every 4 to 5 years, and to prepare various technical papers related to specific aspects of climate science, technology, and the social and economic impacts of climate change. The IPCC's assessments are therefore written with policy making in mind; they do not advocate for particular policies, but they do strive to provide policy-relevant information.

Q. Do the periodic assessments by the IPPC address the science of climate change?

A. Yes. The most recent Assessment Report released by the IPCC is the Third Assessment Report (TAR), released in 2001. The Report of Working Group I of the IPCC, entitled "Climate Change 2001: The Scientific Basis," is the part of the TAR that addresses the science of climate change. (Hereinafter "Working Group I Report".)

Q. How and by whom was the Working Group I Report prepared?

A. The Working Group I report describes in its preface how it was prepared, stating: "This report was compiled between July 1998 and January 2001, by 122 Lead Authors. In addition, 515 Contributing Authors submitted draft text and information to the Lead Authors. The draft report was circulated for review by experts, with 420 reviewers submitting valuable suggestions for improvement. This was followed by review by governments and experts, through which several hundred more reviewers participated. All the comments received were carefully analyzed and assimilated into a revised document for consideration at the session of Working Group I held in Shanghai, 17 to 20 January 2001. There the

[1] IPCC 2004 document, "Sixteen Years of Scientific Assessment in Support of the Climate Convention."

Summary for Policymakers was approved in detail and the underlying report accepted."

The lead and contributing authors of this report were, like the IPCC itself, drawn from the ranks of the world's leading researchers. It is my opinion that the IPCC Working Group I report represents a thorough, fully informed, and authoritative assessment of scientific knowledge related to climate change as of the time it was written.

Q. Is there a summary of the report?

A. Yes. The Summary for Policymakers was adopted as part of the Working Group I Report. A copy of the Working Group I Summary for Policymakers is attached as Exhibit JI-2-B to my testimony.

Q. Does the IPCC Third Assessment Report include an analysis of the potential impacts of global warming?

A. Yes. The IPCC Third Assessment Report (TAR) includes the report of Working Group II of the IPCC, entitled "Climate Change 2001: Impacts, Adaptation, and Vulnerability," hereinafter referred to as "Working Group II Report".

Q. How was the Working Group II Report prepared?

A. The preface of the Working Group II Report describes how it was prepared, stating: "The WGII report was compiled by 183 Lead Authors between July 1998 and February 2001. In addition, 243 Contributing Authors submitted draft text and information to the Lead Author teams. Drafts of the report were circulated twice for review, first to experts and a second time to both experts and governments. Comments received from 440 reviewers were carefully analyzed and assimilated to revise the document with guidance provided by 33 Review Editors. The revised report was presented for consideration at a session of the Working Group II panel held in Geneva from 13 to 16 February 2001, in which delegates from 100 countries participated. There, the Summary for Policymakers was approved in detail and the full report accepted."

As with Working Group I, the authors of the Working Group II report were among the leading researchers in their fields, and their findings are based on a thorough consideration of the science. The Working Group II's Summary for Policymakers is attached as Exhibit JI-2-C.

Q. **Can you identify any other documents for a nontechnical, policymaking audience which you consider to be authoritative on the subject of global warming?**

A. Yes. A good example is a statement issued in 2005 by the U.S. National Academy of Sciences along with national science academies of Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, and the United Kingdom entitled "Joint Science Academies' Statement: Global Response to Climate Change," which I will refer to as the "Joint Science Academies Statement". The Joint Science Academies Statement is attached to my testimony as Exhibit JI-2-D.

Q. **What is the US National Academy of Sciences?**

A. The National Academy of Sciences (NAS) was formed by legislation signed in 1863, and as mandated in its Act of Incorporation it has since then served to "investigate, examine, experiment, and report upon any subject of science or art" whenever called upon to do so by any department of the government. The National Academy of Sciences is comprised of approximately 2,000 members and 350 foreign associates, of whom more than 200 have won Nobel Prizes. Although chartered by the federal government, the NAS is a private, non-profit and independent scientific organization. It is currently headed by Dr. Ralph J. Cicerone, himself an atmospheric scientist with research interests in atmospheric chemistry and climate change. Election to the NAS is considered by many to be one of the highest honors an American scientist can receive.

Q. In addition to expressing its views in the Joint Science Academies Statement, has the NAS released any reports on climate change?

A. The NAS has issued a number of publications and reports on this subject, reflecting the importance with which the scientific community views this issue. In 2001, at the request of the Bush Administration, it released a study entitled "Climate Change Science: An Analysis of Some Key Questions," which endorsed the essential findings and predictions of the IPCC.

Q. In your opinion is the National Academy of Sciences qualified to assess and report on the scientific data related to the increased concentration of CO_2 and the effects of that increase on air, water, and natural resources?

A. Yes. The National Academy of Sciences is eminently qualified to address and produce authoritative reports on these issues.

