OAH 80-2500-31888
E-999/CI-14-643

STATE OF MINNESOTA
OFFICE OF ADMINISTRATIVE HEARINGS

FOR THE PUBLIC UTILITIES COMMISSION

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3

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CRITERIA POLLUTANTS

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In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3	**FINDINGS OF FACT, CONCLUSIONS, AND RECOMMENDATIONS: CRITERIA POLLUTANTS**

This matter is pending before Administrative Law Judge LauraSue Schlatter pursuant to a Notice and Order for Hearing filed by the Public Utilities Commission (Commission) on October 15, 2014.[1]

On January 12-14, 2016, the evidentiary hearing for the Criteria Pollutants (CP) portion of this matter took place in the small hearing room at the Commission's offices in Saint Paul, Minnesota.

Appearances:[2]

Kevin Reuther, Leigh Currie, and Hudson Kingston, attorneys with the Minnesota Center for Environmental Advocacy, appeared on behalf of the Minnesota Center for Environmental Advocacy, Fresh Energy, and Sierra Club, collectively the Clean Energy Organizations (CEOs).

Linda Jensen, Assistant Attorney General, appeared on behalf of the Minnesota Department of Commerce, Division of Energy Resources (Department), and the Minnesota Pollution Control Agency (MPCA) (collectively the Agencies).

B. Andrew Brown and Hugh Brown, attorneys with Dorsey & Whitney L.L.P., appeared on behalf of Great River Energy (GRE), Minnesota Power Company (MP), and Otter Tail Power Company (OTP) (collectively the Utilities).

James R. Denniston, Assistant General Counsel, appeared on behalf of Northern States Power Company, d/b/a Xcel Energy (Xcel).

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[1] NOTICE AND ORDER FOR HEARING (Oct. 15, 2014) (eDocket No. 201410-103872-02).

[2] The listed parties appeared in both the CO_2 and the CP portions of the proceeding. A number of the parties participated in the CO_2 portion of the proceeding, but not in the CP portion. For a complete list of the parties, see the Report for the CO_2 portion of these proceedings dated April 15, 2016 (14-643 CO_2 Report). A list of the parties active in the CP portion of the proceeding and their expert witnesses is attached as Appendix C.

Marc Al and Andrew P. Moratzka, attorneys with Stoel Rives L.L.P., appeared on behalf of Minnesota Large Industrial Group (MLIG).

Tricia DeBleeckere, Energy Analyst, and Sean Stalpes, Energy Analyst, were present at the hearing on behalf of the staff of the Commission.

I. Procedural History

1. In 1993, the Minnesota Legislature enacted Minnesota Statutes section 216B.2422, subdivision 3, which requires the Commission to "quantify and establish a range of environmental costs associated with each method of electricity generation." In addition, the statute requires utilities to use the costs "when evaluating and selecting resource options in all proceedings before the [C]ommission, including resource planning and certificate of need proceedings."[3]

2. In 1994, the Commission established interim cost values, and in 1997, the Commission established final values after a contested case proceeding (First Externalities case).[4] The Commission's 1997 decision establishing final values was affirmed by the Minnesota Court of Appeals.[5]

3. On October 9, 2013, several environmental advocacy organizations filed a motion requesting that the Commission update the cost values for carbon dioxide (CO_2) and nitrogen oxide (NO_x) emissions, establish a cost value for particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), and re-establish a value for sulfur dioxide (SO_2). In the motion, the environmental organizations recommended that the Commission adopt the federal government's Social Cost of Carbon as the cost value for CO_2.[6]

4. On February 10, 2014, the Commission issued an order reopening its investigation into "the appropriate range of externality [cost] values for $PM_{2.5}$, SO_2, NO_x,

[3] 1993 Minn. Laws ch. 356, § 3 at 2523.
[4] *In the Matter of the Quantification of Envtl Costs Pursuant to Laws of Minn. 1993, Chap. 356, Sec. 3,* PUC Docket No. E-999/CI-93-583, ORDER ESTABLISHING ENVIRONMENTAL COST VALUES at 1, 33 (Jan. 3, 1997) (*see also* eDocket No. 20148-102561-01) (93-583 PUC ORDER 1); *In the Matter of the Quantification of Envtl Costs Pursuant to Laws of Minn. 1993, Chap. 356, Sec. 3,* PUC Docket No. E-999/CI-93-583, ORDER AFFIRMING IN PART AND MODIFYING IN PART ORDER ESTABLISHING ENVIRONMENTAL COST VALUES at 8 (July 2, 1997) (*see also* eDocket No. 201410-103872-02) (93-583 PUC ORDER 2).
[5] *In re Quantification of Envtl Costs*, 578 N.W.2d 794 (Minn. Ct. App. 1998), *review denied* (Minn. Aug. 18, 1998).
[6] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3,* PUC Docket No. E-999/CI-00-1636, MEMORANDUM IN SUPPORT OF CLEAN ENERGY ORGANIZATIONS' MOTION TO UPDATE EXTERNALITY VALUES FOR USE IN RESOURCE DECISIONS at 1-2, 18-19 (Oct. 9, 2013).

and CO_2."[7] The Commission ordered the Agencies to convene a stakeholder group to provide recommendations on the scope of the reopened Externalities investigation.[8]

5. On June 10, 2014, the Agencies filed a report stating that there was little stakeholder consensus. The Agencies recommended that the Commission adopt the federal Social Cost of Carbon midpoint values for CO_2,[9] and also made recommendations about the scope and process of the Commission investigation and retention of an expert.[10]

6. On October 15, 2014, the Commission issued the Notice and Order for Hearing in this matter, which set the scope of the reopened Externalities investigation as follows:

> The Commission will investigate the appropriate cost values for $PM_{2.5}$, SO_2, NO_x, and CO_2. The Commission will not further investigate at this time the environmental costs of other greenhouse gasses such as methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Because CO_2 represents 99% of greenhouse gas emissions, an accurate environmental cost value for CO_2 will account for almost all greenhouse gas costs. This will result in a more manageable proceeding and allow the parties to focus their resources.
>
> It would be premature at this stage to adopt the federal SCC values for CO_2 as the Agencies recommend. The Commission still believes that a contested case proceeding is necessary to fully consider the Agencies' proposed CO_2 cost values. The Commission will therefore not act at this time on the Agencies' proposal to adopt the federal SCC values immediately. But, in light of the record so far, the Commission will ask the Administrative Law Judge to determine whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO_2 and, if not, what measure is better supported by the evidence.
>
> The Commission will require parties in the contested case proceeding to evaluate the costs using a damage cost approach, as opposed to (for example), market-based or cost-of-control values.

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[7] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3,* PUC Docket No. E-999/CI-00-1636, ORDER REOPENING INVESTIGATION AND CONVENING STAKEHOLDER GROUP TO PROVIDE RECOMMENDATIONS FOR CONTESTED CASE PROCEEDING at 3 (Feb. 10, 2014).

[8] *Id.*

[9] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3,* PUC Docket No. E-999/CI-00-1636, COMMENTS BY DOC-DER AND MPCA at 9-10 (June 10, 2014).

[10] *Id.* at 16-17.

> When last faced with the question of the preferred approach to estimate environmental cost values, the Commission stated that, as between estimates based on damage or based on cost-of-control, the damage-cost approach is superior because it appropriately focuses on actual damages from uncontrolled emissions.
>
> Nothing in this proceeding justifies reaching a different conclusion now. Where a damage cost can be reasonably estimated, it represents a superior method of valuing an emission's environmental cost. The Commission is persuaded that a damage-cost approach can be used for the emissions under investigation, and will therefore require it.[11]

7. The Commission referred the matter to the Office of Administrative Hearings to address the following issues:

> a. Whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO_2 under Minn. Stat. § 216B.2422 and, if not, what measure is better supported by the evidence; and
>
> b. The appropriate values for $PM_{2.5}$, SO_2, and NO_x [the criteria pollutants] under Minn. Stat. § 216B.2422, subd. 3.[12]

8. Following a prehearing conference on November 14, 2014, the Administrative Law Judge issued an order granting intervention to OTP, MP, the Lignite Energy Council, Xcel, MLIG, GRE, and the Minnesota Chamber of Commerce as full parties in this matter.[13] In addition, the Administrative Law Judge ordered the proceedings to be bifurcated. Testimony regarding CO_2 and the CP would be prefiled according to separate schedules, with separate evidentiary hearings scheduled.[14]

9. On March 19, 2015, the Administrative Law Judge granted intervention to the MPCA as a full party in this matter.[15]

10. On March 27, 2015, the Administrative Law Judge issued an order addressing the evidentiary burdens of proof for this matter. After considering the parties' arguments, the Administrative Law Judge set forth the following parameters for the evidentiary burdens of proof:

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[11] NOTICE AND ORDER FOR HEARING at 4-5 (Oct. 15, 2014) (eDocket No. 201410-103872-02).
[12] *Id.*
[13] FIRST PREHEARING ORDER at 3 (Dec. 9, 2014) (eDocket No. 201412-105272-01). In addition to the Department, the CEOs and Peabody were the only parties named in the Commission's Notice and Order for Hearing issued on October 15, 2014.
[14] *Id.* at 4.
[15] ORDER GRANTING INTERVENTION TO MINNESOTA POLLUTION CONTROL AGENCY (Mar. 20, 2015) (eDocket No. 20153-108414-01).

a. A party or parties proposing that the Commission adopt a new environmental cost value for CO_2, including the Federal Social Cost of Carbon, bears the burden of showing, by a preponderance of the evidence, that the value being proposed is reasonable and the best available measure of the environmental cost of CO_2.

b. A party or parties proposing that the Commission adopt a new environmental cost value for one or more of the criteria pollutants – SO_2, NOx, and/or $PM_{2.5}$ – bears the burden of showing, by a preponderance of the evidence, that the cost value being proposed is reasonable, practicable, and the best available measure of the criteria pollutant's cost.

c. A party or parties proposing that the Commission retain any environmental cost value as currently assigned by the Commission bears the burden of showing, by a preponderance of the evidence, that the current value is reasonable and the best available measure to determine the applicable environmental cost.

d. An environmental cost value currently being applied by the Commission is presumed to be practicable, as required by Minn. Stat. § 216B.2422, subd. 3. A party challenging an existing cost value on the grounds that it is not practicable bears the burden of demonstrating impracticability by a preponderance of the evidence.

e. A party or parties, opposing a proposed environmental cost value must demonstrate, at a minimum, that the evidence offered in support of the proposed values is insufficient to amount to a preponderance of the evidence. This requirement does not apply to a party challenging an existing cost value based on its alleged impracticability, as described in paragraph 4, above.

f. Any proponent of an environmental cost value, including existing environmental cost values, shall file direct testimony in support of its proposal according to the schedule set forth in the Second Prehearing Order in this matter.

g. A party advocating for retention of an existing cost value may not refer by reference to evidence or testimony from the Commission's CI-93-583 docket or related dockets, but must introduce any evidence on which it intends to rely in this

docket, whether the evidence is drawn from an older docket or is new evidence.

h. A party may propose an environmental cost value not proposed in direct testimony in the party's rebuttal testimony only if the new cost value is offered in response to a cost value proposed in direct testimony.[16]

11. On April 16, 2015, the Administrative Law Judge issued an order concluding that testimony regarding the efficacy of renewable energy or renewable energy policy was presumed to be irrelevant and would be excluded from this matter unless its relevance was specifically demonstrated.[17] The Administrative Law Judge also granted intervention to Doctors for a Healthy Environment, the Clean Energy Business Coalition, and Interstate Power and Light Company as full parties in this matter.[18]

12. On May 27, 2015, the Commission issued an order requiring one public hearing to be held for this matter.[19] The Commission's order also required that members of the public be allowed to submit written comments regarding this matter via mail or the Commission's SpeakUp website.[20] The Commission's plan for providing the public notice of the public hearing and written comment period included publishing notice in the Environmental Quality Board Monitor and the MPCA's electronic newsletter, posting notice on state agency websites, issuing a press release, and directly providing the notice to all county administrators.[21]

13. On June 2, 2015, the Commission issued a notice for the public hearing and of the written comment period.[22]

14. On June 1, 2015, parties filed direct testimony in the CO_2 portion of this matter.

15. On August 5, 2015, parties filed direct testimony in the criteria pollutants portion of this matter. The CEOs, the Agencies, Xcel, and MLIG are the only parties that participated actively in the Criteria Pollutants portion of this matter. Ottertail Power filed a post-hearing brief in support of Xcel's position, but did not otherwise participate.

16. On August 12, 2015, parties filed rebuttal testimony in the CO_2 portion of this matter.

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[16] ORDER REGARDING BURDENS OF PROOF at 2-3 (Mar. 27, 2015) (eDocket 20153-108636-01).
[17] THIRD PREHEARING ORDER at 2 (Apr. 16, 2015) (eDocket No. 20154-109385-01).
[18] ORDER GRANTING INTERVENTION TO DOCTORS FOR A HEALTHY ENVIRONMENT, CLEAN ENERGY BUSINESS COALITION, AND INTERSTATE POWER AND LIGHT COMPANY (Apr. 16, 2015) (eDocket No. 20154-109386-01). Interstate Power and Light Company later withdrew from the proceeding. *See* Interstate Power and Light Company Letter Withdrawing (Aug. 13, 2015) (eDocket No. 20158-113202-01).
[19] ORDER REQUIRING PUBLIC HEARING at 2 (May 27, 2015) (eDocket 20155-110744-01).
[20] Public Hearing and Comment Period Notice Plan (May 29, 2015) (eDocket 20155-110942-01).
[21] *Id.*
[22] Notice of Public Hearing and Comment Period (June 2, 2015) (eDocket No. 20156-111067-01).

17. On August 26, 2015, the public hearing was held at the Commission's office in Saint Paul.[23]

18. On September 10, 2015, parties filed surrebuttal testimony in the CO_2 portion of this matter.

19. On September 15, 2015, the Administrative Law Judge filed two orders deciding several different motions to strike and exclude testimony. The Administrative Law Judge denied motions to strike all or portions of the testimony of Dr. Michael Hanemann, Dr. Stephen Polasky, Mr. Nicholas Martin, Mr. Shawn Rumery, and Mr. Christopher Kunkle.[24] The Administrative Law Judge granted a motion to strike a portion of the testimony of Dr. William Happer.[25]

20. On September 21, 2015, the Administrative Law Judge issued an order deciding additional motions to strike and exclude testimony. The Administrative Law Judge denied motions to strike portions of the testimony of Dr. John Abraham, Dr. Andrew Dessler, and Dr. Kevin Gurney.[26] The Administrative Law Judge granted a motion to strike a portion of the testimony of Dr. Peter Reich.[27]

21. On September 24-30, 2015, the evidentiary hearing for the CO_2 portion of this matter took place at the Commission's office in Saint Paul.

22. On October 30, 2015, the parties filed rebuttal testimony in the criteria pollutants portion of this matter.

23. On November 12, 2015, the issues matrix for the CO_2 portion of this matter was filed.[28]

24. On November 24, 2015, parties filed initial briefs in the CO_2 portion of this matter. On the same date, the Administrative Law Judge issued an order denying motions

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[23] A summary of the public hearing testimony, exhibits, and written public comments is attached as Appendix B.

[24] ORDER ON MOTIONS BY MINNESOTA LARGE INDUSTRIAL GROUP AND PEABODY ENERGY CORPORATION TO EXCLUDE AND STRIKE TESTIMONY at 2 (Sept. 15, 2015) (eDocket No. 20159-113992-01); ORDER ON MOTIONS BY PEABODY ENERGY CORPORATION, MINNESOTA DEPARTMENT OF COMMERCE, AND POLLUTION CONTROL AGENCY TO EXCLUDE AND STRIKE TESTIMONY at 2 (Sept. 15, 2015) (eDocket No. 20159-113998-01).

[25] ORDER ON MOTIONS BY PEABODY ENERGY CORPORATION, MINNESOTA DEPARTMENT OF COMMERCE, AND POLLUTION CONTROL AGENCY TO EXCLUDE AND STRIKE TESTIMONY at 2 (Sept. 15, 2015) (eDocket No. 20159-113998-01). The Administrative Law Judge excluded a single photograph of a weather thermometer hanging on a house above a charcoal grill, finding the photograph's probative value was outweighed by its prejudicial effect.

[26] ORDER ON MOTIONS BY MINNESOTA LARGE INDUSTRIAL GROUP AND PEABODY ENERGY CORPORATION TO EXCLUDE AND STRIKE TESTIMONY at 2-3 (Sept. 21, 2015) (eDocket No. 20159-114135-01).

[27] *Id.* A single sentence of Dr. Reich's surrebuttal testimony was excluded as irrelevant because it addressed the impact climate change might have on the needs of wildlife in particular types of habitat.

[28] $C0_2$ Issues Matrix (Nov. 12, 2015) (eDocket No. 201511-115671-01).

to strike and exclude the testimony of Mr. Richard Rosvold and Dr. Roger McClellan in the criteria pollutants portion of this matter.[29]

25. On December 4, 2015, the parties filed surrebuttal testimony in the criteria pollutants portion of this matter.

26. On December 15, 2015, the parties filed reply briefs and proposed findings in the CO_2 portion of this matter.

27. On January 12-14, 2016, the evidentiary hearing for the criteria pollutants portion of this matter took place at the Commission's office in Saint Paul.

28. On March 1, 2016, the issues matrix for the criteria pollutants portion of this matter was filed.[30]

29. On March 15, 2016, the parties filed initial briefs in the criteria pollutants portion of this matter.

30. On April 15, 2016, the parties filed reply briefs and proposed findings in the criteria pollutants portion of this matter.

31. Appendix A provides a brief description of each witness who provided testimony in this proceeding, by party.

FINDINGS OF FACT

I. Background

A. Definitions and Historical Commission Standards

1. The task of the Administrative Law Judge in the present portion of this matter is to review and synthesize information related to the impacts and damages caused by emissions of $PM_{2.5}$, CO_2, and NO_x (the criteria pollutants, or CPs). The issues include complex questions of science, economics, and public policy related to the recommendation of updated externalities or cost values for CP emissions produced by electricity generation in Minnesota.