Q. Would you say that there is a scientific consensus on the issue of global climate change?

A. There is an unequivocal scientific consensus on many aspects of the issue of global climate change. These aspects include:

- The fact that the CO_2 content of the atmosphere is increasing rapidly;
- The fact that this rate of increase, and the resulting abundance of CO_2 in the atmosphere, is unprecedented in at least the past 200,000 years, and probably much longer;
- The fact that the primary source of the increase is combustion of fossil fuels by human industrialized societies, i.e., that it is anthropogenic CO_2;
- The fact that the increased abundance of atmospheric CO_2 has a direct radiative forcing effect on climate by altering the heat transfer characteristics of the atmosphere;
- The fact that this change in the heat transfer properties of the atmosphere will have an impact on the climate of the planet;
- The fact that the climate of the earth is currently changing in ways that are consistent with model predictions based on the increased radiative forcing due to the anthropogenic increase in atmospheric

CO_2, and that these changes include increased sea surface temperatures, increased sea level, loss of arctic permafrost, loss of mountain and polar glacier mass, and destruction of arctic habitat;

- The fact that these observed changes cannot be ascribed to any known natural phenomenon;
- The fact that the magnitude of climate impacts will increase with increasing atmospheric CO_2 content; and
- The fact that once the atmospheric abundance of CO_2 has been increased, it will only return to equilibrium levels through natural processes on a timescale of several centuries.

In addition, there is a strong scientific consensus that natural feedbacks in the climate system would, on balance, tend to reinforce warming rather than mitigate it; that one effect of global warming will be migration of climate zones so that human societies and natural ecosystems will find themselves poorly adapted to their local climate; and that this will result in disruption and dislocation of ecosystems, migration of pest species and disease vectors, and disruptions in agriculture. There is general agreement, if not yet consensus, that global climate change will lead to generally more extreme weather patterns across most of the globe, including more intense storms and rainfall events and more extreme dry spells.

Q. Do the documents identified in this testimony, including the IPCC Working Group reports and the Joint Science Academies Statement, support these conclusions regarding scientific consensus?

A. Yes.

IV. THE RISE OF ATMOSPHERIC CO_2 LEVELS

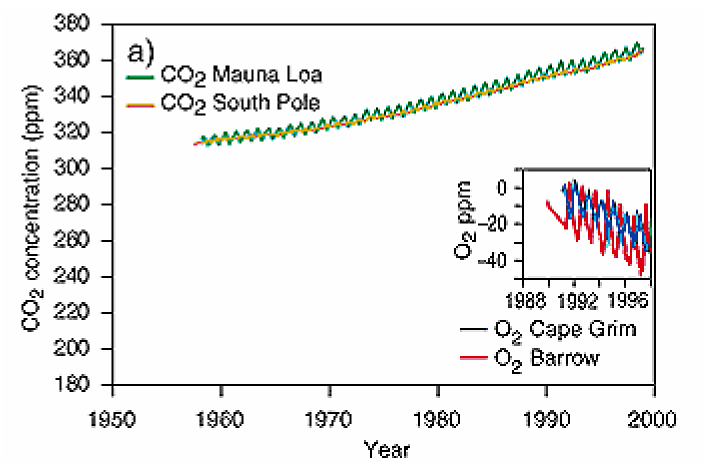
Q. Since the last IPCC report in 2001, what has been observed by climate scientists about global levels of CO_2?

A. The level of CO_2 is still increasing. For example, the U.S. National Oceanic and Atmospheric Administration (NOAA) reported on May 1, 2006, that the average atmospheric carbon dioxide level increased from an average of 376.8 parts per million in 2004 to 378.9 parts per million last year.[2]

Q. Could you put this increase in CO_2 levels in perspective?

A. Yes. I will put this in context with reference to a few figures from the Working Group I Report, which will show some of the key evidence demonstrating the nature of the modern rise in atmospheric CO_2.

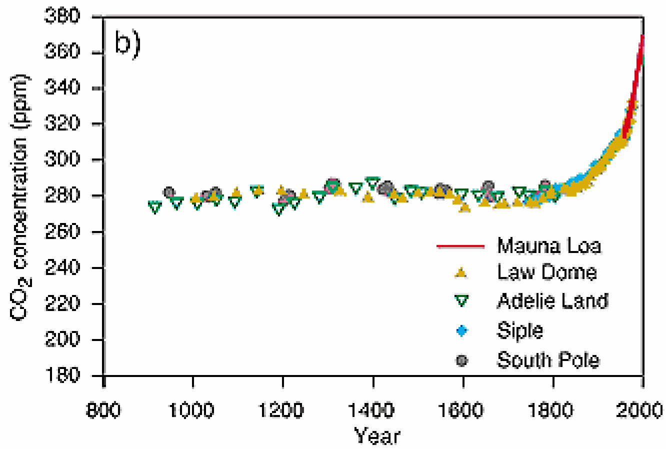
The first graph shows the direct, instrumental measurements of CO_2 from Mauna Loa, in Hawaii, taken since the late 1950s. This graph shows both the seasonal variations in CO_2 associated with the growing season in the northern hemisphere, and the year-to-year increase in atmospheric CO_2 during this period:



In this period alone, essentially my lifetime, atmospheric CO_2 has risen from under 320 parts per million to almost 380 parts per million, and the rate of increase itself is also increasing.

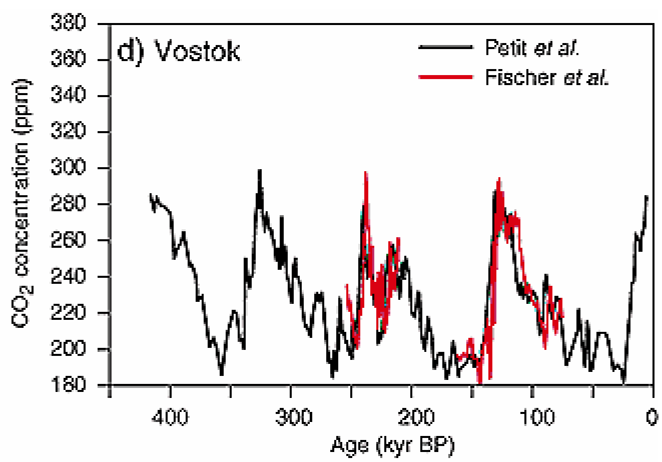
This next graph shows the history of atmospheric CO_2 for the last thousand years or so. This is measured in ancient air samples recovered from bubbles trapped in polar ice, in this case from various sites in Antarctica. The vertical scale is the same as in the previous graph, and in fact it also shows the Mauna Loa data for comparison:

[2] *http://www.cmdl.noaa.gov/aggi*



These data demonstrate that CO_2 levels have been relatively steady in the atmosphere for over 1,000 years, a time of remarkably quiescent climate by geological standards, during which modern human civilization and culture have flourished around the world.

Finally, this last graph shows the variations in atmospheric CO_2 over the last four glacial cycles, also recovered from Antarctic ice cores. The vertical scale is the same as for the two previous graphs, while the horizontal scale is in thousand years before the present:



Remember that the Mauna Loa data begin just below 320 ppm, and increase rapidly from there. This is already higher than has been measured for any time in the last 400,000 years, although the variations during this period were considerable. These variations were accompanied by enormous changes in climate, including the enormous advances of glaciers to cover much of the North American continent and Eurasia.

We have excellent computer models to predict some of the effects of elevated CO_2 levels, and some of these are the topic of my testimony. In addition to this, however, is the extraordinary risk associated with pushing the climate system to where it has never gone in over 400,000 years, and probably in tens of millions of years. This is, in my opinion, a dangerous game to play with the only planet we have.

Q. How high are CO_2 levels projected to go in the century ahead?

A. The IPCC predicts that CO_2 levels in the coming century will continue to steadily rise if the earth follows the "business as usual" path of fossil fuel consumption. These projections, based on various scenarios covering a range of assumptions regarding population growth, economic growth, globalization, etc., suggest that atmospheric CO_2 concentrations could reach from 490 to 1260 parts per million (an increase of 75% to 350% above 1750 concentrations). The higher the concentration, the more likely it is the earth will face dangerous or even catastrophic warming. Even concentrations above 550 or even 500 parts per million have the potential to cause dramatic and irreversible changes to our planet.

Q. How long will these increased CO_2 levels persist in the atmosphere?

A. The IPCC Working Group I Summary for Policymakers states that "several centuries after CO_2 emissions occur, about a quarter of the increase in CO_2 concentration caused by these emissions is still present in the atmosphere." [p. 17]. Thus, CO_2 that we put in the atmosphere today will affect the climate of the planet for many centuries to come.

V. CLIMATE CHANGE TO DATE

Q. Please describe, in general, changes in global temperatures in the last century, and the likely causes of those changes.

A. The IPCC Working Group I Summary for Policymakers states that "[t]he global average surface temperature has increased over the 20th century by about 0.6 °C." [p.2] This is the conclusion drawn both from the more recent instrumental record, and from a number of so-called paleothermometers—the collected evidence from a large number of temperature proxies that all point the same direction.

We know that there is a causal relationship between atmospheric CO_2 levels and rising average surface temperatures. This relationship was originally postulated by the great mathematician and scientist Joseph Fourier as early as 1824, and was first quantified by Svante Arrhenius in 1896. As the quality of both measurement technology and numerical analysis have improved, these ideas have been strengthened and refined, and shown to be observable and measurable.

Q. How do we know that this warming is not part of a natural trend?

A. The IPCC Working Group I Summary for Policymakers concludes that "[t]here is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities….There is a longer and more closely scrutinized temperature record and new model estimates of variability. The warming over the past 100 years is very unlikely to be due to internal variability alone, as estimated by current models." [p.10]. [footnote omitted]

It goes on to state that "[i]n the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations." [p.10]

Based on what I have seen in the scientific literature in the last few years I would expect the fourth annual report, due next year, to express even more certainty on this point in particular.