2. When an economic activity imposes a cost or benefit on an unrelated third party, the cost or benefit is known as an economic external cost or "externality."[31] Externalities can be viewed as positive or negative depending on their impact.[32]

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[29] ORDER ON MOTIONS BY DEPARTMENT OF COMMERCE, POLLUTION CONTROL AGENCY AND CLEAN ENERGY ORGANIZATIONS TO EXCLUDE AND STRIKE TESTIMONY at 2 (Nov. 24, 2015) (eDocket No. 201511-115904-01).
[30] Criteria Pollutants Issues Matrix (Mar. 1, 2016) (eDocket No. 20163-118846-01).
[31] Ex. 800 at 7-8 (Hanemann Direct).
[32] *Id.*

3. Environmental economics, as relevant to this proceeding, focuses on the costs of externalities from electricity generation in order to develop and implement public policies, such as government regulations and tax remedies aimed at reducing environmental damages.[33] The results of this proceeding will affect how utilities in Minnesota select, allocate, and build resources for the future.

4. When it set final cost values pursuant to Minn. Stat. § 216B.2422, subd. 3 in the January 1997 Order in the First Externalities case, the Commission established several principles to guide its quantification of those values. These principles, as applicable to CP cost values, included a) a preference that a damage cost approach be used; b) establishment of a range of values to appropriately take into consideration a level of uncertainty; c) adopting geographically-sensitive values, including ranges depending on the location of the proposed generation site, and categorized as urban, metropolitan fringe, and rural; d) quantifying the costs of environmental damages occurring locally and regionally in Minnesota for pollutants other than CO_2; and e) calculating in-state damages based on generating plants in Minnesota and located up to 200 miles from the state border, but not beyond.[34]

5. In addition, in the First Externalities case, the Commission found that the National Ambient Air Quality Standards (NAAQS) were not up-to-date and did not reflect the latest scientific knowledge. Based on that record, and on the Commission's finding that the damage cost study available in the First Externalities proceeding more dependably reflected environmental costs in Minnesota, the Commission in the First Externalities proceeding did not consider the NAAQS in establishing environmental costs.[35]

B. Process and Issues

6. Three of the four parties to this portion of this proceeding - the CEOs, the Agencies and Xcel - each presented a distinctive integrated assessment computer model (IAM) that estimates the impacts and the damages caused by emissions of CPs from electricity generating units (EGUs, or sources) in or near Minnesota.[36] Each of the three models starts with a baseline level of air pollution, drawn from outside sources or calculated within the model based on observed data on national ambient pollution. The models are designed to take inputs about the amount and location of EGU emissions of the CPs at issue in this proceeding and then calculate the change in air pollution concentration as a result of those emissions. At a minimum, the models incorporate information about where people live.[37] The models also include data about baseline mortality rates for the affected populations, then apply a concentration-response function

[33] Ex. 800 at 10, 12-13 (Hanemann Direct).
[34] 93-583 PUC ORDER 1 at 14-16.
[35] *Id.* at 16-17.
[36] Ex. 120 (Marshall Opening Statement); Ex. 616 (Desvousges Opening Statement); Ex. 813 (Muller Opening Statement).
[37] The CEOs only consider human mortality. The Agencies consider human morbidity (illness) and economically important crops as well. Ex. 809, NZM-2 at 13, 22 (Muller Direct). Xcel also includes agricultural damage, visibility, soiling, and corrosion. Ex. 604 at 24 (Desvousges Direct).

drawn from epidemiological literature to estimate how much death rates will increase due to the increase in air pollution at that location. Finally, the models apply a damage amount, known as the "value of a statistical life" (VSL), to determine a monetized damage per ton of CPs emitted.[38]

7. The Agencies and the CEOs agreed that the choice of model is less important than decisions regarding the following four issues:

- What VSL to use;
- What concentration response function to use;
- What geographical scope to include in the damages calculation; and
- How to define the sources of emissions locations.[39]

8. Xcel disagreed with the CEOs and the Agencies, emphasizing that the CEOs' and Agencies' air quality modeling results were neither accurate nor reliable and that the Commission should not base CP externality values on those models or their results.[40] Xcel asserted that only its model could predict accurate and reliable air quality changes and, along with its parameters and inputs, provide the best externality values.[41]

9. MLIG, the fourth party actively involved in this portion of the proceeding, posited that none of the other parties carried their burdens of proof. MLIG asserted that Minnesota's ambient air concentration of $PM_{2.5}$ is already below the NAAQS standard of 12 micrograms per cubic meter ($\mu g/m^3$), which the most up-to-date science has shown to be the lowest concentration to cause mortality. Therefore, MLIG argued, none of the other parties demonstrated that a marginal increase in $PM_{2.5}$ will have impacts with a demonstrated cost value.[42]

II. The Agencies' Recommended Model and Values

A. The AP2 Model

1. Basic Modeling Process

10. The Agencies' proposed CP cost values are derived from the AP2 model, a reduced form IAM which is the successor to the APEEP model.[43] The Agencies asserted that AP2 and APEEP have been proven reliable because they have "been used in many peer-reviewed studies."[44] For example, the National Academies of Sciences' National Research Council used APEEP in a 2010 study of the social costs of energy use and production.[45] The Agencies' expert witness, Dr. Nicholas Muller, developed the APEEP

[38] Ex. 120 (Marshall Opening Statement); Ex. 616 (Desvousges Opening Statement); Ex. 813 (Muller Opening Statement). As described in the detailed descriptions of each of their models, the Agencies and Xcel applied damage amounts to the additional impacts included in their calculations.
[39] Ex. 120 (Marshall Opening Statement); Ex. 813 (Muller Opening Statement).
[40] Xcel Initial Post-hearing Brief (Xcel Initial Br.) at 2.
[41] *Id.* at 2-4.
[42] Evidentiary Hearing Transcript Volume (Tr. Vol.) 7 at 174-178 (McClellan).
[43] Ex. 808 at 12 (Muller Direct).
[44] *Id.*
[45] Ex. 808 at 12-13 (Muller Direct).

and the AP2 models.[46] The Agencies chose a reduced form model largely because the Commission required them to do so, but also because the simpler computational processes make the model better suited to the Agencies' modeling needs.[47]

11. The Agencies stated for the record at the evidentiary hearing that the AP2 model had "very recently . . . passed through and completed peer review."[48]

12. The Agencies asserted that the AP2 model stands out from other reduced form models because of its air quality model connecting emissions to concentration estimates. According to the Agencies, AP2 is defined by the manner in which it simply and accurately predicts ambient pollutant concentrations.[49]

13. AP2 is also different from photochemical models, according to the Agencies, because a photochemical air quality model describes space as a three-dimensional grid, made up of cells which are generally 12 km by 12 km. A photochemical model expresses time in units as small as a minute and contains "explicit characterization of atmospheric chemistry rather than constant rates of conversion" as AP2 does.[50]

14. The Agencies explained that AP2 analyzes effects from exposure to ambient $PM_{2.5}$ and to ozone (O_3) to "capture the major impacts of emissions of NO_x, SO_2, and $PM_{2.5}$.[51] The Agencies maintained that the impacts of these pollutants identified by past research include adverse impacts on human health (both premature mortality and morbidity, or illness), reduced crop and timber yields, reduced visibility, and acidification of water. For this proceeding, the Agencies included human health effects, both mortality risks and morbidity. The illnesses the Agencies focused on are principally respiratory and cardiovascular effects. In addition, the Agencies included adverse consequences of O_3 on yields of economically important crops. The Agencies excluded impacts on visibility effects, timber yields and acidification because they contribute a "very small share to total damage" and are estimated using uncertain modeling techniques.[52]

15. The Agencies also determined that this proceeding calls for multiple executions of the model to estimate damages for emissions originating from multiple sources. For that reason, a reduced form model is appropriate because it can be executed repeatedly more easily and efficiently than a photochemical model. The reason that damages must be estimated for emissions originating from multiple sources, according to the Agencies, is because the emissions have strongly varying impacts depending on the location of the emission source. The Agencies' modeling approach required them to change emissions at each individual location, while holding all other

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[46] Tr. Vol. 8 at 8 (Muller).
[47] Ex. 808 at 9, 11 (Muller Direct).
[48] Tr. Vol. 6 at 150 (Jensen). This statement was made by counsel for the Agencies in the context of lifting the trade secret designation from any materials provided or filed by the Department in the proceedings.
[49] Ex. 808 at 13-14 (Muller Direct).
[50] *Id.* at 21.
[51] *Id.* at 14.
[52] Ex. 808 at 14 -15 (Muller Direct); *see also* Ex. 809, NZM-2 at 13 (Muller Direct) (health effects); Ex. 809, NZM-2 at 22 (Muller Direct) (agricultural effects).

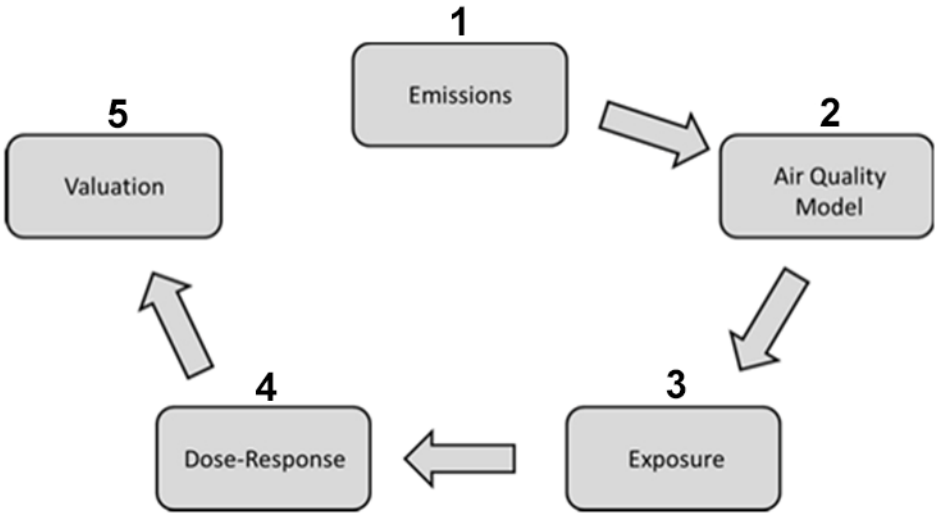
locations and emissions fixed, then calculate the impact of the subject source's emissions, and reset the baseline for all emissions before modeling the next location.[53] Therefore, the Agencies decided each emissions source must be modeled individually.[54]

16. The Agencies conducted separate modeling runs for each of the three separate pollutants, because "the toxicity of different pollution types varies."[55] The Agencies conducted three model runs for each of the 87 counties in Minnesota, six individual Minnesota power plants and almost 400 sources and source locations outside of Minnesota – a total of approximately 500 sources and about 1,500 model runs. The 1,500 runs were doubled or tripled after testing of the sensitivity of results to parameter values was taken into account, as discussed in section D below.[56]

17. The Agencies found two primary drawbacks connected to photochemical modeling. One was the computational burden inherent in modeling highly complex systems. A second was the concern that photochemical models become less transparent as they increase in complexity.[57] The Agencies concluded that the large number of model runs required in this case combined with the computational burdens involved with photochemical modeling make reduced form modeling a better approach in this proceeding.[58]

[53] Ex. 808 at 10 (Muller Direct).
[54] *Id.* at 10.
[55] *Id.* at 11.
[56] *Id*. The parameter values included "the monetary value attributed to mortality risk and the effect of exposure on mortality rates" which have been referred to earlier in this report as the VSL and the concentration response. *Id.* The Agencies do not explain why they say "doubled or tripled." The Administrative Law Judge presumes that some of the sources were not evaluated in every test, meaning some sources were run twice while others were run three times.
[57] *Id.* at 9.
[58] *Id.* at 11. The Agencies used elements of photochemical modeling to inform the results of the AP2 model and to check the performance and verify the reliability of the AP2 model against the output of a photochemical model. *Id.* at 9-10.

18. A standard air pollution IAM, as described by the Agencies, has five modules, one for each step of the analysis, as shown below:[59]



Structure of Integrated Assessment Model Applied to Air Pollution.

19. The Agencies explained the diagram of the IAM structure as it applies to air pollution modeling. The first box above represents the location and amounts of the emissions. In the second box, emissions and estimates of the concentration of harmful pollutants in the air (ambient pollutant concentrations) are connected to one another. Box three takes the concentration estimates emerging from box two and uses them to calculate exposure by combining the predicted concentrations with data on entities sensitive to contact with ambient pollution. This step requires detailed data on the location of populations that have exhibited sensitivity to air pollution. Box four represents the translation from exposure to physical, environmental, and health effects using dose-response functions. The physical effects are converted to monetary terms in the step represented by the final valuation box.[60]

20. The Agencies asserted that the most significant difference between photochemical models and reduced form models is in the air quality modelling step. Generally, the other steps are "nearly identical in reduced form and process models."[61] The significant areas of difference between the two types of air quality models have to do with time, space, and chemistry.[62]

21. AP2 relies on data and parameter values widely employed in the scientific literature to estimate damages caused by air pollution.[63] For this proceeding, the Agencies used 2011 data with the AP2 model, including the EPA's 2011 emissions data, which is the most recent year for which EPA has published a detailed emissions inventory,

[59] Ex. 808 at 5 (Muller Direct) (numbers added to illustration).
[60] *Id.* at 6-7.
[61] *Id.* at 11-12.
[62] *Id.*
[63] *Id.* at 13.

as well as 2011 population and vital statistics data. In addition, the Agencies used the EPA's monitor readings for local air pollution.[64]

22. The air quality model data for AP2 is organized in a matrix, or table, according to the Agencies. The rows of the table represent pollutant sources and the columns represent locations receiving pollution (pollution receptors). The Agencies noted that AP2 recognizes all counties in the contiguous 48 states of the United States (U.S.) as pollution receptors.[65] Each entry in the matrix provides information about how air pollution concentrations in a particular location change for each ton emitted from a specified source. The sum of the values in a given row shows how the AP2 model predicts air pollution levels will change in all locations due to a one-ton emission from a specific source. Similarly, the sum of all values in a particular column illustrates the AP2 model prediction for how air pollution concentrations in a county will change due to a one-ton emission from all sources.[66]

23. The Agencies stated that the AP2 model and documentation used in the analysis for this proceeding will be made available to the Minnesota Department of Commerce for future use.[67]

2. Future Damages Projections

24. The Agencies estimated future damages using the AP2 model for 2020, 2025, 2030, 2035, and 2040.[68] The purpose of the future projections, according to the Agencies, is to gauge the stability of the marginal damage estimates, given changes over time to population, income, and vital statistics. The Agencies anticipated that the future damage projections will help to determine whether, and how often, updates to these damages values will be needed.[69] The table in Finding 72 below, includes the future damages projections.

25. The Agencies explained that they developed the projections by using essentially the same model that they used to develop the estimates in this proceeding, but projected changes in population, mortality and morbidity rates, emission levels, VSL, and crop damage. The Agencies relied on sources such as the EPA's BenMAP model. They then applied population growth factors to 2010 Census data to project population growth and mortality and morbidity rates.[70] In the absence of high-quality future emissions projections, the Agencies used 2011 National Emissions Inventory emissions.[71] To estimate future income growth for purposes of developing a modified VSL for future damage calculations, the Agencies relied on "projections of real disposable income per capita, by Census Division, derived from the Energy Information

[64] Ex. 808 at 13-14 (Muller Direct); Ex. 809, NZM-2 at 9-52 (Muller Direct).
[65] Ex. 808 at 20 (Muller Direct).
[66] *Id.*
[67] *Id.* at 71. The Agencies' proposal for updating the values is discussed in Finding 25.
[68] *Id.* at 16.
[69] *Id.* at 45.
[70] *Id.* at 46. The Environmental Benefits Mapping and Analysis Program, Community Edition (BenMAP-CE) is available online at http://www2.epa.gov/benmap. *See* Ex. 809, NZM-2 at 59 (Muller Direct).
[71] Ex. 808 at 47 (Muller Direct).

Administration's *Annual Energy Outlook 2015.*"[72] For the VSL modification, the Agencies also relied on the EPA's BenMAP tool of 0.40 regarding income-valuation elasticity.[73] Because crop damage forecast prices are not available, the Agencies used recent prices reported by the U.S. Department of Agriculture (USDA).[74]

3. Geographic Scope of Sources

26. Citing the First Externalities case, the Agencies maintained that the appropriate geographic scope of emissions sources for this proceeding encompasses not only source locations throughout Minnesota, but also in the contiguous U.S. that are within 200 miles of Minnesota.[75] The Agencies recommended the continued use of 200 miles as the limit of sources because emissions from these sources could have an impact on Minnesota's air quality, and because these out-of-state sources may generate electricity to meet demand in Minnesota.[76]

27. The Agencies used the AP2 model to estimate the impacts of SO_2, NO_x, and $PM_{2.5}$ in marginal damages-per-ton-emitted. The Agencies explained that "marginal damage indicates the change in damage from one more ton of emission of a particular pollutant from a particular source."[77] To accomplish this, the Agencies first measured concentrations, exposures, physical impacts, and damages connected with baseline emissions for a particular source or group of sources. Then, one ton of one of the three pollutants was added to the source's baseline emissions and changes in concentrations, exposures, physical impacts, and damages were then calculated to establish the marginal damage resulting from the addition of that ton.[78]

28. The Agencies applied the AP2 model to six large power plants in Minnesota, including Sherburne County, Riverside, Black Dog, A.S. King, High Bridge, and Clay Boswell. The AP2 model also estimated marginal damages for $PM_{2.5}$, NO_x, and SO_2 for every county in the state of Minnesota. For counties that have power plants currently operating in them, the Agencies used AP2 to calculate marginal damages based on the power plants located in the counties. For counties with no operational power plants, the Agencies produced damage estimates "intended to represent the damage from emissions *if a power plant* were to be located in that county in the future."[79] These last damage estimates, said the Agencies, are for planning purposes if a plant were to be proposed in that county in the future.[80]

29. The Agencies also modeled sources within 200 miles of the Minnesota state border.[81] These sources included 26 large power plants in Illinois, Iowa, Michigan,

[72] Ex. 808 at 47 (Muller Direct).
[73] *Id.* at 47-48.
[74] *Id.* at 48.
[75] *Id.* at 15.
[76] *Id.* at 16.
[77] *Id.* at 17.
[78] *Id.* at 18.
[79] *Id.*
[80] *Id.* at 18-19 (emphasis in original).
[81] Ex. 808 at 19 (Muller Direct).

Nebraska, North Dakota, South Dakota and Wisconsin.[82] Each of these plants has an "effective height of emissions of over 500 meters under average local weather conditions."[83] In addition, the out-of-state sources included marginal damages from all counties within 200 miles of the state of Minnesota. Just as they did with Minnesota counties, the Agencies used an active existing plant within a county to model the damages for that county. For counties without an active plant, the Agencies estimated what the damages from emissions would be if a power plant were located there.[84]

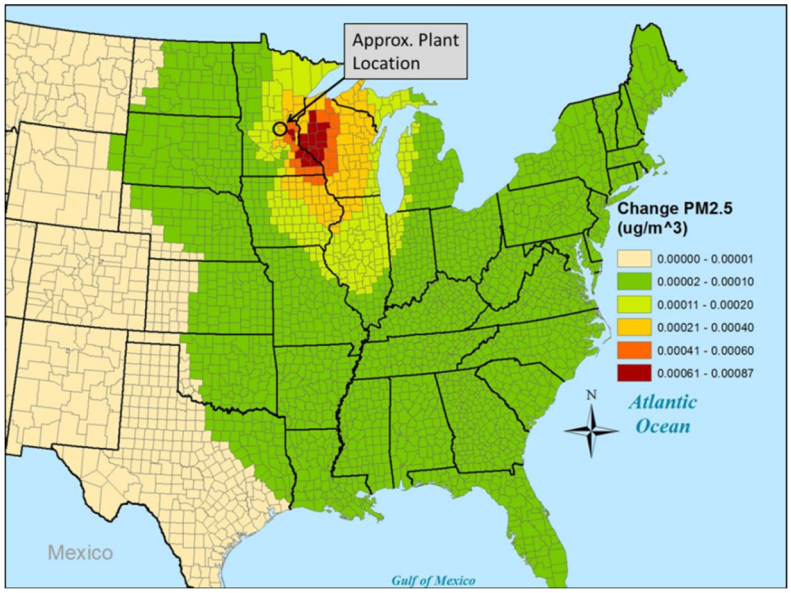
30. The Agencies maintained that movement of the pollution in the atmosphere represented in the AP2's matrix reflects the AP2's use of location-specific annual and seasonal average weather data such as wind direction, wind speed, and temperature.[85]

31. The Agencies asserted that the AP2 air quality modeling accounts for the conversion of emitted SO_2 and NO_x into other substances. AP2 represents reactions, such as the combination of SO_2 emissions with ambient ammonium to form ammonium sulfate, an important component of $PM_{2.5}$, using constant rates of conversion that are defined as a function of wind speed.[86]

4. Geographic Scope of Damages

32. The Agencies illustrated how AP2 estimates air pollution damage by incorporating the dispersion pattern based on independent wind direction and speed data. As an example, the Agencies provided a map showing the predicted effects on $PM_{2.5}$ concentrations due to the emission of 100 tons of primary $PM_{2.5}$ from the Sherburne County (Sherco) plant:[87]

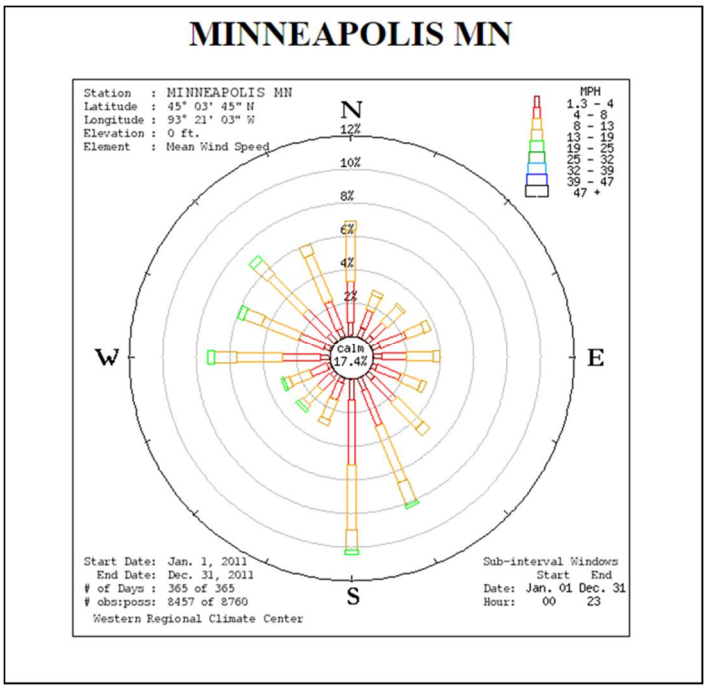
[82] Ex. 809, NZM-2 at 29 (Muller Direct). The Agencies inadvertently included incorrect page citations in Dr. Muller's testimony to Attachment 2. *See* Ex. 809, NZM-2 (Muller Direct). The citations in this Report are to the correct pages.
[83] Ex. 808 at 19 (Muller Direct). The Agencies define "effective height" as "stack height plus plume rise." *Id*.
[84] *Id.* at 19-20.
[85] *Id.* at 20.
[86] *Id.* at 21.
[87] Ex. 808 at 32 -34 (Muller Direct). The map is derived from AP2 outputs, using the high damage scenario. *Id.* The Agencies used 100 tons of emissions in this example because the change in concentration associated with one ton is quite small and would be difficult to illustrate clearly on this map. *Id.*



33. The Agencies pointed out that largest change in ambient concentrations occurs near the source of the emissions. While the most significant changes in concentration occur within about 200 miles of the plant, the Agencies asserted that emissions from the plant affect $PM_{2.5}$ levels throughout the eastern U.S.[88] In addition, the Agencies asserted that using the annual average wind speed and direction data to model dispersion of emissions demonstrates that the emitted pollution travels primarily south or southeast from the source of the emissions.[89]

34. The Agencies compared the AP2 dispersion pattern as demonstrated in the map above to a windrose plot for Minneapolis for the year 2011:[90]

[88] *Id.* at 32-33.
[89] *Id.* at 33.
[90] *Id.* at 35.



35. The Agencies noted that the windrose plot (plot) shows the direction from which the wind blows, rather than the direction towards which it blows. The Agencies asserted that the plot demonstrates that the wind blows from due west almost eight percent of the time, and the plot shows the wind blowing from the quadrant stretching from due west to due north almost one-third of the time, making that quadrant the most frequent wind direction. The Agencies maintained that the "significant increase in pollution concentrations to the southeast of the source is consistent with the windrose plot."[91]

B. Agencies Approach to Health Impacts

36. The Agencies acknowledged that changes in air pollution only affect a fraction of the population. According to the Agencies, IAMs use concentration-response, or dose-response, relationships to estimate this relationship. Concentration-response relationships are generally mathematical functions that input ambient concentration estimates, then produce changes to the occurrence of negative effects such as premature mortality, aggravated asthma, etc., as outputs. The Agencies emphasized that IAMs use functions that are drawn from peer-reviewed research in the appropriate scientific field. In the case of concentration-response relationships dealing with human health, the Agencies stated that "IAMs use results from the epidemiology (or public health) literature."[92]

[91] Ex. 808 at 36 (Muller Direct).
[92] *Id.* at 6.

37. The Agencies relied on "the most recently available updates to two landmark studies" for their concentration-response data.[93] These studies are Lepeule's 2012 update of the *Harvard Six Cities* (*Lepeule or Six Cities*) study, and Krewski's 2009 update of the *American Cancer Society* (*Krewski or ACS*) study.[94] The Agencies reported that the *Lepeule* study "suggests that a one unit change [of $PM_{2.5}$] (typically expressed in terms of $\mu g/m^3$) is associated with a 1.4% increase to adult mortality rates." The Agencies stated that the *Krewski* study says "that a one unit change (again, in $\mu g/m^3$) is associated with a 0.6% increase to adult mortality rates." The Agencies recognized the significance of applying either the much larger *Lepeule* number or the *Krewski* number, noting that, because most of air pollution damages relate to mortality effects, which of the two numbers is applied will have "an appreciable effect on total damages."[95] The *Lepeule* 1.4% value is the high end of the Agencies' concentration-response range while the *Krewski* 0.6% value is the low end of the range.[96]

38. The Agencies converted negative impacts on human health to monetary terms using results from the non-market valuation literature in economics.[97] They explained that the VSL "is a rate, measured in units of money per unit probability." It measures the maximum rate a person would pay to slightly reduce his chance of dying (mortality risk), generally within the current year. [98] It is neither an estimate of what a person would pay to avoid certain death, nor an estimate of how much a person would demand to accept certain death.[99] The Agencies cited examples of people paying a certain sum to avoid an increased risk of death, such as purchasing bicycle helmets, smoke detectors or fire extinguishers.[100]

39. The Agencies explained that the VSL estimates are approached either using a stated preference or a revealed preference method of analysis. Stated preference analysis is based on responses to highly structured surveys. Revealed preference analysis is based on evidence from market transactions like those described above and through studies that demonstrate the impact on wages of small changes to risks of death on the job.[101]

40. Because there is no generally-accepted "correct" VSL value, the Agencies used two VSLs in their AP2 analysis "in an attempt to generate a range of damage estimates."[102] As the upper end of the range, the Agencies used is the EPA's VSL, which

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[93] *Id.* at 39.
[94] Ex. 808 at 39 (Muller Direct) (citing J. Lepeule et al., *Chronic Exposure to Fine Particles and Mortality: An Extended Follow-Up of the Harvard Six Cities from 1974 to 2009*, 120 Environmental Health Perspectives 7, 965 (2012); and D. Krewski et al., *Extended Follow-up and Spatial Analysis of the American Cancer Society Study Linking Particulates Air Pollution and Mortality*, 140 HEI Research Report (2009)).
[95] Ex. 808 at 39-40 (Muller Direct).
[96] Ex. 809, NZM-2 at 11-12 (Muller Direct).
[97] Ex. 808 at 36 (Muller Direct).
[98] *Id.* at 40.
[99] *Id.*
[100] *Id.* at 41.
[101] *Id.*
[102] *Id.*

is approximately $9.5 million in 2011 dollars. The EPA's VSL was produced from a collection of studies, including 21 revealed preference studies, and five stated preference studies. The Agencies say that the fact that the EPA's VSL has been used many times in air pollution-related policy analyses adds credibility to the study.[103] In addition, the Agencies found the credibility of the EPA VSL was strengthened by a recent meta-analysis of revealed preference studies generating VSL estimates ranging from $7.2 to $10.5 million, using 2010 incomes.[104]

41. The Agencies chose the results of the Kochi meta-analysis, which reported a VSL of approximately $3.7 million in 2011 dollars for the lower end of its range.[105] The Kochi meta-analysis consists of several stated preference VSL studies.[106]

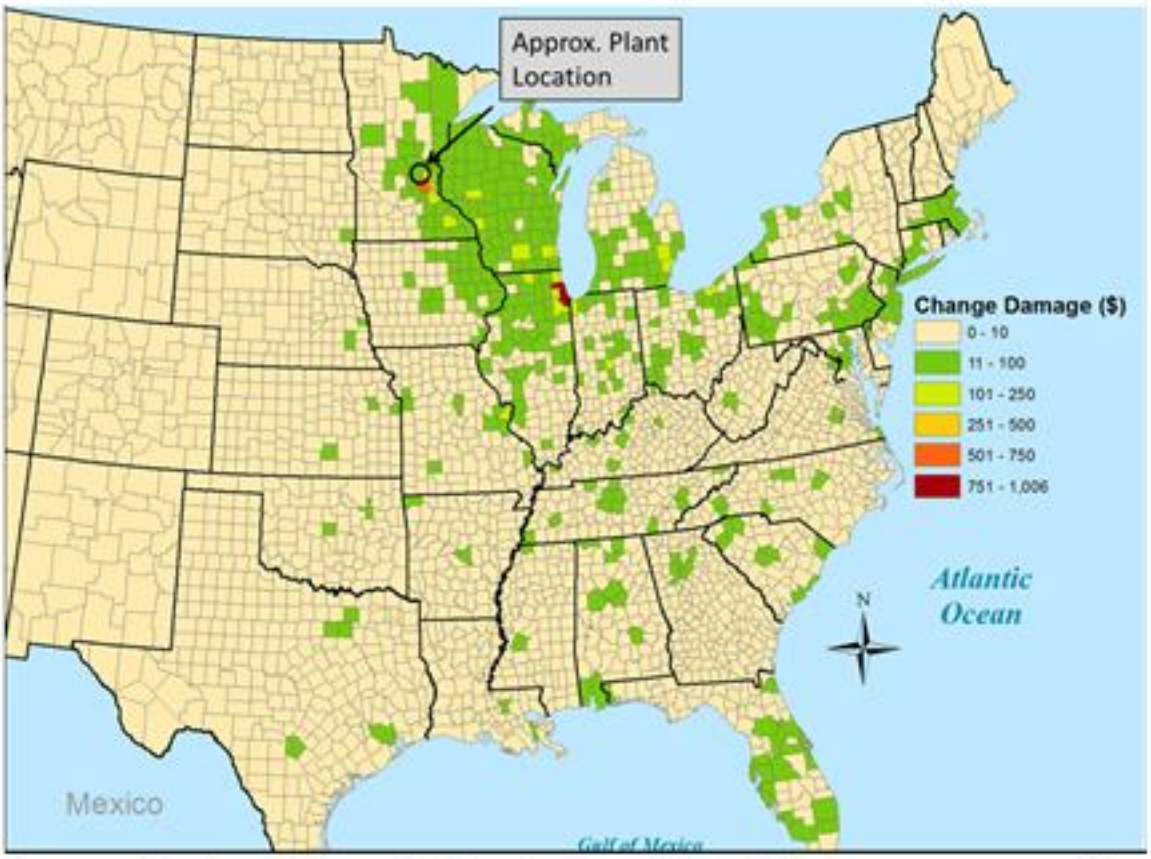
C. Calculating Damages

42. The Agencies described the calculation of damages as a process of tabulating the change in exposure to pollutants, impacts on human health and agriculture, and calculating the monetary equivalents of those impacts. In this way, the Agencies maintain, the effects are added up to estimate the total damages, across space, of emissions from a particular source.[107]

43. To demonstrate the change in damages caused by the emission of one ton of primary $PM_{2.5}$ from the Sherburne County power station, the Agencies provided an illustrative map. For purposes of this illustration, the Agencies used findings from the Lepeule study for the concentration-response function and the higher-value mortality risk. Thus, this illustration uses the AP2 model's "high damage" assumptions:[108]

[103] *Id.* at 41-42.
[104] Ex. 808 at 42 (Muller Direct). The Agencies explained that a "meta-analysis" is a statistical approach that combines results from multiple studies within a specific area of research, thus synthesizing existing research by identifying areas of agreement or discrepancies among existing studies. Ex. 808 at 42, fn 1 (Muller Direct).
[105] Ex. 808 at 42 (Muller Direct) (citing I. Kochi et al., *An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for Environmental Policy Analysis*, 34 Environmental & Resource Economics, 385 (2006)).
[106] *Id.*
[107] Ex. 808 at 37 (Muller Direct).
[108] *Id.* at 36-38.

Estimated Change in Monetary Damages Due to Emission of Primary $PM_{2.5}$ from Sherburne County Power Station.



Source: Derived from AP2 outputs using high damage scenario.