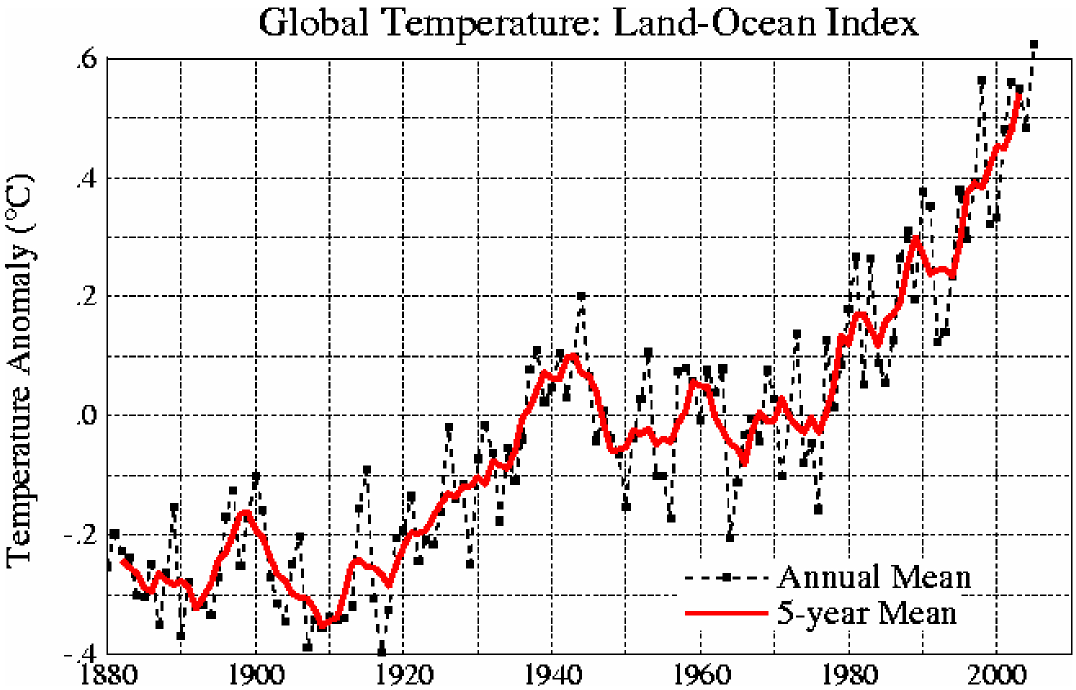
Q. Since the IPCC report was issued in 2001, what has been observed by climate scientists about global temperatures?

A. The highest annual average global surface temperature ever measured occurred during the 2005 calendar year, based upon an ongoing NASA analysis. The NASA scientific team noted that 2005 was slightly warmer than 1998, the warmest previous year known. However, in 1998, there was an "El Niño" event,[3] which was not the case in 2005. This event has a strong effect on the equatorial Pacific surface ocean and would have affected the temperature record in that year.[4]

Below I have reproduced one of the graphs from this study, showing the mean surface temperature "anomaly" from 1880 through the present. By anomaly the authors mean the difference between the annual average surface temperature for a given year and the long-term average surface temperature, which they define as the overall average for the period 1951 through 1980. If a year is exactly average in terms of temperature, the anomaly would be zero. The graph also shows the "smoothed" 5-year mean temperature anomaly over this period:

[3] El Niño is an occasional disruption of the ocean-atmosphere system in the tropical Pacific, in which the trade winds weaken and warm water from the western boundary floods much of the surface equatorial Pacific. Thus this large warm anomaly would tend to elevate average global surface temperatures, independent of any other effects.

[4] The GISS Surface Temperature Analysis is produced by Dr. James Hansen, director of NASA's Goddard Institute for Space Studies (GISS) at Columbia University in New York, along with Dr. Reto Ruedy and Dr. Ken Lo, also with the Goddard Institute, and Dr. Makiko Sato of the Columbia University Center for Climate Systems Research.



There are a number of ways to look at this. Four of the five warmest years on record have occurred since 2000. The ten hottest years on record have all occurred since 1990. Nineteen of the twenty warmest years on record have occurred since 1980, and so on. The evidence is consistent, statistically significant, and convincing. In addition, it is consistent with what is and has been predicted by computer models of the climate in response to today's elevated concentrations of atmospheric CO_2.

VI. PROJECTED WARMING

Q. What additional warming is predicted for the century ahead?

A. The IPCC predicts that the average surface temperature of the earth will increase by 1.5 to 5.8 degrees Celsius by 2100. The range reflects uncertainty about future emission levels and about precisely how the earth will respond to those emissions.

Q. Can you provide any perspective on the significance of the projected changes in global temperatures in this century?

A. These may sound like small figures, but the average surface temperature differential between the last ice age and the present was only about 5 degrees Celsius. During the last ice age, earth was a profoundly different place, with much of North America covered by an ice sheet a mile or more thick. At the upper range of the IPCC's 2001 warming prediction, earth would experience a warming equivalent to the one that melted that ice sheet. The recovery from the last major glacial period took 5,000 to 10,000 years. The warming we are discussing here will occur within a single century.

VII. IMPACTS OF CLIMATE CHANGE GLOBALLY

Q. What kinds of impacts are associated with warming projections in this range?

A. The IPCC Working Groups I and II Reports predict a large number of very serious negative impacts associated with this warming, including:

- rising sea levels, exposing coastal areas to increased risk of inundation and storm damage;
- Damage to or loss of natural ecosystems, such as prairie wetlands and alpine;
- Migration of habitats, leading to species extinctions and expansion of disease vectors and pests;
- heat waves leading to higher morbidity and mortality from heat stress;
- more intense precipitation events resulting in increased floods, mudslides, and soil erosion; and
- increased summer drying in most continental interiors resulting in more droughts; reduced crop yields, reduced water availability and quality.

The higher the atmospheric abundance of CO_2 rises, the more severe we can expect these impacts to be; to some extent they are expected even at the lower warming projections. Indeed, there is evidence that the 0.6 °C warming we have experienced to date has already initiated some of these impacts.