44. According to the Agencies, the Twin Cities and Chicago metropolitan areas show the most significant increases in damages from the increase in primary $PM_{2.5}$ emissions at the Sherburne County power station.[109] The Agencies asserted that these two urban areas experience relatively large changes in $PM_{2.5}$ concentrations and also have relatively large human populations, so the change in damages for each location is "quite large."[110] The Agencies made similar observations regarding counties that include large cities on the east coast of the U.S., in addition to other large cities in the Midwest.[111]

[109] Ex. 808 at 37 (Muller Direct).
[110] *Id.*
[111] *Id.*

D. Agencies' Approach to Uncertainty

1. Defining Uncertainty

45. The Agencies acknowledged that modeling damages from pollutants involves considerable uncertainty. They divided uncertainty into three categories: input uncertainty, parameter uncertainty, and model uncertainty.[112]

46. According to the Agencies, the data that is used to populate a model is input uncertainty. For example, the Agencies stated that EPA emissions data composed of measured emissions from power plants and estimated emissions from vehicles, homes and small commercial buildings contains the uncertainty arising from estimated emissions, creating input uncertainty.[113]

47. Parameter uncertainty, according to the Agencies, arises in the context of the choices a researcher may make. In this case, parameter uncertainty arises with respect to mortality dose-response and the VSL. Where multiple credible parameter choices exist, the variation of damage values that result from different choices of parameter values constitute an example of parameter uncertainty.[114]

48. The Agencies maintained that they accounted for uncertainty in key parameters by estimating marginal damages as a range.[115] The Agencies developed the range by focusing on those parameters where experts disagree as to the "true" or "preferred" value and the choice of parameter has a significant effect on damage estimates.[116] Because they met both these criteria, the Agencies developed damage ranges for the concentration-response functions and the VSL.[117] The Agencies produced both high- and low-end marginal damage estimates for each source and each pollutant.[118]

49. The Agencies stated that model uncertainty occurs when different models using the same input data and parameter values produce different results. The Agencies maintained that "[s]ources of model uncertainty center on temporal, chemical and spatial resolution (among other factors)."[119]

2. Evaluating the AP2 Model

50. The Agencies maintained that the preferred manner of addressing uncertainties in the context of modeling environmental pollution damages is to conduct sensitivity analyses.[120] A sensitivity analysis tests the ways in which different data

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[112] Ex. 808 at 43 (Muller Direct).
[113] *Id.*
[114] *Id.*
[115] Ex. 808 at 44 (Muller Direct).
[116] Ex. 808 at 44 (Muller Direct).
[117] Ex. 808 at 44 (Muller Direct); *see also* Ex. 809, NZM-2 at 27 (Muller Direct) (detailed description of the bases for the high- and low-end damage estimates).
[118] Ex. 808 at 45 (Muller Direct).
[119] *Id.*
[120] *Id.* at 44.

sources, parameter values, or models affect outcomes by using a series of model simulations, according to the Agencies.[121]

51. The Agencies claimed that the reduced form AP2 air quality model is able to replicate the annual and seasonal predictions from a photochemical model for SO_2, NO_x, ozone (O_3), and $PM_{2.5}$.[122]

52. To demonstrate the effectiveness of the AP2 model, the Agencies compared its concentration estimates to two alternative sources of ambient concentration estimates. First, the Agencies compared the AP2 output for 2011 to the 2011 output from CAMx, a state-of-the-art model that both the EPA and the MPCA have used.[123] This comparison was done for $PM_{2.5}$, including primary and secondary $PM_{2.5}$, SO_2 and NO_x, and for O_3. In addition, the Agencies evaluated AP2 against real ambient monitor data that is publicly available from the EPA.[124]

53. The Agencies explained that they utilized two statistical diagnostic measures which have been used in earlier air quality modeling performance studies to compare AP2 and CAMx performance.[125] The diagnostics are the mean fractional bias (MFB) and the mean fractional error (MFE).[126]

54. The Agencies relied on the work of Boylan and Russell[127] to describe the way in which the MFB and MFE are applied using "performance goal" and "performance criteria" standards, as follows[128]:

> [T]he model performance goal for major components of $PM_{2.5}$ has been met when both the mean fractional error (MFE) and the mean fractional bias (MFB) are less than or equal to approximately +50% and ± 30%, respectively.
>
> [T]he model performance criteria for major components of $PM_{2.5}$ has been met when both the mean fractional error (MFE) and the mean fractional bias (MFB) are less than or equal to approximately +75% and ± 60%, respectively.

55. The Agencies emphasized that Boylan and Russell's performance goals are more stringent than the performance criteria and that the performance goals "establish a

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[121] *Id.*
[122] *Id.* at 22.
[123] *Id.*
[124] Ex. 808 at 22 (Muller Direct.)
[125] *Id.* at 23.
[126] *Id.* The Agencies provided the formulas used to calculate the MFB and the MFE. Ex. 809, NZM-2 at 8 (Muller Direct).
[127] Ex. 808 at 23 (Muller Direct) (citing J. Boylan & A. Russell, *PM and Light Extinction Model Performance Metrics, Goals, and Criteria for Three-Dimensional Air Quality Models*, 40 Atmospheric Environment 26, 4946 (2006)).
[128] *Id*. at 23. (Emphasis added.)

very high standard for evaluation of a model."[129] Nonetheless, according to the Agencies, even Boylan and Russell's performance criteria "provide a clear standard for adequacy of a model."[130]

56. The Agencies evaluated AP2's ambient pollution concentration estimation performance on three data sets, all at county levels: 1) all states in the contiguous U.S.; 2) states included in the U.S. Bureau of Economic Analysts (USBEA) Plains and Great Lakes regions;[131] and 3) the state of Minnesota.[132]

57. The Agencies provided the results of the air quality model performance evaluation comparing AP2 and CAMx predictions for $PM_{2.5}$:[133]

Air Quality Model Diagnostics: AP2 and CAMx Comparison for $PM_{2.5}$

Region	AP2 Estimate ($\mu g/m^3$)	CAMx Estimate ($\mu g/m^3$)	MFB	MFE	Rho	PE (Rho)	N
National	8.12[A] (3.48)[B]	8.33 (2.83)	0.05	0.20	0.80	0.88	3,109
Great Lakes & Great Plains	9.13 (3.52)	9.37 (2.48)	0.07	0.18	0.83	0.99	972
Minnesota	9.72 (4.23)	8.87 (1.92)	0.01	0.27	0.79	0.99	87

A = arithmetic mean; B = standard deviation; N = number of counties.

58. The Agencies asserted that AP2's air quality diagnostics predict $PM_{2.5}$ national average levels which are 2.5% lower than CAMx levels. The MFB and MFE are both within Boylan and Russell's standards, implying, according to the Agencies, that the AP2 "is performing 'close to the best a model can be expected to achieve'" when compared to the CAMx model.[134] In the Great Lakes and Great Plains states, AP2 again predicts $PM_{2.5}$ average levels slightly lower than CAMx, but still within Boylan and Russell model performance goals. In the Minnesota alone comparison, the models are closer to one another, with AP2 slightly higher than CAMx. The Agencies argued that, by Boylan and Russell standards, the Minnesota comparison "indicates that AP2 produces nearly unbiased results when compared to the CAMx photochemical model."[135]

59. The Agencies pointed out that the above table also provides information about two additional comparative diagnostics. The columns labeled "Rho" and PE (Rho) represent a correlation, which "is a standard measure of the association between two

[129] *Id.*
[130] Ex. 808 at 23-24 (Muller Direct).
[131] These states include Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana and Ohio. Ex. 809, NZM-2 at 53 (Muller Direct).
[132] Ex. 808 at 24 (Muller Direct).
[133] Ex. 809, NZM-2 at 54 (Muller Direct).
[134] Ex. 808 at 24-25 (Muller Direct) (internal citation omitted).
[135] *Id.* at 26.

variables used in applied statistical analysis."[136] The Rho measure ranges from -1 to 1. According to the Agencies, "[t]wo variables are said to be positively correlated if higher than average values of one variable tend to occur with higher than average values of the other variable."[137] The Agencies maintained that the correlation of AP2 and CAMx of .80 at the national level is evidence of a strong positive correlation between the two models.[138] The Rho value is slightly higher (0.83) at the Great Lakes and Plains states level than it is for the national comparison, and just slightly lower (0.79) for the Minnesota comparison.[139]

60. The Agencies explained that the column labeled PE (Rho) represents population-weighted exposure. Stressing that damages are "primarily a function of adverse human health effects,"[140] the Agencies stated the purpose of the PE comparison is to determine whether the human exposures to ambient pollution predicted by the AP2 and CAMx models are correlated.[141] The Agencies asserted that, at the national level, the results of the AP2 and CAMx predictions regarding human population exposures are very highly positively correlated.[142] For both the Great Lakes and Plains states and the Minnesota PE comparisons, the correlation was .99, which the Agencies characterized as "strikingly similar" and "near perfect."[143]

61. The Agencies provided an additional table illustrating the results of the air quality model performance evaluation comparing AP2 and CAMx predictions specifically for sulfate and nitrate species of $PM_{2.5}$:[144]

[136] *Id.* at 25.
[137] *Id.*
[138] *Id.*
[139] *Id.* at 26.
[140] *Id.* at 25-26.
[141] Ex. 808 at 26 (Muller Direct).
[142] *Id.*
[143] *Id.*
[144] Ex. 809, NZM-2 at 55 (Muller Direct).

Air Quality Model Diagnostics:
AP2 and CAMx Comparison for Major $PM_{2.5}$ Species

National	AP2 Estimate ($\mu g/m^3$)	CAMx Estimate ($\mu g/m^3$)	MFB	MFE	Rho	PE (Rho)	N
Sulfate	1.81[A] (1.17)[B]	1.75 (0.65)	-0.16	0.36	0.91	0.94	3,109
Nitrate	1.00 (0.70)	0.98 (0.69)	0.05	0.56	0.62	0.76	3,109

Great Lakes & Great Plains	AP2	CAMx	MFB	MFE	Rho	PE (Rho)	N
Sulfate	1.64 (1.10)	1.72 (0.58)	-0.21	0.34	0.96	0.99	972
Nitrate	1.54 (0.73)	1.70 (0.57)	-0.12	0.34	0.37	0.96	972

Minnesota	AP2	CAMx	MFB	MFE	Rho	PE (Rho)	N
Sulfate	0.91 (0.30)	1.37 (0.14)	-0.44	0.44	0.89	0.99	87
Nitrate	1.76 (1.19)	1.88 (0.46)	-0.16	0.32	0.43	0.97	87

A = arithmetic mean; B = standard deviation; N = number of counties

62. The Agencies contended that this separate analysis is important because sulfate and nitrate are components, or species, of $PM_{2.5}$ and because the Commission requires damage estimates for NO_x and SO_2, which contribute directly to concentrations of nitrate and sulfate $PM_{2.5}$.[145]

63. The Agencies summarized the results of this comparison, stating that in all but two categories the AP2 analyses for sulfate and nitrate met the highest Boylan and Russell model performance goals. The two categories in which the AP2 did not meet that standard are sulfate in the Minnesota comparison and nitrate in the national comparison. The Agencies asserted that in those two cases, AP2 still fell within the model performance criteria, "which implies the model is performing acceptably relative to CAMx (Boylan and Russell, 2006)."[146]

64. The Agencies maintained that the AP2's sulfate predictions "are strongly positively correlated with those produced with CAMx . . . ." at all three of the geographic levels because for sulfate the Rho values are 0.89 or higher and the PE correlations are all above 0.90.[147] The Agencies acknowledged that the AP2's nitrate predictions "are

[145] Ex. 808 at 27-28 (Muller Direct).
[146] Ex. 808 at 27 (Muller Direct).
[147] *Id.*

less strongly correlated than for sulfate."[148] Nonetheless, the Agencies asserted, "the AP2 model meets the model performance criteria at each scale for nitrate."[149]

65. The Agencies compared both the AP2 and CAMx against actual EPA measurements of $PM_{2.5}$ (called AQS data) for 2011, and reported the following results:[150]

Air Quality Model Diagnostics:
AP2, CAMx, and AQS Comparison for Total $PM_{2.5}$

	Summary Statistics			AP2[C]			CAMx[C]			
Spatial Scale	AP2 Est. **(µg/m³)**	CAMx Est. **(µg/m³)**	AQS observed value **(µg/m³)**	MFB	MFE	Rho	MFB	MFE	Rho	N
National	8.72[A] (4.06)[B]	9.07 (3.55)	9.63 (2.41)	-0.18	0.32	0.56	-0.12	0.27	0.52	606
Great Lakes & Great Plains	10.69 (4.08)	10.87 (2.68)	9.99 (2.31)	0.02	0.22	0.59	0.08	0.14	0.77	142
Minnesota	11.53 (5.21)	10.78 (3.01)	8.09 (1.76)	0.26	0.40	0.72	0.27	0.28	0.83	10

A = arithmetic mean B = standard deviation
C = model diagnostics using AQS monitoring data N = number of counties

66. The Agencies interpreted the comparison illustrated above to mean that, on the national level, AP2 and CAMx performed to a similar degree of accuracy when evaluated against the AQS monitoring data**.** According to the Agencies, while both models performed within the Boylan and Russell performance goals, the AP2 predictions correlate slightly more strongly with the AQS data than CAMx's predictions. At the regional scale, both models again performed within the performance goals, but the Agencies state that, while AP2's lower MFB value implies less bias in AP2's predictions, CAMx's predictions correlate more strongly to the actual data from the Great Lakes and Plains states.[151] With respect to the limited Minnesota comparison, the Agencies stated that both models satisfy the performance goals. But the Agencies noted that CAMx's predictions in this instance again correlate more strongly with the AQS data. Furthermore, "both models over-predict $PM_{2.5}$ levels with respect to the observed AQS readings."[152] The Agencies concluded that, because there are only ten counties in Minnesota with $PM_{2.5}$ monitors, all of the Minnesota-only results have limited usefulness.[153]

67. The Agencies also conducted a comparison of the AP2 and the CAMx predictions regarding O_3. Like the tests for $PM_{2.5}$, the Agencies compared AP2 to CAMx at the national, regional and state levels, and compared both models predictions of O_3

[148] *Id.* at 27-28.
[149] *Id.* at 28.
[150] Ex. 809, NZM-2 at 56 (Muller Direct).
[151] Ex. 808 at 29 (Muller Direct).
[152] Ex. 808 at 29-30 (Muller Direct).
[153] *Id.*

concentrations to EPA monitor readings of ambient O_3[154]. The Agencies first provided the results of the AP2 and CAMx comparisons to one another:[155]

Air Quality Model Diagnostics: AP2 and CAMx Comparison for O_3

Region	AP2 Estimate (ppb)	CAMx Estimate (ppb)	MFB	MFE	Rho	PE (Rho)	N
National	48.48[A] (6.64)[B]	50.16 (5.34)	-0.04	0.10	0.51	0.970	3,109
Great Lakes & Great Plains	47.83 (4.53)	47.74 (4.65)	0.00	0.08	0.47	0.998	972
Minnesota	46.50 (3.42)	41.75 (2.27)	0.11	0.11	0.63	0.999	87

A = arithmetic mean, ppb: parts per billion; B = standard deviation; N = number of counties. Values are 8-hour daily maximums, averaged over the O_3 season.

68. The Agencies reported that AP2 performs well at each level in this comparison. Because neither MFB nor MFE exceeded 0.11, the Agencies claimed AP2 was well within the Boylan and Russell performance goals, as used in the $PM_{2.5}$ analysis. The Agencies asserted that Rho values of 0.47 to 0.63 are "positive" and the population exposures "are nearly perfectly correlated."[156] Based on these findings, the Agencies argued that these results "provide strong evidence of adequate performance for AP2 with respect to its estimation of ozone concentrations."[157]

69. The Agencies then reported the results of the comparisons of AP2 and CAMx predictions of O_3 concentrations to actual EPA ambient O_3 monitoring data (AQS data) for 2011:[158]

[154] *Id.* at 30.
[155] Ex. 809, NZM-2 at 57 (Muller Direct).
[156] Ex. 808 at 30 (Muller Direct).
[157] *Id.*
[158] Ex. 809, NZM-2 at 57 (Muller Direct)

Air Quality Model Diagnostics: AP2, CAMx, AQS Comparison for O_3

	Summary Statistics			AP2[C]			CAMx[C]			
Region	AP2 Estimate Ppb	CAMx Estimate Ppb	AQS ppb	MFB	MFE	Rho	MFB	MFE	Rho	N
National	50.29[A] (7.81)[B]	50.69 (5.60)	77.79 (10.85)	-0.43	0.43	0.45	-0.42	0.42	0.54	794
Great Lakes & Great Plains	51.12 (5.65)	48.79 (4.62)	77.61 (10.42)	-0.41	0.41	0.48	-0.45	0.45	0.51	184
Minnesota	48.35 (5.87)	42.31 (2.44)	67.91 (8.80)	-0.34	0.34	0.70	-0.46	0.46	0.78	14

A = arithmetic mean; B = standard deviation; N = number of counties; C = model diagnostics using AQS monitoring data. Values are 8-hour daily maximums, averaged over the O_3 season.

70. The Agencies explained that, at the national level, AP2 and CAMx both "significantly" under-predicted O_3 relative to the AQS readings."[159] The MFE and MFB values at the national level in both models are very similar in that both models meet the performance goals for MFE but only the model performance criteria for MFB. The regional level results are similar. Based on MFE and MFB measures, AP2 demonstrates a superior performance to CAMx in the Minnesota-specific comparison with the AQS readings, according to the Agencies. But here too, the Agencies acknowledge that the Rho value for CAMx is greater than the value for AP2. The Agencies point out that, as with $PM_{2.5}$, the Minnesota-only comparison for O_3 only involves a small number of counties (14) with O_3 monitoring stations.[160]

71. Based on all of the evaluations they conducted, the Agencies concluded that the AP2 model performs well for both $PM_{2.5}$ and O_3 when compared with CAMx. The Agencies maintained that the "predicted concentrations from both AP2 and CAMx are annual averages for $PM_{2.5}$ (expressed in $\mu g/m^3$) and seasonal averages for O_3 (expressed in parts per billion, or ppb).[161] The Agencies argued that, although there is temporal variability of these averages in the course of a year, evaluation of a model based on annual average predictions is sensible. According to the Agencies, the reason annual averages make sense in this context is because the concentration-response functions for mortality (the most significant contributor to damages) "that relate increases in mortality rates to changes in air pollution employ central tendency measures of air pollution, such as annual averages."[162]

E. Agencies' Recommended Values

72. The Agencies provided various permutations of the damages AP2 calculated, suggesting that the Commission could use them in a variety of ways.[163]

[159] Ex. 808 at 31 (Muller Direct).
[160] *Id.*
[161] *Id.* at 32.
[162] *Id.*
[163] Ex. 811 at 25-26 (Muller Surrebuttal).

Among other options, the Agencies provided a presentation of a simple set of average marginal damages for each pollutant across all Minnesota sources:[164]

Final Summary of Environmental Cost Values for 2011 through 2040. All Counties Receiving Pollution from Minnesota Sources. (Constant year-2011 USD)

	Low Damage Assumptions			High Damage Assumptions		
Year	$PM_{2.5}$	SO_2	NOx	$PM_{2.5}$	SO_2	NOx
2011	26,012 A	11,818	1,183	140,102	64,180	6,219
2015	26,574	12,288	1,206	143,108	65,551	6,338
2020	27,434	12,681	1,243	147,754	67,706	6,531
2025	28,950	13,347	1,311	155,920	71,331	6,880
2030	31,184	14,304	1,407	168,074	76,589	7,384
2035	33,327	15,241	1,494	179,752	81,742	7,837
2040	34,808	15,942	1,551	187,844	85,606	8,138

A= values reported in $/short ton. Values are average marginal damages across sources.

73. The Agencies also provided data on minimum and maximum values and standard deviations for the 2011 model year:

Summary of Environmental Cost Values for 2011 Model Year. All Counties Receiving Pollution from Minnesota Sources ($/ton emitted)

	Low Damage Assumptions			High Damage Assumptions		
Pollutant	Average (Std. Dev.)	Min. Value	Max. Value	Average (Std. Dev.)	Min. Value	Max. Value
Primary $PM_{2.5}$	26,012[A] (16,047)	12,835	105,163	140,102 (83,803)	69,949	553,638
SO_2	11,818 (3,222)	4,310	23,897	64,180 (17,089)	23,533	127,410
NOx	1,183 (778)	65	5,351	6,219 (4,133)	267	28,069

A= values reported in $/short ton. 93 power plants and county source locations.

74. Because of the magnitude of difference between the high and low-ends of the ranges for the concentration-response and VSL values, and because these parameters are so critical to the outcome of the damage estimates, the Agencies observed that these differences in the concentration-response and VSL parameters translate into approximately a "five-fold increase in average damages per ton of $PM_{2.5}$ emissions."[165] SO_2 damages are lower than $PM_{2.5}$ damages, but increase proportionally when the high-end parameters are used. NOx damages, which are the smallest per ton of emissions, also increase proportionally.[166]

75. The Agencies also provided a map displaying the total damage caused by a ton of emission of primary $PM_{2.5}$ in a given county (see Finding 78 below). The map includes damages both within and outside the county where the emissions are released,

[164] Ex. 808 at 72 (Muller Direct); Ex. 809, NZM-2 at 48, Table 14 (Muller Direct).
[165] Ex. 808 at 50 (Muller Direct).
[166] *Id.* at 49.

and includes receptor counties outside of Minnesota (but within the U.S.). The same map includes sources within 200 miles outside of Minnesota's borders.[167]

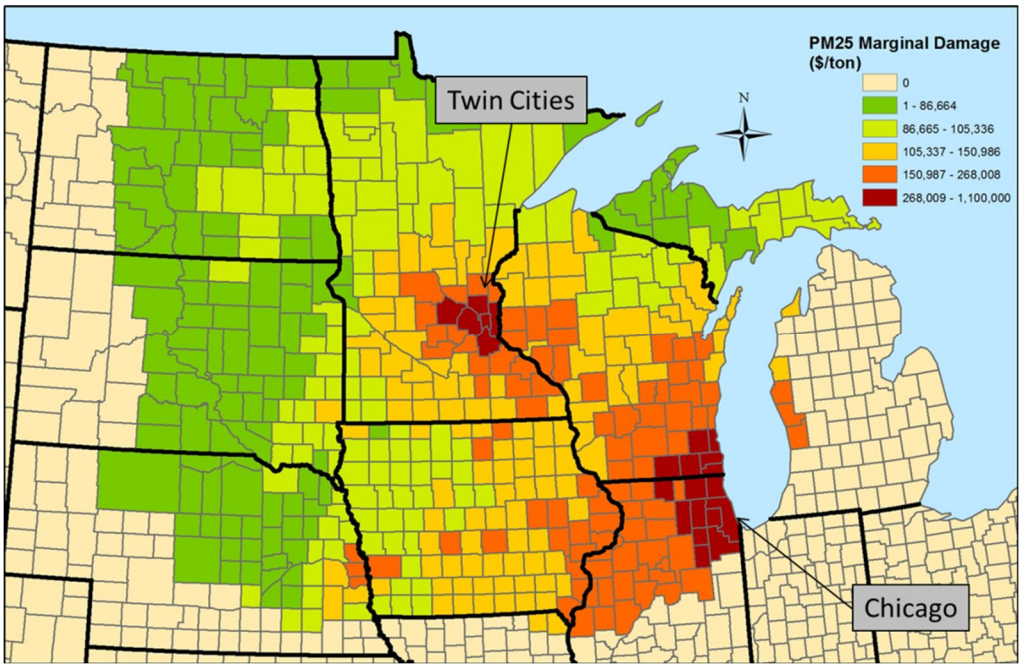
76. The Agencies noted that, because the highest damages occur when emissions are released in close proximity to large cities, the sources producing the highest damages are in counties in the Twin Cities area in Minnesota, and counties in the Chicago area in Illinois.[168]

77. According to the Agencies, both low- and high-end damages, across pollutants, showed only a small (2% to less than 5%) increase from 2011 to 2015, as increased population and income were essentially canceled out by decreased mortality rates.[169] The Agencies maintained that "all three pollutants show a similar trend in their average values" and that those values increase in the future through 2040.[170] The Agencies noted that the damages increase due to a dominance of increased population and income growth despite a general expected continued decline in mortality rates.[171] The Agencies asserted that the growth of damages for sources outside the state is expected to increase gradually during the same time period.[172]

78. Another alternative way of viewing damages the Agencies proposed assembles them based on quantiles of the distribution of the values. This approach provides an average damage value or value range for any source location falling within a given quantile:[173]

[167] *Id.* at 51-53.
[168] *Id.* at 54.
[169] *Id.* 66-67.
[170] *Id.* at 68.
[171] *Id.* at 67-68.
[172] *Id.* at 69-70.
[173] Ex. 808 at 51-54 (Muller Direct); Ex. 809, NZM-2 at 35 (Muller Direct).

Marginal Damages for Emissions of Primary $PM_{2.5}$ Inclusive of Sources both within and outside the State of Minnesota, High-Damage Scenario



79. The following table describes the quantiles illustrated in the map above:[174]

Groupings of Environmental Cost Values for 2011 Model Year. All Counties Receiving Pollution from Minnesota Sources ($/ton emitted):

Percentile	$PM_{2.5}$	SO_2	NO_x	Map Color
0 – 25th	< 86,664	< 22,537	< 4,348	Dark Green
25th – 50th	86,665 – 105,336	22,538 – 59,160	4,349 – 4,752	Light Green
50th – 75th	105,337 – 150,986	59,161 – 65,908	4,753 – 4,753	Light Orange
75th – 95th	150,987 – 268,008	65,909 – 79,702	5,344 – 8,196	Dark Orange
95th – 100th	268,009 – 1,100,000	79,703 – 127,140	8,197 – 28,687	Red

[174] Ex. 808 at 54 (Muller Direct). The map caption indicates that it includes sources inside and outside of Minnesota. However, the chart caption says "All Counties Receiving Pollution from Minnesota Sources." According to Dr. Muller's testimony, the groupings embodied in the map are shown in the chart. The discrepancy in the captions is not explained.

80. As a third way to structure the damages data, the Agencies agreed that the values could be combined to provide urban, metro-fringe and rural land-use designation values, as was done in the First Externalities case and as Xcel is recommending in this case.[175] The Agencies noted that "there is significant variation in the environmental cost values within these land-use designations and so simply relying on one source location within each . . . is inherently problematic."[176]

81. The Agencies summarized the marginal damages for sources outside of Minnesota as follows:[177]

Summary of Environmental Cost Values for 2011 Model Year. All Counties Receiving Pollution from Sources outside of Minnesota ($/ton emitted).

	Low Damage Assumptions			High Damage Assumptions		
Pollutant	Average (Std. Dev.)	Min. Value	Max. Value	Average (Std. Dev.)	Min. Value	Max. Value
Primary PM2.5	24,122[A] (17,393)	10,804	217,919	130,485 (89,806)	59,303	1,100,000
SO2	8,656 (4,157)	3,221	20,863	47,158 (22,515)	17,631	110,679
NOx	939 (437)	55	2,559	4,967 (2,398)	227	13,757

A= values reported in $/short ton.

82. The Agencies maintained that they chose these out-of-state sources because they "might conceivably provide power to Minnesota *and* appreciably affect air quality in the state."[178] The Agencies estimated the average damage per ton at about 7% lower for sources outside Minnesota than the average damage per ton within the state, for both high- and low-damage approaches. The averages were significantly lower for SO_2 and NO_x. The Agencies observed that the variation in damages across sources is higher outside of Minnesota than it is within the state, and attributed the wide range in damages to the great variety of population densities among and within the states surrounding Minnesota.[179]

83. According to the Agencies, the largest damages per ton outside of Minnesota are in DuPage, Will, and Cook Counties. DuPage and Will Counties are just west of Chicago and Cook County contains Chicago. These are the top three counties

[175] Ex. 811 at 26 (Muller Surrebuttal).
[176] *Id.*
[177] Ex. 808 at 63 (Muller Direct); Ex. 809, NZM-2 at 47 (Muller Direct).
[178] Ex. 808 at 63 (Muller Direct) (emphasis in original).
[179] *Id.* at 63-64.

for both SO_2 and $PM_{2.5}$. The highest damages for NO_x are different – McHenry County is also adjacent to and west of Chicago, while Waukesha and Milwaukee Counties are adjacent to or encompassing Milwaukee, Wisconsin. The pattern is clear, say the Agencies, that proximity to high-density population drives the spatial pattern for high damages per ton of emissions.[180] The Agencies reported that the high and low ends of the damages range effect damage costs in much the same way for sources outside of Minnesota as they effect damage costs for sources within the state.[181]

III. The CEOs' Recommended Model and Values

A. The InMAP Model

84. The CEOs explained that it is often not straightforward to connect air pollutant emissions and their ultimate impacts, so comprehensive models that attempt to predict the impacts of such emissions attempt to include everything that is known about the atmosphere. The CEOs acknowledged that such models are considered "the most accurate predictors of atmospheric change" but asserted that they are often not practical for studying pollution because the models require significant amounts of computational resources.[182]

85. As described by the CEOs, reduced form models only attempt to include the atmospheric processes "most important for answering the question at hand," relying on the output from more complex models for their data. Because of this, the CEOs recognized that reduced form models "may be less accurate" than comprehensive models, but maintained that they are generally more practical to run.[183]

86. The CEOs proposed cost values for the CPs based on the results of a reduced form model called the Intervention Model for Air Pollution (InMAP), developed by Dr. Julian Marshall and Dr. Christopher Tessum.[184] InMAP calculated the CP damage cost values in this proceeding based on power plants in Minnesota, and within 200 miles of Minnesota's borders, excluding Canada.[185] InMAP predicted impacts on human health.[186]

87. The CEOs explained that InMAP predictions are constructed on baseline air quality information taken from a complex air quality model called WRF-Chem.[187] WRF-Chem is run once, estimating a baseline state of the U.S. atmosphere. At that point, certain information is extracted from the results of the WRF-Chem baseline for use in the

[180] Ex. 808 at 65 (Muller Direct).
[181] *Id.*
[182] Ex. 115 at 6 (Marshall Direct).
[183] *Id.*
[184] Ex. 115 at 5 (Marshall Direct); Tr. Vol. 6 at 38 (Marshall).
[185] Ex. 115 at 17, fn 6 (Marshall Direct).
[186] *Id.* at 5.
[187] WRF-Chem is a comprehensive air quality model that models, among other things, weather conditions (wind speed, direction, clouds, precipitation); atmospheric transport of emitted pollution by wind and turbulence; transformation of pollutants as they interact with each other and sunlight; and removal of pollution from the air by surfaces, clouds and precipitation. Ex. 115 at 10 (Marshall Direct).

InMAP analysis.[188] After InMAP takes into account the changes in emissions (as described below), InMAP is run to see how the changes in emissions will cause changes in emissions concentrations.[189]

88. According to the CEOs, InMAP approaches the reduced form modeling exercise by dividing the air above the land in the U.S. into three-dimensional grid cells. The cells vary in horizontal length from 1 km to 48 km and extend vertically from ground level to 20,000 meters (m). The cells vary from a height of 57 m closer to the ground to 1400 m at the top of the model.[190]

89. By applying annual average wind speed, direction, and turbulence properties in each grid cell, InMAP calculates how pollution emitted in one cell moves between grid cells.[191] InMAP also accounts for the conversion of SO_2 and NO_x into $PM_{2.5}$.[192]

90. The CEOs presumed that proximity of the emissions being measured to people, the height of those emissions, the atmospheric conditions surrounding the emissions and people, and the baseline health of the affected people can cause the damages attributable to marginal increases in the emissions to vary.[193] Given that these factors vary with respect to proximity to high- or low-population centers, the CEOs determined that estimates of damages attributable to CP emissions would vary based on the location of the source of the emissions.[194] Because counties are a familiar method of identifying geographical areas, the CEOs calculated average damages from emissions occurring in each county in Minnesota.[195]

91. To arrive at a value for each county, the CEOs took the following steps:

- Assuming that emissions are evenly spread over the land of the county in question, the CEOs provided pollution emission inputs into InMAP separately for each county.[196]

- Using an air pollution model that relies on atmospheric information including wind speed, direction, amounts of turbulence, and sunlight, as well as information about how these atmospheric properties affect pollution, the CEOs calculated the change in atmospheric concentration of pollutants which was attributable to the change in emissions of those pollutants. The CEOs stated that the output from the InMAP model is spatially explicit and that, in general, pollutant

[188] Ex. 115 at 15 (.Marshall Direct).
[189] *Id.* at 15-16.
[190] Ex. 115 at 9 (Marshall Direct).
[191] *Id*.
[192] *Id.*
[193] *Id.* at 6. "Marginal" emissions refers to the changes in emissions from an existing baseline. *Id.* at 9.
[194] *Id.* at 6-7.
[195] *Id.*
[196] *Id.* at 7.

concentrations are higher near the source of emissions than they are further away.[197]

- InMAP calculated how each county's emissions affected pollution concentrations in each ground level cell across the entire contiguous U.S. with spatial resolution between 1 km and 48 km. This amounted to about 50,000 ground-level grid cells in all.[198]

- Next, the CEOs used the output from the air pollution model to estimate the damage to human health that would be caused by the predicted change in the concentration of pollutants. At this point, the CEOs incorporated results from epidemiological studies, as well as United States (U.S.) Census data regarding population distribution and data about baseline health levels from the U.S. Centers for Disease Control and Prevention (CDC).[199] The CEOs asserted that this method of combining its InMAP grid cells with Census data enabled it to "estimate the changes in $PM_{2.5}$ concentrations caused by each scenario at the place of residence of every resident of the contiguous U.S."[200]

- For this proceeding, the CEOs calculated the average impacts of emissions in each county at three emission heights.[201] The three emission heights are designed to account for the effective stack height which is the height of the smoke stack in addition to the height that the emission plume rises due to the buoyancy and initial upward velocity of the emissions. The CEOs used effective stack heights of 29m, 310m, and 880m, which are meant to represent the vertical centers of the InMAP grid cell layers. The heights are based on the effective stack heights for small (25^{th} percentile), medium (75^{th} percentile) and large power plant stack heights in Minnesota.[202]

- Finally, the CEOs assigned a dollar value to the human health impacts, establishing a dollars-per-ton cost for damages from emissions of each pollutant.[203]

92. Because each step in the process of estimating the damages costs involves a degree of "variability and uncertainty," the dollar assignment is not exact. The CEOs made what they determined was a "best-estimate," including using results from two

[197] Ex. 115 at 7 (Marshall Direct).
[198] *Id.* at 18.
[199] *Id.* at 7.
[200] *Id.* at 18.
[201] *Id.* at 16.
[202] *Id.* at 17-20.
[203] *Id.* at 8.

"equally valid" epidemiological studies of air pollution health effects to define the ends of a range of likely values.[204]

93. The CEOs did not consider the direct health effects of SO_2 and NO_x. Instead, they calculated these effects as they form secondary $PM_{2.5}$ in the atmosphere. Therefore, the CEOs asserted, their model likely underestimated the "total health impacts of power plant emissions."[205]

94. The CEOs described "primary $PM_{2.5}$" as those particulates emitted directly from the source in particulate form.[206] Primary particulates affect the air quality closer to the source of the emission because they are in particulate form at the time they are emitted. "Secondary $PM_{2.5}$" are the particulates formed into $PM_{2.5}$ through the transformation of other pollutants, such as SO_2 or NO_x, through chemical interactions in the atmosphere.[207] The pollutant gases, sometimes called $PM_{2.5}$ precursors, travel quite far before they become $PM_{2.5}$. Therefore, they can affect the air quality at significant distances from the source of the pollution.[208]

95. The CEOs focused on three properties of $PM_{2.5}$ when they chose to use InMAP as their model. Because health effects of $PM_{2.5}$ are "most strongly connected" to exposures of periods of a year or more, the CEOs claimed it was "important to model annual average $PM_{2.5}$ concentrations attributable to emissions.[209] Next, because $PM_{2.5}$ health effects can occur at long distances, but also vary locally within the bounds of a city, the CEOs determined it was important for the model they used to cover as large a geographic area as possible but also to resolve differences in concentrations among neighborhoods "anywhere in the plume."[210] Finally, the CEOs concluded their model should be able to account for both primary and secondary $PM_{2.5}$. The CEOs found that InMAP meets all of these specifications.[211]

96. According to the CEOs, InMAP estimates the transformation of SO_2 and NO_x "based on spatially explicit information derived from output from WRF-Chem . . . ."[212] The CEOs state that InMAP can then model transformations of the individual pollutants from gas-phase to particulate matter and back to gas-phase "using reaction properties that vary from location to location."[213] The CEOs asserted that this modeling is more realistic than is available with other reduced form models because other models "generally assume chemical reactions only occur in one direction at a rate that does not vary."[214]

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[204] Ex. 115 at 8 (Marshall Direct).
[205] *Id.* at 11.
[206] *Id.*
[207] *Id.*
[208] *Id.*
[209] *Id.* at 12.
[210] *Id.*
[211] *Id.*
[212] *Id.* at 13.
[213] *Id.*
[214] *Id.*

97. The CEOs explained that "[p]ollutants can be removed from the atmosphere by either dry or wet deposition."[215] Dry deposition occurs when pollutants leave the air and attach to surfaces. Wet deposition occurs when pollution leaves the air and is absorbed by either clouds, rain, or water. InMAP is designed to calculate both dry and wet deposition of pollutants in a spatially explicit manner, using a combination of theoretical information and data from WRF-Chem.[216]

98. While there are other reduced form models available for calculating the impacts and damages of air pollution, the CEOs found InMAP most appropriate in the context of this proceeding.[217] The CEOs compared InMAP to APEEP, the predecessor to AP2, the model used by the Agencies in this matter.[218] According to the CEOs, InMAP is a "more refined" model than APEEP in the following ways:[219]

- InMAP models the transportation of pollution more realistically, based on wind speed, direction and turbulence properties in each cell of its grid, while APEEP assumes a constant speed and direction of the pollution, based on the county where the pollution is emitted; and that the pollution spreads slowly and evenly.