Q. Are the impacts of future warming likely to unfold gradually?

A. Many scientists believe that this is unlikely. While the computer models are unable to predict specific abrupt climate changes, we know from the geologic history that when the planet is changing from one type of climate to another, such as from an ice age to an interglacial, it often makes those changes in an abrupt, lurching fashion. The well-dated ice core records, in particular, show several abrupt and sudden climate swings of a magnitude that would be extremely disruptive were they to occur today. Unfortunately, we cannot predict with certainty at what level of atmospheric CO_2 such abrupt climate events would be likely to occur.

VIII. IMPACTS OF CLIMATE CHANGE ON SOUTH DAKOTA

Q. Turning now to the regional impacts of climate change, can you identify any credible sources that forecast the impacts of increased atmospheric CO_2 on the geographic region around South Dakota?

A. First let me note that it is much more difficult to predict climate change impacts for specific areas than it is for the planet as a whole, because of the significant complexities associated with changes in atmospheric circulation and cycling of moisture. Further, even the most highly resolved climate models still treat the Earth in large chunks compared to human scales—the most recent GISS model,[5] for example, has a grid size of 4^{o} longitude by 3^{o} latitude—an area about 2/3 the size of South Dakota in a single grid square.

Nonetheless, certain forecasts can be made for mid-continental areas such as South Dakota, which appear to be a robust feature of climate models. Furthermore, a team of leading university and government scientists in the Great Lakes region conducted an extensive study in 2003 of the likely

[5] A climate model produced by NASA's Goddard Institute for Space Studies at Columbia University in New York.

impacts of climate change in the Great Lakes area, including Minnesota, which provides valuable guidance. The report, entitled "Confronting Climate Change in the Great Lakes Region: Impacts on Our Communities and Ecosystems" ("Great Lakes Study"), was co-sponsored by the Ecological Society of America and the Union of Concerned Scientists. I consider this report to present scientifically sound, credible projections of the likely impacts of climate change in the nearby region.

Q. What approach did the Great Lakes Study use in forecasting local impacts of increased atmospheric CO_2?

A. The Great Lakes Study based its analysis upon global climate simulations using two of the world's leading climate models. In addition, they analyzed historical climate and weather data to establish relationships between climate trends (predictable by the models) and local temperature and weather characteristics.

Q. What did the Great Lakes Study team conclude about the likely impacts of climate change on the region?

A. I will quote from the subreport, which deals specifically with impacts on Minnesota, which is likely to be the closest proxy in this study for impacts in Eastern South Dakota:

> **Climate Projections**
> In general, Minnesota's climate will grow considerably warmer and probably drier during this century, especially in summer.
>
> • *Temperature:* By the end of the 21st century, temperatures are projected to rise 6–10 °F in winter and 7–16 °F in summer. This dramatic warming is roughly the same as the warming since the last ice age. Overall, extreme heat will be more common and the growing season could be 3–6 weeks longer.
>
> • *Precipitation:* While annual average precipitation may not change much, the state may grow drier overall because rainfall cannot compensate for the drying effects of a warmer climate, especially in the summer. Seasonal precipitation in the state is likely to change, increasing in winter by 15–40% and decreasing in summer by up to 15%. Minnesota, then, may well see drier soils and perhaps more

> droughts.
>
> • *Extreme events:* The frequency of heavy rainstorms, both 24-hour and multiday, will continue to increase, and could be 50–100% higher than today.
>
> • *Ice cover:* Declines in ice cover on the Great Lakes and inland lakes have been recorded during the past 100–150 years and are expected to continue.
>
> **How the Climate Will Feel**
> These changes will dramatically affect how the climate feels to us. By the end of the century, the Minnesota summer climate will generally resemble that of current-day Kansas, and winters may be like those in current-day Wisconsin.

The report goes on to project specific impacts on the region, including impacts on water resources, agriculture, human health, wetlands and shorebirds, recreation and tourism, and forests and terrestrial wildlife. Some of these impacts will be similar in South Dakota and some will not. What is a consistent theme for all regions studied in this manner, however, is that the seasonal temperatures, seasonal pattern of rainfall, growing season, and other climate variables will be affected.

Q. Understanding that you cannot predict impacts on South Dakota itself with great specificity, what can you predict in more general terms?

A. I can make a number of general predictions with fairly high level of confidence. South Dakota is likely to experience increased heating for more of the year, which will lead to increased evaporation and transpiration and ultimately to decreased soil moisture. This is likely to harm both agriculture and natural vegetation. There will be an increase in heat stress as the number of extremely hot days increases, and an increase of heat-related morbidity and mortality. Although total rainfall may not change appreciably or may even increase, the region can expect an increased probability of severe drying and drought in the summer months and resulting ecological and economic damage.

As a result, plant and animal species that reside in South Dakota today will be displaced, and others will encroach the state's habitats as conditions change within the state and in the surrounding regions. Many species of plants and animals will not be able to adapt to change and will become extinct. Agricultural pests and diseases are likely to spread as a result of the disruption of ecosystems. As a result of increased storm intensity, flooding and pollution of streams from soil erosion can be expected to increase.