- InMAP's grids provide more detailed spatial resolution than APEEP, which models county-level resolution. InMAP's results are based on its grid, expressed on an average-per-county basis, while APEEP assumes emissions occur at the geographic center of each county.

- InMAP's modeling of the atmosphere transformation of SO_2 and NO_x into secondary $PM_{2.5}$ and back to gas-phase pollutants is more realistic than APEEP's, which is a constant, one-directional change from gas-phase to secondary $PM_{2.5}$.

- InMAP models wet and dry deposition more realistically than APEEP, because it varies deposition spatially, while APEEP uses a constant deposition rate.

99. The air-quality model runs required for the InMAP process used by the CEOs took about five weeks of computing time, using a standard desktop computer.[220]

100. The CEOs tested InMAP's accuracy by creating 11 scenarios of marginal changes in emissions and running them in WRF-Chem and then InMAP. The CEOs compared the results from the two model runs and, according to the CEOs, found that the

[215] Ex. 115 at 13 (Marshall Direct).
[216] *Id.*
[217] *Id.* at 15.
[218] *Id.* at 14. The comparison also applied to COBRA, another reduced form air pollution model, but that model was not used by any party to this proceeding.
[219] *Id.* at 14-15.
[220] *Id.* at 17.

changes in $PM_{2.5}$ concentrations compared "with excellent accuracy."[221] The population-weighted mean fractional error and bias was less than ten percent (values less than 50 percent are generally considered acceptable), and precision R^2 value was approximately 0.99, which indicates excellent agreement.[222]

101. Using results from epidemiological studies (discussed below at Findings 103 to 106), the CEOs explained that the InMAP model calculates the average health impacts of emissions from each county. InMAP combines the change in concentration of $PM_{2.5}$ in each grid cell with the number of people (based on U.S. Census data) in each grid cell, the baseline mortality data in each grid cell (based on data from the CDC) and the epidemiological study results. The result of this calculation is the number of deaths in each grid cell caused by $PM_{2.5}$ emissions.[223] The grid cell numbers are then combined to provide total numbers "of U.S. deaths caused by emissions from each county."[224]

102. The CEOs chose to use the VSL recommended by the EPA Scientific Advisory Board. The EPA number value is an average of 26 studies published between 1974 and 1991, adjusted for changes in currency value and income growth. The CEOs resulting VSL number, in 2015 dollars, is $9.8 million.[225]

B. CEOs' Approach to Health Impacts

103. The CEOs asserted that "[t]he consensus among epidemiological studies is that $PM_{2.5}$ exposure causes an increased likelihood of death and that there is no safe level for $PM_{2.5}$ concentrations . . . $PM_{2.5}$ causes increased rates of mortality even at the lowest observed levels."[226]

104. The CEOs relied on the *Lepeule* and *Krewski* studies, which are the same two studies on which the Agencies relied. The CEOs pointed out that both studies are "cohort" studies.[227] A "cohort" study is one that follows a group of people for an extended time period and, according to the CEOs, is the most robust type of study for this purpose.[228]

105. According to the CEOs, the *Lepeule* study found that mortality rates increased by 14% for every ten $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentrations.[229] The *Krewski* study found a 7.8% increase in mortality rates for every 10 $\mu g/m^3$ increase.[230] The *Lepeule* study was dated 2012 while the *Krewski* study was

[221] Ex. 115 at 16 (Marshall Direct).
[222] *Id.* at 16, fn 5. R^2 is the symbol for squared Pearson correlation coefficient values. Ex. 116, Schedule 3 at 7 (Marshall Rebuttal).
[223] Ex. 115 at 23 (Marshall Direct).
[224] *Id.* at 24.
[225] *Id.* at 25.
[226] *Id.* at 21.
[227] *Id.* at 22.
[228] *Id.* at 21.
[229] *Id.* at 22.
[230] Ex. 115 at 22 (Marshall Direct).

dated 2009.[231] However, the *Krewski* study involved about 500,000 people while the *Lepeule* study tracked 8,096 people.[232]

106. The CEOs claimed that $PM_{2.5}$ causes health problems in addition to increases in mortality, including increased risk of "stroke, heart attack, heart disease, asthma attack, lung disease, lung cancer and acute lower respiratory infection."[233] Nonetheless, the CEOs did not incorporate the impacts of these other health problems in their analysis because many of these problems are associated with mortality. The CEOs maintained it is difficult to include these impacts and avoid double-counting.[234]

C. CEOs' Recommended Values

107. For each county within Minnesota and within 200 miles of its borders, the CEOs proposed three ranges of monetary damages estimates for emissions of $PM_{2.5}$, NO_x and SO_2, offered by stack height. The CEOs recommended that the applicable estimates could be chosen by going to the county in which the emission source is located or proposed, determining the appropriate stack height, then applying the appropriate range of values.[235]

108. The CEOs provided examples of cost values from a sample of four Minnesota counties, for illustrative purposes:[236]

[231] *Id.* at 22, fn 9-10.
[232] *Id.* at 22, fn 11.
[233] *Id.* at 22.
[234] *Id.* at 23.
[235] *Id.* at 26-27.
[236] Ex. 115 at 27 (Marshall Direct); *see also* Ex. 115, Schedule 3 (Marshall Direct) (complete list of the CEOs' recommended damages by county).

Externality Damages (2015 dollars-per-ton damages values) for SO_2, NO_X, and $PM_{2.5}$ emissions in various counties at low, medium, and high stack heights.

County	Pollutant	Low stack height	Medium stack height	High stack height
Ramsey County	$PM_{2.5}$	$339,328 – 591,975	$99,675 – 173,887	$31,486 – 54,929
	SO_2	$15,914 – 27,762	$16,430 – 28,663	$17,472 – 30,480
	NO_x	$30,657 – 53,482	$12,816 – 22,358	$5701 – 9945
Lake of the Woods County	$PM_{2.5}$	$4550 – 7938	$4410 – 7694	$4152 – 7243
	SO_2	$2321 – 4049	$2439 – 4256	$2754 – 4804
	NO_x	$845 – 1474	$813 – 1418	$715 – 1247
Sherburne County	$PM_{2.5}$	$67,097 – 117,054	$56,047 – 97,776	$29,046 – 50,672
	SO_2	$13,415 – 23,403	$14,328 – 24,995	$14,576 – 25,429
	NO_x	$10,014 – 17,470	$8460 – 14,758	$4771 – 8324
Mower County	$PM_{2.5}$	$81,433 – 142,063	$79,189 – 138,148	$66,384 – 115,810
	SO_2	$33,460 – 58,373	$34,399 – 60,010	$37,788 – 65,922
	NO_x	$17,855 – 31,148	$16,881 – 29,449	$11,649 – 20,322

109. The CEOs also established a set of generic damages values for a generating plant with an unknown location in Minnesota. Using InMAP, the CEOs calculated damages "caused by the fleet of existing power plants in Minnesota."[237] The CEOs obtained information from the EPA's 2011 National Emission Inventory about power plant location, stack properties, and emission amounts to calculate a weighted average of the damage costs for each power plant in Minnesota.[238] This calculation led the CEOs to the following generic cost values, per ton, in 2015 dollars:

[237] Ex. 115 at 18 (Marshall Direct).
[238] *Id.* at 18, 27- 28. The CEOs stated "[a] weighted averaged is like a normal average with the difference that each value is given a weight (in this case, the weight is the total pollution emissions from the plant) and values with higher weights influence the average more than values with lower weights." *Id.* at 18, fn 7.

- $PM_{2.5}$: $125,000 - $218,000
- SO_2 : $ 16,000 - $ 28,000
- NO_x : $ 14,000 - $ 24,000

110. The CEOs considered their recommended cost values for the PCs conservatively low because they: 1) predicted U.S. mortality impacts only, and did not include other health impacts; 2) only included impacts from primary and secondary $PM_{2.5,}$ but did not include direct impacts from SO_2 and NO_x; and 3) did not include other economic damages.[239]

IV. Xcel's Recommended Model and Values

A. Xcel's Proposed Model

111. Xcel approached the task of developing recommendations for updated values for the CPs based on consideration of the following criteria:

- Use a damage cost approach to value environmental costs;
- Develop the most accurate and credible estimates for use in Minnesota for $PM_{2.5}$, SO_2 , and NO_X environmental values;
- Address the inherent uncertainty in estimating human health and other damages in a systematic and reasonable way;
- Use sound scientific and economic models;
- Minimize subjective judgments;
- Yield a practicable range; and
- Be transparent, replicable, and updatable.[240]

Xcel asserted that its proposed values meet all of these criteria.[241]

112. Xcel explained that there are three basic kinds of commonly-used air quality models:[242]

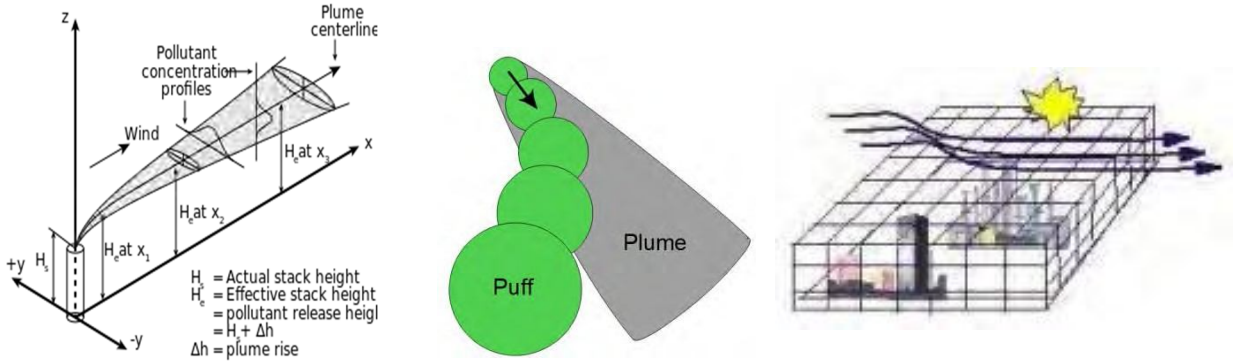
> Steady-State Gaussian Plume Models: Lagrangian Plume models assume the instantaneous straight-line transport of emissions from the source to downwind receptors using a single hourly wind speed and direction. The plume has a Gaussian (bell-shaped) distribution of concentrations around the centerline of the plume. The left panel in [the figure below] illustrates

[239] *Id.* at 28.
[240] Ex. 604 at 4 (Desvousges Direct).
[241] *Id.* at 8-9.
[242] Ex. 604, WHD-1, Schedule 3 at 1-2 (Desvousges Direct).

the structure of a Plume model. Plume models do not reliably treat chemical transformation. Examples of plume models include AERMOD, ISC and APEEP.

Non-Steady-State Gaussian Puff Models: Lagrangian Puff models represent a plume as a series of overlapping circular Gaussian puffs that move within a three-dimensional (3-D) wind field over time. This allows the plume to turn with the wind, which a Plume model cannot do as illustrated in the middle panel of [the figure below]. Although Puff models have 3-D wind inputs, each puff can only be transported by a single wind so it has limited ability to simulate transport and dispersion in complex flow fields. Puff models typically have simple representations of chemical transformation because they do not treat photochemical reactions. Examples of Puff models include CALPUFF, SCIPUFF and HYSPLIT.

Photochemical Grid Models (PGMs): Eulerian PGMs divide the region to be modeled into vertically stacked horizontal grid cells and simulate the 3-D movement of pollutants among the grid cells (right panel [of figure below]). PGMs treat emissions from all sources, including sources far upwind (e.g., global sources) through boundary conditions (BCs), so can include detailed photochemical chemical mechanisms that accurately simulate ozone and secondary PM formation. Examples of PGMs include CMAQ and CAMx.



Schematic representation of a Steady-State Gaussian Plume (left), differences in Gaussian Plume and Puff (middle) and Eulerian Photochemical Grid Model (right) air quality modeling techniques.

113. Xcel determined it needed a model that would "accurately and reliably simulate the effects emissions from the EGU will have on primary SO_2, NO_2 and $PM_{[2.5]}$ concentrations as well as ozone and secondary $PM_{[2.5]}$ near and far downwind of the source."[243]

114. Based on a document the EPA publishes called Appendix W, which provides the EPA's recommended modeling approaches for various applications, Xcel

[243] Ex. 604, WHD-1, Schedule 3 at 1 (Desvousges Direct).

determined the CAMx model would best suit the needs of this proceeding.[244] Xcel quoted the EPA's latest modeling guidelines to explain its choice of CAMx:

> [T]he EPA believes photochemical grid models are generally most appropriate for addressing ozone and secondary $PM_{2.5}$ because they provide a spatially and temporally dynamic realistic chemical and physical environment for plume growth and chemical transformation. Publically available and documented Eulerian photochemical grid models such as the Comprehensive Air Quality Model with Extensions (CAMx) and the Community Multiscale Air Quality (CMAQ) model treat emissions, chemical transformation, transport, and deposition using time and space variant meteorology. These modeling systems include primarily emitted species and secondarily formed pollutants such as ozone and $PM_{2.5}$[.][245]

115. Xcel determined that the CAMx model was a better choice for this proceeding than the CMAQ model because the CAMx model "also includes a subgrid-scale Plume-in-Grid module that is a Lagrangian puff model that treats the near-source plume chemistry and dynamics of point source plumes until the plume size is comparable to the grid cell size when the mass from the puffs are released to the grid model."[246] Xcel concluded that the CAMx model's "Plume-in-Grid module" would provide for "more accurate treatment of the emissions from the hypothetical EGU point source plumes near the source."[247]

116. Xcel used the CAMx photochemical grid model (PGM). Xcel pointed out that CAMx has been publicly available for about 20 years and is now available free of charge. There are 477 registered CAMx users and, as of late November 2015, there had been 632 downloads of the model in 2015.[248]

117. Xcel estimated changes in ambient air concentrations that would be emitted by hypothetical new emissions sources. Then, Xcel estimated the potential effects of those air quality changes on human health, including premature morbidity and mortality, agriculture (crop production), materials (corrosion and soiling), and visibility. Last, Xcel estimated values for each of the environmental effects for each scenario it explored to calculate monetized damages.[249]

118. Xcel extended its study area of potential air quality changes approximately 100 miles out from Minnesota's borders to include parts of Iowa, Wisconsin, Michigan, Illinois, Nebraska, South Dakota, and North Dakota. Xcel made this choice to be consistent with the study in the First Externalities case.[250] Because the CAMx model requires a rectangular grid for its study area, Xcel explained, the study in this proceeding

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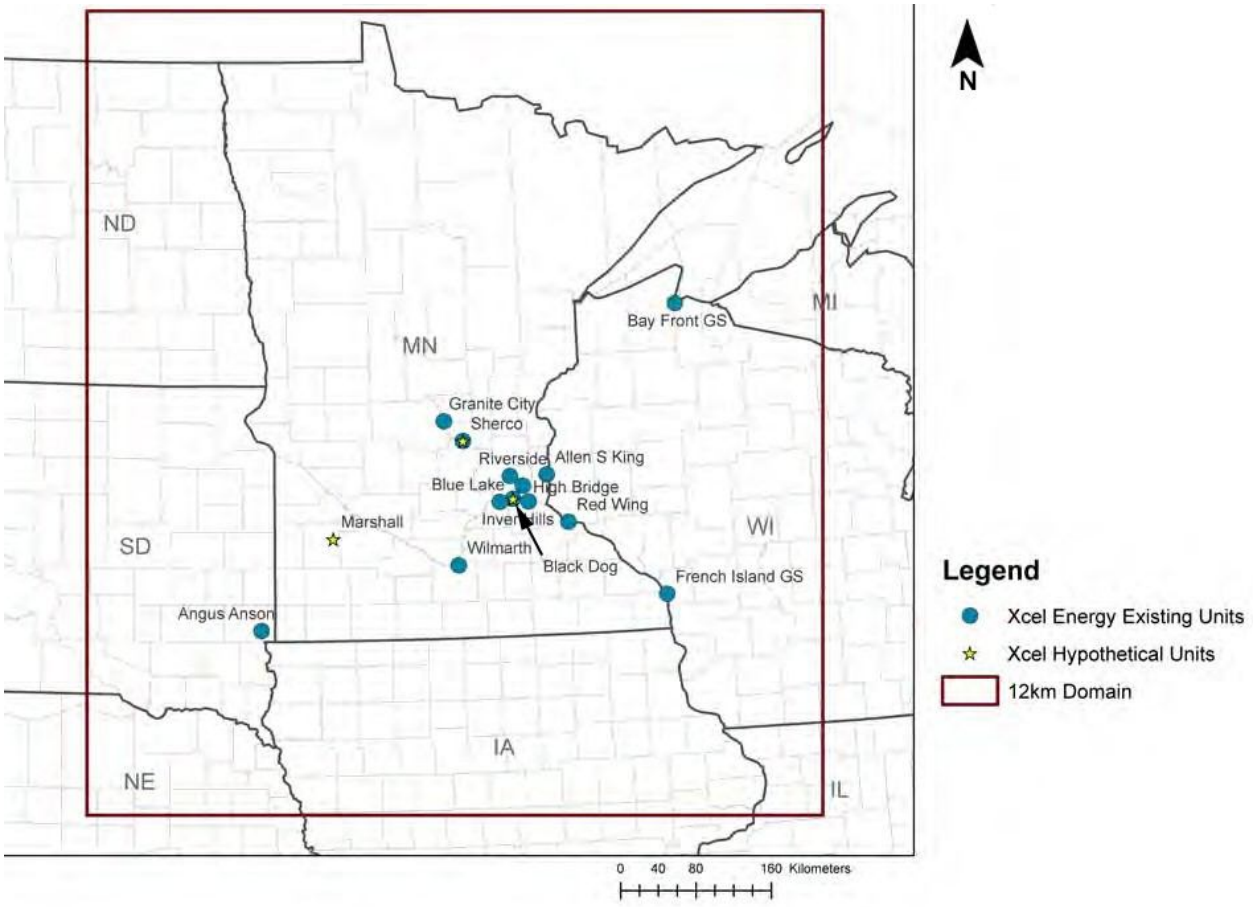
[244] *Id.*
[245] Ex. 604, WHD-1, Schedule 3 at 3 (Desvousges Direct).
[246] *Id.*
[247] *Id.*
[248] Ex. 608 at 5-6 (Desvousges Surrebuttal).
[249] Ex. 604 at 15 (Desvousges Direct).
[250] *Id.* at 19.