In addition, a large percentage of prairie wetlands will be damaged or dry up, particularly the ephemeral seasonal wetlands that are so important to waterfowl production, likely resulting in a loss of waterfowl population. The impact on Prairie Pothole Region, wetlands and waterfowl will be discussed more fully below.

Q. Is it likely that most of the changes in the South Dakota climate will be detrimental?

A. Yes. It is an unfortunate fact that most of the climate changes described in the Great Lakes Study are likely to be detrimental to the environment of South Dakota. In fact, *any* rapid change in hydrology, temperature, seasonality, and habitat is likely to be economically and socially disruptive. The ecosystem and agriculture of the state exist in a balance, which is adapted to a certain set of climatic conditions, including a long-term range of variability. Once this system is changed that balance is disturbed, invariably resulting in damage to the natural system as it exists and is valued today.

Q. Is your testimony on these climate change trends supported by specific findings and conclusions in the IPCC report, Working Group I?

A. Yes.

Q. What are the key findings and conclusions from that Report on which you rely?

A. The IPCC Working Group I Summary for Policymakers contains the following statements and forecasts which support the conclusions I have presented:

1. "Increase of heat index over land areas" is projected to be "very likely, over most areas" during the 21st century. [p. 15, Table 1] [footnotes omitted].

2. "More intense precipitation events" are projected to be "very likely, over many areas" during the 21st century. [p. 15, Table 1] [footnotes omitted].

3. "Increased summer continental drying and associated risk of drought" is projected to be "likely, over most mid-latitude continental interiors" in the 21st century. [p. 15, Table 1] [footnote omitted].

Q. Are you familiar with and have you reviewed a recent publication by W. Carter Johnson and coauthors, entitled "Vulnerability of Northern Prairie Wetlands to Climate Change", appearing in the October, 2005 issue of the journal Bioscience?[6]

A. Yes.

Q. Can you summarize the approach taken by the researchers as reported in this article?

A. The researchers base their analysis on global circulation models predictions of future climate, with increased atmospheric CO_2, in the Prairie Pothole Region (PPR). The PPR extends from northern Iowa and Nebraska, across most of the eastern Dakotas and up into Canada.

The authors then apply these climate conditions to a calibrated model of the PPR wetlands to determine how the wetlands will respond and what the

[6] Johnson, W.C., B.V. Millett, T. Gilmanov, R.A. Voldseth, G.R. Guntenspergen and D.E. Naugle, "Vulnerability of Northern Prairie Wetlands to Climate Change", *Bioscience 55(10),* pp.863-872, October, 2005.

implications will be for migrating waterfowl, in what they refer to as the "heart of the PPR's 'duck factory' during the 20th century." [p. 869]

Q. What do the authors conclude regarding expected future changes in climate in this region?

A. Johnson and coauthors summarize the climate model results as follows:

> Increased drought conditions in the PPR are forecast to occur under nearly all global circulation model scenarios. Regional climate assessments suggest that the central and northern Great Plains of the United States may experience a 3.6 °C to 6.1 °C increase in mean air temperature over the next 100 years. Longer growing seasons, milder winters in the north, hotter summers in the south, and extreme drought are projected to be a more common occurrence over the PPR. Trends in mean annual precipitation are more difficult to predict, and range from no change to an increase of 10% to 20% concentrated in the fall, winter, and spring, accompanied by decreased summer precipitation and a higher frequency of extreme spring and fall precipitation events. [pp. 864-865. References removed.]

Q. Can you comment on the conclusions reached in that article regarding the impact of these changes on the ecology of the Prairie Pothole Region?

A. The authors find that global climate change is likely to have a significant negative effect on this region, and ultimately on the population of waterfowl that use this region as a breeding ground:

> The observed sensitivity of the model to climate variability suggests that wetlands in the drier portions of the PPR, such as the US and Canadian High Plains, would be especially vulnerable to climate warming, even if precipitation were to continue at historic levels. Only a substantial increase in precipitation would counterbalance the effects of a warmer climate. Additionally, the most productive wetlands, currently centrally located in the PPR, may become marginally productive in a warmer, drier future climate. Historically a mainstay for waterfowl, the region including the Dakotas and southeastern Saskatchewan would become a more episodic and less reliable region for waterfowl production, much as areas farther west have been during the past century. [p. 871]

Interestingly, the authors find this to be the case even though some regions will become wetter and others will become dryer:

> A logical question is whether the favorable water and cover conditions in the eastern PPR that we simulated can compensate for habitat losses in the western and central PPR. Historically, the eastern PPR and northern parklands served as a safe haven for waterfowl during periodic droughts. Today, however, options are limited, because more than 90% of eastern PPR wetlands have been drained for agricultural production. Although wetland restoration programs have been under way since the mid-1980s, less than 1% of basins drained in Minnesota and Iowa have been restored. Restoration efforts in the east have developed slowly, largely because of the high cost of farmland easements. [pp.871-872, references removed]

Q. Does this finding support your assertion, stated earlier, that *"any* rapid change in hydrology, temperature, seasonality, and habitat is likely to be economically and socially disruptive"?

A. Yes.

IX. BIG STONE UNIT II's CO_2 EMISSIONS

Q. Are fossil-fired electric generation plants in the United States, such as the proposed Big Stone Project. a significant contributor to the production and build-up of these gases?

A. Yes. The United States contributes more than any other nation, by far, to global greenhouse gas emissions on both a total and a per capita basis, contributing 24 percent of the world CO_2 emissions from fossil fuel consumption.

Coal-fired power plants in the United States already emit almost one-third of U.S. emissions, or 8% of all the world's anthropogenic CO_2 into the atmosphere, a staggering contribution to the global buildup of greenhouse gases. Further, recent analysis has shown that in 2004, power plant CO_2

emissions were 27 percent higher than they were in 1990.[7] Coal fired power plants are unquestionably a major and growing source of greenhouse gases, and thus a significant cause of global climate change.

Q. Other than their relative contribution to increasing atmospheric CO_2 each year, are there any other characteristics of coal-fired power plants like the proposed Big Stone Unit II that raise particular concerns regarding climate change?

A. Yes. Large, base load coal plants in the United States are built to produce electricity for decades, as long as 70 years in the case of some of the older plants still operating today. The evidence I have presented and discussed in my testimony shows that climate change is a serious threat to the environment and to human societies, including that of South Dakota, and that that threat is becoming increasingly obvious and severe. Today, the United States is almost alone among industrialized nations in failing to impose any cost on our electric sector or our industries for producing the greenhouse gases that cause this problem. As a result, utilities around the nation are making plans to invest in infrastructure that will emit CO_2 by the millions of tons into the indefinite future. The Big Stone II proposal is a good example of this shortsighted and distorted investment strategy.

Q. What would the lifetime emissions of CO_2 from the Big Stone II Unit be?

A. If built and operated as proposed, the Big Stone II Unit would add over 4.5 million tons of CO_2 to the atmosphere every year of its operational life, inexorably and significantly contributing to the buildup of greenhouse gases in the atmosphere. Assuming it operates for fifty years, that amounts to lifetime emissions of over 225 million tons of CO_2. For perspective, this lifetime production is roughly equal to the total amount of CO_2 produced by the entire country of Spain in one year.

[7] EIA, "Emissions of Greenhouse Gases in the United Sates, 2004;" Energy Information Administration; December 2005, xiii

Q. Could you compare the projected CO_2 emissions from the Big Stone II Unit to South Dakota emissions today?

A. The Big Stone II Unit's annual emissions would represent an enormous increase in South Dakota's emission levels. According to the EPA,[8] South Dakota's CO_2 emissions in 2001 (the last year for which these figures are available) was 13.23 million tons. The Big Stone II Unit's emissions of over 4.5 million tons per year of CO_2 would therefore represent approximately a 34% increase in the state's 2001 CO_2 emissions. It would more than double the current rate of emissions from the state's electric sector (3.79 million tons).

The EPA states that the average annual CO_2 emissions for an American automobile is about 6.75 tons.[9] At 4.5 million tons per year, emissions from the Big Stone Unit II would be equivalent to emissions from almost 670,000 cars. According to the federal Department of Transportation, there were fewer than 400,000 cars registered in South Dakota in 2004.[10] This means that the Big Stone Unit II is very likely to emit over two-thirds more CO_2 than all of the cars currently registered in South Dakota, combined.

Q. What is the significance of the Midwestern United States to the Global Warming phenomenon?

A. The Midwest is America's heartland and responsible for 20% of the CO_2 emissions in the United States, and 5% of the world's total emissions. The Midwest alone is responsible for more global warming gas pollutants than any country in the world other than the U.S. itself, China, the former Soviet Union, India and Japan.

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[8] U.S. EPA, "Carbon Dioxide Emissions from Fossil Fuel Combustion (Million Metric Tons CO2)," Prepared by the U.S. EPA using DOE/EIA State Energy Consumption Data (2001) and EIIP emission factors.

[9] U.S. EPA, "EPA's Personal Greenhouse Gas Calculator," states that 13,500 lbs/year of CO2 emissions is "about average per vehicle."

[10] Federal Highway Administration (Department of Transportation), "State Motor-Vehicle Registrations – 2004."

X. SCIENTIFIC CONCLUSIONS RELATED TO LEGAL STANDARDS

Q. Based upon your background, education, training and experience, your reading of the Governmental and non-governmental documents and treatises, including those that you have described, and assuming that the emissions from the proposed plant will operate as described in the record, including emissions of over 4.5 million tons of CO_2 annually, do you have an opinion to a reasonable level of scientific certainty, as to whether the proposed Big Stone II facility will cause irreversible changes anticipated to remain beyond the life of the facility?

A. Yes. My opinion is that the emissions of over 4.5 million tons of CO_2 per year from this proposed facility would cause irreversible damage to the environment, especially considering its expected lifetime of 50 years or more and the slow recovery time for atmospheric CO_2. These emissions will contribute to elevated levels of CO_2 in the atmosphere, to increased radiative forcing of climate and to accelerated global climate change for several centuries to come. I consider this to be a significant and irreversible impact on the environment, both globally and in South Dakota.

Q. Based upon your background, education, training and experience, your reading of the Governmental and non-governmental documents and treatises, including those that you have described, do you have an opinion, to a reasonable level of scientific certainty, as to whether the proposed Big Stone II facility will have cumulative or synergistic adverse consequences in combination with other operating energy conversion facilities, existing or under construction?