goes beyond the original study area, which did not include parts of Iowa, Michigan, Illinois, Nebraska or North Dakota.[251] The model Xcel designed for Minnesota used a 65 by 71 array of twelve-kilometer resolution grid cells. This design is consistent with the EPA's photochemical grid modeling guidance, according to Xcel.[252]

119. Xcel provided the following map showing the geographic area included in its study, along with the locations of its own generating units and the locations of the three hypothetical generating units at its rural (Marshall), metropolitan fringe (Sherco) and urban (Black Dog) scenario sites:[253]

Xcel Geographic Study Area



120. Xcel included primary and secondary $PM_{2.5}$ in its study, attributing the effects of secondary $PM_{2.5}$ to SO_2 and NO_x as appropriate. In addition, Xcel included ozone, attributing its effects to NO_x emissions, because ozone "is formed in the atmosphere through a set of complex nonlinear photochemical reactions involving NO_x

[251] *Id.*
[252] *Id.* at 19, fn 8.
[253] Ex. 604 at 20 (Desvousges Direct) (arrow added to show Black Dog location).

and volatile organic compounds (VOCs)."[254] Xcel reported that the effects of all of these CPs were measured at the county level.[255]

121. To accomplish the air quality modeling, Xcel applied the CAMx model "for a year-long modeling period using hourly inputs" to create a baseline of modeled existing ambient concentrations.[256] Emissions inputs were based on data from the National Emissions Inventory (NEI).[257] According to Xcel, CAMx modeling "includes full-science chemistry and other algorithms to produce reliable estimates."[258] Xcel compared the results to observed ambient air quality data in a Model Performance Evaluation, and they compared well.[259] Xcel then applied CAMx again to estimate incremental changes in air quality based on Xcel's three hypothetical resource planning scenarios: urban, metropolitan fringe, and rural.[260]

122. According to Xcel, one hypothetical new coal-fired power plant was added to each of the three scenarios. Each hypothetical plant was modeled for each hour of the year to estimate changes in atmospheric chemistry over the baseline concentrations.[261] The locations for the three scenarios were at Black Dog (urban), Sherco (metropolitan fringe) and Marshall, Minnesota (rural). The generating units at each of these locations were assumed to have annual emissions and stack parameters identical to Xcel's Sherco Unit 1, based on 2014 operations data.[262]

123. The weather inputs used for Xcel's CAMx model were drawn from the Weather Research Forecast (WRF), a forecasting model developed by the National Center for Atmospheric Research (NCAR), and spans the year from October 1, 2012 through September 30, 2013, the most recent meteorological data available at the time.[263]

124. Xcel calculated air quality impacts separately for each of the three hypothetical energy generating units (EGU), using the CAMx O_3 and $PM_{2.5}$ source apportionment tools. CAMx produced hourly gridded concentrations for the 92 chemical species in the model's chemical mechanism, for 25 vertical layers in each of the 65 x 71x 12 km grid cells, for 24 hours a day, each day of the year. For each of the three scenarios, this resulted in approximately 93 trillion hourly concentrations.[264]

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[254] Ex. 604 at 16 (Desvousges Direct).
[255] *Id.*
[256] Ex. 604, WHD-1, Schedule 3 at 1 (Desvousges Direct).
[257] Ex. 604 at 17 (Desvousges Direct).
[258] *Id.*
[259] Ex. 604 at 17-18 (Desvousges Direct); Ex. 604, WHD-1, Schedule 3 at 1 (Desvousges Direct). Xcel states that, to the extent that the actual conditions differed from the modeled ambient concentrations, "CAMx was more likely to overstate baseline ambient concentrations, especially for ozone and PM 2.5." Ex. 604 at 18 (Desvousges Direct); *see also* Ex. 604, WHD-1, Schedule 2 at 16-24; Schedule 3 (Desvousges Direct) (detailed information regarding Xcel's testing of its CAMx modeling).
[260] Ex. 604 at 18 (Desvousges Direct); Ex. 604, WHD-1, Schedule 3 at 1 ((Desvousges Direct).
[261] Ex. 604 at 18 (Desvousges Direct).
[262] *Id.*
[263] Ex. 604, WHD-1, Schedule 3 at 3 (Desvousges Direct).
[264] Ex. 604 at 20 (Desvousges Direct).

B. Xcel's Approach to Non-Health Damages

125. Xcel relied on a willingness-to-pay approach to monetize damages for visibility and avoided soiling, as well as for improved levels of health (health damages are discussed in section C below). For agricultural damages, Xcel relied on two sets of five-year averages for productions and prices. Xcel used the replacement costs of materials for corrosion values.[265]

126. For its agricultural damages costs study, Xcel used EPA dose-response functions from the National Crop Loss Assessment Network (NCLAN) and W126, a cumulative exposure index.[266]

127. After considering the various effects of changes in crop yields on farmers, taxpayers and consumers, Xcel recommended estimating damages only with regard to the change in profits to farmers.[267] Taxpayers are relevant here because improving air quality could affect farm subsidies. Xcel acknowledged this is a conservative assumption, reflecting only an upper bound on air pollution damages. However, Xcel asserted that "the theoretical lower bound on damages is *negative*: improving air quality could induce farms to divert more resources to farming, exacerbating subsidies and the problem of agricultural surpluses."[268] Xcel concluded that, while the change in profits approach is reasonable to establish a high value for an agricultural damage range, the proper value to assume for the low end of the range is zero.[269]

128. Xcel reported it located no new empirical studies on pollution and visibility, so it relied on the approach it took in the First Externalities case, updating background visibility levels. Based on the updated calculations, Xcel recommended a value of $22.14 in 2014 dollars, per mile of visible distance.[270]

129. Xcel maintained that it also was unable to find a study more recent than the one it used in the First Externalities case "that provides a more credible estimate of soiling losses from $PM_{[2.5]}$."[271] After updating the soiling estimates for inflation, Xcel recommended a mean value of $5.26 and a standard error of $2.59 in 2014 dollars for soiling. Xcel included these estimates by county, along with the 2014 estimates of number of households.[272]

130. Xcel relied on a replacement cost approach for materials corrosion damages also used in the First Externalities proceeding. Because it is not based on a willingness-to-pay approach but instead only on the cost of replacing the materials, Xcel asserted that this damage cost approach is likely an overestimate of the value of reducing

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[265] *Id.* at 24.
[266] Ex. 604, WHD-1, Schedule 2 at 64-65 (Desvousges Direct).
[267] *Id.* at 67-69.
[268] *Id.* at 69.
[269] *Id.* at 70.
[270] *Id.* at 71.
[271] *Id.* at 72.
[272] Ex. 604, WHD-1, Schedule 2 at 72 (Desvousges Direct); *see also* Ex. 604, WHD-1, Schedule 2 at 75, Table 6.1.1 (Desvousges Direct).

corrosion losses. However, because Xcel failed to find a more appropriate study conducted since the First Externalities case, Xcel updated its information using that approach for this proceeding.[273]

C. Xcel's Approach to Health Impacts

131. Xcel asserted that it selected the studies on which it relied for this proceeding based on three criteria: scientific soundness, similarity, and richness of detail.[274] Xcel's stated goal was to use studies that matched "the needs for our damage cost study as closely as possible, and include sufficient information on population descriptions, central tendency measures, and variability."[275] Xcel relied on meta-analyses when it was feasible and preferred long-term cohort studies over short-term cross-sectional studies.[276]

132. Following an extensive literature search, Xcel decided to rely on a 2013 meta-analysis (*Hoek* study) for its long-term mortality study "that incorporates the results of the major cohort studies."[277] The *Hoek* study included 11 cohort studies which estimated "the excess risk to all-cause mortality associated with a 10 $\mu g/m^3$ increase in ambient concentrations of $PM_{2.5}$."[278] Xcel explained that the *Hoek* study's meta-analysis weighted each of the estimates to reflect the standard error of each one. In this way, studies with smaller standard errors were given more weight to reflect more statistical certainty in the risk results.[279]

133. Xcel also compared the *Lepeule* and *ACS* studies, and the summary statistics of a number of other studies, to the *Hoek* study's result.[280]

134. Xcel took steps to account for uncertainty in the literature by including values from the *ACS* study to indicate low, but not the lowest, risks[281] and from the *Lepeule* study[282] to represent high, but not the highest, risks, giving a weight of 12.5% to each.[283] Xcel assigned a weight of 75% to the *Hoek* study.[284] Xcel explained that it used the weights and the standard errors from each of the three studies to derive an overall distribution.[285] Representing the low and high ranges of values at the 25th and 75th

[273] Ex. 604, WHD-1, Schedule 2 at 72 (Desvousges Direct).
[274] Ex. 604 at 21 (Desvousges Direct).
[275] Ex. 604 at 21 (Desvousges Direct).
[276] *Id.* at 22.
[277] *Id.* at 23 (citing G. Hoek et al., *Long-Term Air Pollution Exposure and Cardio-Respiratory Mortality: A Review,* 12 Environmental Health 43 (2013)).
[278] Ex. 604, WHD-1, Schedule 2 at 36 (Desvousges Direct).
[279] *Id.* at 36-37.
[280] *Id.* at 36-38.
[281] *Id.* at 37.
[282] *Id.*
[283] *Id.*
[284] *Id.*
[285] *Id.*

percentiles of the distribution, Xcel's range of risk for a 10 μg/m^3 change in $PM_{2.5}$ extends from 5.3% to 7.3%, with 6.8% representing the mean.[286]

135. Xcel used a Monte Carlo analysis, randomly drawing thousands of times from its distribution of concentration response values to account for uncertainty to estimate health costs from premature mortality due to exposure to $PM_{2.5}$.[287]

136. Xcel considered the effects of O_3 separately and found relatively little literature on the subject.[288] In general, the mortality risks from O_3 exposure alone were much lower than the risks from exposure to $PM_{2.5}$. Xcel recommended a range from zero to 0.37% risk, with a 0.22% mean.[289]

137. Xcel also examined studies exploring morbidity as a result of air pollution. Its review revealed "outcomes associated with air pollution mostly involve effects on the respiratory system, but potential cardiovascular effects have also been noted."[290] For morbidity effects of $PM_{2.5}$, Xcel relied on two studies. One 'estimates the effect of $PM_{2.5}$ on sinusitis and chronic bronchitis in adults, the other on asthma in children."[291] Xcel reported that the studies it relied upon:

> found that $PM_{2.5}$ levels are positively associated with the incidence of sinusitis in adults with an increase in odds of 18 percent . . . for a 10 μg/m^3 increase in ambient $PM_{2.5}$ concentrations. Chronic bronchitis has an increase in occurrence of 8 percent . . . for a 10 μg/m^3 increase in $PM_{2.5}$. The authors did not find a positive relationship between $PM_{2.5}$ and asthma.[292]

138. Looking only at studies of children, Xcel concluded that the "effect of a 10 μg/m^3 increase in $PM_{2.5}$ on the risk of asthma in children is 24 percent . . . ."[293]

139. Xcel examined literature on morbidity effects of SO_2, NO_2, and O_3, concluding that such studies have wide-ranging and unpredictable results. Nonetheless, Xcel incorporated morbidity effects from all of the CPs, except O_3, that relate to sinusitis, chronic asthma, chronic bronchitis, and cardiovascular incidents.[294]

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[286] *Id.* at 37-38.
[287] Ex. 604 at 7 (Desvousges Direct).
[288] Ex. 604, WHD-1, Schedule 2 at 38 (Desvousges Direct).
[289] Ex. 604, WHD-1, Schedule 2 at 38-39 (Desvousges Direct).
[290] *Id.* at 41.
[291] *Id.* at 42.
[292] *Id.* at 43-44.
[293] *Id.* at 44.
[294] *Id.* at 44-46.

1. Mortality Damages: The VSL

140. Xcel noted that several important "reviews and discussions" of the VSL literature have been published since the First Externalities case, including Ashenfelter (2006), Viscusi (2012, and Viscusi and Aldy (2003).[295]

141. Xcel maintained that hedonic wage studies (one of two kinds of "revealed preference" studies) have two strong advantages over stated preference studies.[296] First, revealed preference studies "combine solid data on household wages with fairly objective data about on-the-job risks."[297] In addition, "they infer VSLs from people's actual tradeoffs between money and mortality risks in real-world decisions, making them especially credible."[298] Because of these advantages, Xcel maintains, "most empirical estimates of VSLs are based on hedonic wage studies, and most damage cost studies of air pollution rely on them."[299]

142. Xcel identified two issues with using the hedonic wage studies in the air pollution context. One issue is the age difference between most participants in the labor market and the ages at which they tend to face risks at work, as opposed to the ages of most people facing the largest risks of premature mortality as a result of air pollution, which tends to affect the elderly population.[300] Xcel asserted that evidence "is emerging that potentially would suggest" that adjustments should be made in the VSL analysis based on age differences.[301]

143. Xcel also questioned whether the nature of workplace risks and environmental risks are "qualitatively similar and whether people feel similarly about facing them."[302] Xcel theorized that, if one kind of risk engenders stronger feelings of dread or fear, people would be willing to pay more to avoid that risk than they would be to avoid a less dreaded risk of the same magnitude.[303] The implication of this is that workplace risks may feel more real. If that is true, and people are willing to pay more to avoid workplace risks, the VSL arising out of hedonic wage studies may be misleading.

144. Stated preference studies, according to Xcel, can either be contingent value studies which "describe a single scenario and elicit the WTP [willingness to pay] for that

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[295] *Id.* at 48 (citing W.K. Viscusi, *What's to Know? Puzzles in the Literature on the Value of Statistical Life,* 26 Journal of Economic Surveys, 763 (2012); W.K. Viscusi & J.E. Aldy, *The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World,* 27 Journal of Risk and Uncertainty, 5 (2003); and O. Ashenfelter, *Measuring the Value of a Statistical Life: Problems and Prospects*, 116 Economic Journal, C10 (2006)).

[296] Xcel refers to the other type of revealed preference study as a "consumer-market" study. These studies are the type of studies that rely on people's choice of cars with particular safety features, or a willingness to trade time and bother to wear seat belts, change batteries in a smoke detector, or wear a bike helmet. Ex. 604, WHD-1, Schedule 2 at 49 (Desvousges Direct).

[297] Ex. 604, WHD-1, Schedule 2 at 48 (Desvousges Direct).

[298] *Id.*

[299] *Id.*

[300] *Id.*

[301] *Id.* at 48-49.

[302] *Id.* at 49.