A. Yes. My opinion is that this facility will have a cumulative effect, in combination with other operating energy conversion facilities, both existing and under construction, of causing the level of atmospheric carbon dioxide to be significantly elevated relative to what it would be without this plant. The cumulative impact of coal-fired electrical generation plants in the

United States alone contributes about 8% of all anthropogenic CO_2 emissions today. This represents a substantial and growing contribution to global warming and global climate change, and a considerable threat to the environment globally and in South Dakota.

In dealing with a global problem such as warming, it is appropriate to look at the cumulative impact of like facilities. This is particularly true of coal fired electrical plants, since the number of plants is relatively small, but the cumulative impact is great.

Q. Are you aware that the Administrative Rules of South Dakota provide the following guidance in identifying the environmental, health and welfare effects of a proposed electrical generation facility:

> **The environmental effects shall be calculated to reveal and assess demonstrated or suspected hazards to the health and welfare of human, plant and animal communities which may be cumulative or synergistic consequences of siting the proposed facility in combination with any operating energy conversion facilities, existing or under construction. ASDR 20:10:22:13.**

A. Yes.

Q. Considering that definition of environmental effects, and based upon those same assumptions and factors as in the previous two questions, do you have an opinion as to whether this facility, considering the cumulative effect which you have described in your previous answer, will or will not pose a threat of serious injury to the environment or to the social and economic condition of inhabitants or expected inhabitants in the siting area?

A. Yes. In my opinion, the environmental effects of this facility will pose a threat of serious injury to the environment in South Dakota and in the broader region.

As noted in my earlier testimony, the continued growth of carbon dioxide emissions from coal fired power plants as well as from other sources is extremely likely to trigger dangerous and irreversible global climate change. Any increase in emissions will increase the ultimate environmental damage and social costs, as well as the likelihood of abrupt and potentially catastrophic climate shifts. South Dakota, specifically, would expect severe drying and droughts in the summer months, disruptive changes in precipitation patterns in the winter, more intense storms, and adverse impacts on local ecosystems and on agriculture. We can expect harmful migration of pests, loss of a number of species of plants and animals due to habitat destruction and migration and invasive species, and a severe impact on the prairie pothole resource and its breeding waterfowl populations.

Q, Based upon your background, education, training and experience, your reading of the Governmental and non-governmental documents and treatises, including those that you have described do you have opinion as to whether the facility will or will not substantially impair the health, safety or welfare of the inhabitants in South Dakota?

A. Yes. My opinion is that the environmental effects of the facility as discussed above will substantially impair the health and welfare of the inhabitants of South Dakota, along with those of the rest of the world.

Q. Please explain your opinion.

A. The expected health impacts of climate change include morbidity and mortality due to increased heat in the region, and expanded habitat for disease vectors. Welfare impacts include the economic impacts expected to agriculture, as well as the loss of recreational hunting grounds and loss of the economic benefits of hunting, tourism and recreation in the region.

Q. Based upon your background, education, training and experience, your reading of the Governmental and non-governmental documents and treatises, including those that you have described, do you have an opinion as to whether the facility will result in any pollution, impairment, or destruction of the air, water, or other natural resources or the public trust therein?

A. Yes. My opinion is that this facility will result in impairment of the air, by increasing the carbon dioxide levels in the atmosphere. I state this based both on the volume of carbon dioxide emissions that it will cause over its lifetime, over 225 million tons, and on the fact that this will elevate the carbon dioxide load of the atmosphere for several centuries. This facility, by itself and cumulatively with other electrical generation plants, will exacerbate the effects of global warming and global climate change. The levels of carbon dioxide in the atmosphere will determine how much global warming, and hence how much environmental damage, ultimately occurs. Reducing carbon emissions now will have a definite impact on the ultimate severity of climate impacts and on the ultimate costs of remediation. Likewise, investments in infrastructure which materially increase those emissions, will surely increase the severity of future impacts and costs.

This plant's emissions of carbon dioxide, by itself and cumulatively with other electrical coal fired generation plants, will also impair the water resources of South Dakota. This is because the adverse environmental impacts of global warming, including changes in the patterns of precipitation to which our ecosystems, our society and our agriculture are adapted, will be made more severe than they would be without this plant or without the cumulative effect of this and other electrical generation plants. As noted elsewhere in my testimony, such water impairment will likely include increasingly severe summer droughts, more intense storms and extreme rainfall events, increased soil erosion and silting, and the loss of much of the prairie pothole wetland resource and its associated waterfowl populations.

Q. In summary, what would you say is the significance of the Big Stone II plant to the problem of Global Warming, assuming that it will emit over 4.5 million tons of CO_2 each year for approximately the next 50 years, or longer?

A. The significance of the proposed plant is this: This plant, alone and in combination with other energy conversion facilities, will contribute materially and significantly to the environmental, social and economic destruction associated with global climate change. We cannot pretend to be protecting the environment of either South Dakota or the world at large from this overwhelming threat while we continue to build long-lived infrastructure that has exactly the opposite effect. In this respect, I conclude that Big Stone Unit II will have a significant, long-term, and costly adverse impact on the environment both in South Dakota and throughout the region, the continent and the planet.

Q. Does this conclude your testimony?

A. Yes.