[303] *Id.*

scenario," or they can be "choice experiments" which provide a variety of scenarios with differing risk levels, costs, and possibly other factors, asking respondents to choose among the scenarios.[304] The VSLs are inferred based on the patterns of the respondents' choices, especially patterns regarding how respondents trade money for risk levels.[305] Xcel argued that stated preference studies are often used to measure values for things not traded in markets and can overcome some of the disadvantages of hedonic wage studies. They can focus on such things as environmental risks and avoid some of the unique features of the labor setting, such as workers' compensation and life insurance benefits, and can focus on specific populations, such as people who are older and less likely to be in the labor market.[306] On the other hand, stated preference studies have limited value because they are not real. People do not always do what they say they will do. In the stated preference study context, people do not have to bear the consequences of their actions. Therefore, according to Xcel, stated preference studies may be biased.[307]

145. Because Xcel found advantages and disadvantages to both revealed preference studies and to stated preference studies, it used both kinds of studies for its estimates of the VSL.[308]

146. Based on numerous studies, Xcel created a VSL distribution with a mean value of $5.9 million, and low and high values based on the 25th and 75th percentiles, of $4.1 and $7.9 million.[309]

D. Xcel's Approach to Uncertainty

147. Xcel expressed continued concerns about the uncertainty surrounding estimating effects of emissions on human health, agriculture and other impacts. In addition to unresolved issues regarding such questions as the effects of weather on crop yields, or atmospheric responses to emissions, Xcel mentioned, as examples, questions surrounding multiple emission sources and the ability of studies to control for individual risk factors.[310]

148. Xcel addressed the uncertainty involved in estimating damages from CP emissions in several different ways. Xcel selected meta-analyses whenever feasible, supplemented by individual studies that were more recent or to reflect variability or uncertainty. More precise studies, with smaller variances, were given greater weight in their combined results.[311]

149. Xcel concluded in this matter, as it did in the First Externalities proceeding, that a range, rather than a single point estimate, better reflects the variability in damage

[304] *Id.* at 49-50.
[305] *Id.* at 50.
[306] *Id.*
[307] Ex. 604, WHD-1, Schedule 2 at 50 (Desvousges Direct).
[308] *Id.*
[309] Ex. 604 at 24 (Desvousges Direct); *see also* Ex. 604, WHD-1, Schedule 2 at 50-59 (Desvousges Direct) (more thorough discussion of Xcel's calculation of its VSL values).
[310] Ex. 604 at 6-7 (Desvousges Direct).
[311] *Id.* at 7.

cost studies.[312] For each of its three scenarios (rural, metropolitan fringe and urban), Xcel based its high and low values on the 25th and 75th percentiles of the distribution. Xcel chose those percentiles as the high and low values based on its reasoning that the range strikes a balance which captures inherent uncertainty, a reasonable degree of risk tolerance and the statutory requirement for a practicable range.[313]

150. Xcel also subjected CAMx to model performance evaluations using EPA modeling guidance.[314] CAMx and WRF achieved commonly-used performance goals and criteria "a majority of the time," according to Xcel.[315] The CAMx base achieved the ozone model performance goal for bias and error 86% of the time at Minnesota ozone monitoring sites.[316] The "PM performance criterion for bias and error were achieved 93% of the time across monitoring sites in the Minnesota modeling domain."[317]

151. Xcel compared the CAMx daily maximum 8-hour O_3 and total $PM_{2.5}$ mass monthly model performance evaluations "against performance goals and criteria for monitoring sites in Minnesota and vicinity using Soccer Plots."[318] Xcel reported that the CAMx base case bias in daily maximum 8-hour ozone concentrations for the modeling year was -1.%, which achieves the EPA's ozone bias performance goal. Furthermore, Xcel asserts, the CAMx annual O_3 error was 10.1%, which is more than three times lower than the EPA's O_3 error performance goal. Xcel acknowledged that the ozone performance had an overestimation bias for the warmer months. In ten months the ozone bias performance goal was achieved (all months achieved the O_3 error goal). However, October and November had an overestimation bias that fell just outside of the O_3 bias performance goal, according to Xcel.[319]

152. Xcel reported the annual $PM_{2.5}$ bias was 18.3%, which achieves both the $PM_{2.5}$ bias performance goal and criterion. In addition, the $PM_{2.5}$ error, 38%, is below the $PM_{2.5}$ error performance goal of 50% and criterion of 75%. Xcel stated that the $PM_{2.5}$ performance Soccer Plot demonstrates that the CAMx $PM_{2.5}$ performance achieves the $PM_{2.5}$ performance criteria for all 12 months of the year, and the $PM_{2.5}$ performance goal for 8 months. Finally, Xcel maintained that failure to achieve the $PM_{2.5}$ performance goal was due to an overestimation bias.[320]

153. Xcel also reported that, based on EPA reviews of 69 PGM models that were published in peer-reviewed literature from 2006 to March, 2012, Xcel's CAMx base case performance for daily maximum 8-hour ozone concentrations in Minnesota was in the top

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[312] *Id.* at 8.
[313] *Id.* at 7.
[314] Ex. 604, WHD-1, Schedule 3 at 31-35 (Desvousges Direct).
[315] Ex. 604, WHD-1, Schedule 2 at 20 (Desvousges Direct).
[316] Ex. 604, WHD-1, Schedule 2 at 20 (Desvousges Direct).
[317] *Id.*
[318] *Id.* A Soccer Plot is a scatter plot of bias versus error, with the boxes representing model performance goals and criteria. *Id.*; *see also* Ex. 604, WHD-1, Schedule 3 at 3-4 (Desvousges Direct) (more detailed explanation of the Soccer Plot and modeling).
[319] Ex. 604, WHD-1, Schedule 2 at 20 (Desvousges Direct).
[320] *Id.* at 20 – 21.

10 percentile and the $PM_{2.5}$ performance was in the top 50 percentile of model simulations in the study.[321]

154. Based on these performance results, Xcel concluded that "the CAMx modeling system is an accurate and reliable tool for estimating the air quality impacts associated with the hypothetical EGUs. If anything, the model sometimes has a slight overestimation bias for both ozone and $PM_{2.5}$ concentrations, which suggest the model may produce conservative results for the EGU air quality impact assessment (i.e., tending toward overestimating the EGU air quality impacts)."[322]

E. Xcel's Recommended Values

155. Xcel provided its recommended ranges for $PM_{2.5}$, SO_2, and NO_x for its rural, metropolitan fringe, and urban scenarios:[323]

Recommended Environmental Values (per short ton, 2014 dollars)

Emission	Rural			Metro-Fringe			Urban		
	Low	Median	High	Low	Median	High	Low	Median	High
$PM_{2.5}$									
$/ton	3,437	6,220	8,441	6,450	11,724	16,078	10,063	18,305	25,137
NOx									
$/ton	1,985	4,762	6,370	2,467	5,352	7,336	2,760	5,755	7,893
SO_2									
$/ton	3,427	6,159	8,352	4,543	8,245	11,317	5,753	10,439	14,382

156. The high and low recommended values are based on the 25th and 75th percentiles of the distribution. The median represents the 50th percentile.[324]

157. Xcel acknowledged that its recommended values in this proceeding are "significantly higher" than the values it proposed and that were established by the Commission in the First Externalities proceeding. It reasoned that this is because of significant advances in the scientific understanding of possible effects of fine particulate matter on human health.[325] Specifically, Xcel noted that there are new and improved

[321] *Id.* at 21.
[322] *Id.*
[323] Ex. 604 at 6 (Desvousges Direct).
[324] *Id.* at 5.
[325] *Id.* at 6.

studies available on premature mortality risks that rely on long-term-cohort methodologies. Xcel contrasted this to the time of its original study in the First Externalities proceeding in which only the short-term health effects of PM_{10} were estimated. In addition, according to Xcel, meta-analyses on epidemiological and economic studies are now more common, making it easier to rely on a large number of studies. Finally, Xcel pointed out that photochemical grid modeling, enhanced computer systems and the software needed to run the complex models have all become available since the First Externalities proceeding.[326]

158. Xcel provided data from the MPCA showing that aggregate CP emissions in Minnesota have declined significantly since 1997.[327] Nonetheless, damage costs are higher now, according to Xcel, because CAMx measures chemical transformations in the atmosphere more accurately than the tools Xcel had available during the First Externalities case, Xcel could draw on the new, long-term, large-population studies, and the geographic area of this study is larger than the area of the earlier study.[328]

159. Xcel asserted that the increase in damages in its current investigation has occurred "despite significant reductions in power sector emissions and improvements in air quality since that time" and that the majority of the increase in the damage values "is potential costs associated with premature mortality, attributable mainly to particulate matter, which in some scenarios accounts for 90 percent of the potential externality cost."[329]

160. Xcel maintained that its damage costs likely overestimate the actual environmental cost values for CPs because Xcel did not adjust for age at all for mortality risks, it only adjusted agricultural impacts on the low end of the range, and it included cost of illness measures for some morbidity effects. Xcel also located a hypothetical generating plant in an urban setting. In addition, Xcel claimed that the CAMx model, while reliable, overstates actual $PM_{2.5}$ and ozone concentrations.[330]

[326] *Id.* at 11-12.
[327] *Id.* at 12.
[328] *Id.* at 13.
[329] Ex. 604 at 6 (Desvousges Direct).
[330] *Id.* at 8.

161. Xcel provided a table of its CP externality costs by potential effects, per short ton, in 2014 dollars:[331]

	RURAL			METRO FRINGE			URBAN		
$PM_{2.5}$	**Low**	**Median**	**High**	**Low**	**Median**	**High**	**Low**	**Median**	**High**
Mortality	3,351	5,927	7,653	6,261	11,072	14,297	9,762	17,264	22,291
Morbidity	53	219	671	121	497	1,537	194	796	2,459
Soiling	10	51	94	20	107	196	32	169	310
Visibility	23	23	24	47	48	49	75	76	77
Sub-Total	**3,437**	**6,220**	**8,441**	**6,450**	**11,724**	**16,078**	**10,063**	**18,305**	**25,137**
NOx									
Mortality	1,933	4,117	5,422	2,394	4,897	6,424	2,674	5,344	6,994
Morbidity	32	132	410	48	189	613	58	153	604
Agriculture	-	470	470	-	209	209	-	195	195
Soiling	6	30	55	7	39	71	8	44	80
Visibility	13	13	14	17	18	18	19	20	20
Sub-Total	**1,985**	**4,762**	**6,370**	**2,467**	**5,352**	**7,336**	**2,760**	**5,755**	**7,893**
SO_2									
Mortality	3,322	5,875	7,586	4,384	7,753	10,011	5,533	9,785	12,635
Morbidity	58	165	572	94	368	1,122	129	487	1,502
Materials	6	6	6	18	18	18	33	33	33
Soiling	17	90	164	14	72	133	18	93	170
Visibility	23	23	24	32	33	33	41	42	42
Sub-Total	**3,427**	**6,159**	**8,352**	**4,543**	**8,245**	**11,317**	**5,753**	**10,439**	**14,382**

V. Criticisms of and Responses to Parties' Models and Recommended Externalities Values

A. Xcel's Criticisms of and Responses to Agencies' Recommendations

162. Xcel criticized the AP2 model on the basis that it relies on outdated science and data that come from varying time periods. Its meteorological data comes from 1990 and is based on annual averages, while its emissions data comes from 2011. Its air quality dispersion model approach was developed in 1973.[332] In addition, the wind speed and direction used to model the transport of the model's plume from source to receptor are assumed to be constant. [333] Xcel explained that, in the AP2 model, for each of 16 cardinal directions "a single annual average wind speed and direction is used to transport the

[331] *Id.* at 27.
[332] Ex. 606 at 5 (Desvousges Rebuttal).
[333] *Id.*

plume from the source to receptors far downwind (e.g., Florida), when in reality wind speeds and direction are continuously changing both temporally and spatially."[334] Thus, Xcel concluded, the AP2 model "cannot accurately simulate the transport and dispersion of emissions."[335]

163. The Agencies responded that the positive correlation between the AP2 predicted annual average $PM_{2.5}$ and monitor data, which is a greater positive correlation than the parallel CAMx correlation, demonstrates that the 1990s historical average weather data "is not fundamentally problematic."[336] The Agencies asserted that, while daily weather varies significantly, it is much less variable year-to-year.[337]

164. Xcel rejected AP2's modeling of O_3 and secondary $PM_{2.5}$ on an annual rather than hourly basis, noting that annual modeling is inconsistent with the ability to model the chemical and physical processes that form O_3 and secondary $PM_{2.5}$. Xcel stated that the EPA, which has used the reduced form air quality modeling approach in the past, no longer accepts that approach as credible.[338] Xcel pointed to the EPA's most recent modeling guidelines in this regard:

> The EPA has determined that advances in photochemical model science indicate it is now reasonable to provide more specific, generally-applicable guidance that identifies particular models or analytical techniques that may be used under specific circumstances for assessing the impacts of an individual source on ozone and secondary $PM_{2.5}$. Quantifying secondary pollutant formation requires simulating chemical reactions and thermodynamic partitioning in a realistic chemical and physical environment.[339]

165. Xcel claimed that the AP2 model failed to account for the fact that O_3 and secondary $PM_{2.5}$ vary significantly, seasonally and daily. Xcel provided the example that O_3 and secondary sulfate $PM_{2.5}$ are higher in summer but secondary nitrate $PM_{2.5}$ is higher during colder periods.[340]

166. The Agencies argued that, in the AP2 model, mortality concentration responses are measured using annual data. Therefore, it is appropriate to use annual numbers as inputs to calculate those responses.[341] Furthermore, the Agencies argued, they are not aware of anything in the air-quality modeling literature that speaks to the

[334] *Id.* at 34.
[335] *Id.*
[336] Ex. 811 at 3 (Muller Surrebuttal).
[337] *Id.* at 3-4.
[338] Ex. 606 at 36 (Desvousges Rebuttal).
[339] Ex. 606 at 35 (Desvousges Rebuttal).
[340] *Id.* at 34.
[341] Ex. 811 at 4 (Muller Surrebuttal).

question of whether annual estimations are inappropriate.[342] It is model performance that is most important, the Agencies emphasized.[343]

167. Xcel claimed that, by modeling a plant that emits each pollutant in isolation from the other pollutants, the AP2 model overestimates the impacts of SO_2 and secondary $PM_{2.5}$ formation. [344] Xcel asserted that this is because, in plumes where there are high concentrations of NO_x, the NO_x will suppress O_3 and $PM_{2.5}$ formation near the source. Xcel maintained that, when pollutants are modeled in isolation from one another, $PM_{2.5}$ impacts from SO_2 are overestimated. [345] Xcel explained that another concern with modeling the release of SO_2 and NO_x separately is because NO_x emissions are involved in the formation rate of sulfate, and ammonia preferentially bonds with sulfate over NO_x. If NO_x and SO_2 emissions are modeled separately "the amount of particulate nitrate formed will be overstated due to increased ammonia availability that would have bonded with SO_4 if SO_2 emissions were modeled simultaneously."[346] Therefore, according to Xcel, modeling pollutants separately is not appropriate in this context. [347]

168. The Agencies replied that modeling individual pollutants separately is not only appropriate, it is an approach that is commonly used in the field.[348]

169. Xcel disagreed with the Agencies' choice to combine differing kinds of sources to model. The Agencies modeled a number of existing power plants, along with a hypothetical power plant for those counties where there is no actual power plant located. Therefore, Xcel claimed, some counties have values based on a hypothetical facility, some have values based on an actual existing facility (named or not named), and the six counties where the named facilities are located have values based on both the named facilities and a second actual, or hypothetical, facility. These inconsistencies, argued Xcel, lead to confusion and to inaccurate comparisons.[349]

170. The Agencies disagreed that the combination of facilities modeled will lead to confusion. The hypothetical costs, according to the Agencies, are for the purpose of "prospectively determining what the impacts would be if a plant were located there." The individual modeling for existing plants is to "capture the externality values for some of the largest emitters in the state . . . and [because] it would be erroneous to assume that these specific plants would be representative of other plants in the county . . . ."[350] Because these values "represent the environmental cost from emissions produced by different entities" the Agencies claimed that there is no problem with providing both sets of values.[351]

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[342] *Id.* at 5.
[343] *Id.*
[344] Ex. 606 at 5 (Desvousges Rebuttal).
[345] *Id.* at 38.
[346] *Id.* at 39.
[347] *Id.*
[348] Ex. 811 at 27-28 (Muller Surrebuttal).
[349] Ex. 606 at 5-6, 41 (Desvousges Rebuttal).
[350] Ex. 811 at 21-22 (Muller Surrebuttal).
[351] *Id.* at 22.

171. Xcel maintained that the Agencies' modeling of hypothetical plants for its county-by-county analysis failed to take into account the manner in which the dispersion of emissions is affected by factors such as "stack height, stack diameter, stack gas exit velocity, local topography, adjacent buildings, mixing in the stack of other pollutants and hourly varying temperature and wind speed."[352]

172. The Agencies countered that, if these arguments by Xcel were valid, then Xcel's modeling of only three source locations could not provide adequate detail to "represent all of the variation in local factors that would matter for all of the existing power plants in Minnesota."[353] Thus, Xcel's criticism of the Agencies' lack of localized factors is inconsistent with Xcel's own modeling.[354]

173. Xcel pointed out that the Agencies' values for the hypothetical plants were much higher than for the named, specific plants, even where the two are in the same county. This is especially significant for the higher end of the Agencies' values, according to Xcel, which claimed that the Agencies' $PM_{2.5}$ values for hypothetical plants are four times higher than those based on the six named plants.[355]

174. The Agencies asserted that the hypothetical plants had higher cost values than the six named plants because they are modeled to have lower effective heights than the six named plants. The reason for this is because the Agencies' hypothetical plants are modeled to correspond to most plants other than the six named plants. Because a lower effective height generally corresponds to a shorter smokestack, it means that, all else being equal, the change in air quality will be larger.[356]

175. Xcel pointed out that the Agencies' recommended values are many times higher than the Agencies' witness, Dr. Muller, previously published for Minnesota counties in an earlier study, using similar methods and models.[357] Specifically, Xcel alleged that $PM_{2.5}$ damages are an average of almost 28 times higher in the instant proceeding, SO_2 damages 11 times higher, and NO_x damages twice as high as those calculated in Dr. Muller's previous study.[358]

176. The differences between the two studies, according to the Agencies, are that the earlier (2009) study "used very different assumptions than the present analysis."[359] For example, the 2009 study used a $2 million VSL, expressed in year-2000 dollars, and adjusted for the age of the exposed population. In addition, the Agencies noted that the air quality model for the 2011 version of AP2 results in "somewhat higher impacts on ambient concentrations than earlier versions of the model."[360]

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[352] Ex. 606 at 38 (Desvousges Rebuttal).
[353] Ex. 811 at 29 (Muller Surrebuttal).
[354] *Id.*
[355] Ex. 606 at 6 (Desvousges Rebuttal).
[356] Ex. 811 at 22 (Muller Surrebuttal).
[357] Ex. 606 at 6 (Desvousges Rebuttal).
[358] *Id.*
[359] Ex. 811 at 23 (Muller Surrebuttal).
[360] *Id.* at 23-24.

177. Xcel challenged the Agencies' performance evaluations of AP2 on several grounds. First, Xcel argued that the Agencies' results, which are based on annual $PM_{2.5}$ averages, cannot be properly evaluated using performance goals and criteria developed for daily average $PM_{2.5}$ visibility observations as the Agencies did.[361] Given that the Agencies applied values designed for evaluating daily averages to annual average values, Xcel maintained that it would be reasonable to expect a lower error rate on an annual basis. Xcel reasoned that this is because there is a lower variability in annual averages that do not include the variations that would be part of a model based on daily average $PM_{2.5}$ concentrations.[362] Second, Xcel asserted the Agencies performance evaluations were flawed because they did not include any graphical displays of model performance. Third, Xcel disputed the validity of the Agencies' comparison to CAMx because: a) the Agencies' CAMx data was presented in an annual average by grid and county; b) the CAMx run was conducted by the EPA rather than the Agencies; c) CAMx results were not analyzed separately, based on distance from the source (within or beyond 50 kilometers); and d) the Agencies did not compare marginal changes in ambient concentrations, they only compared absolute levels of ambient concentrations.[363] Finally, Xcel alleged that the AP2 performance evaluation is not and cannot be meaningful because of the temporal inconsistency between the period from which meteorological data was drawn (1990) and the period from which annual emissions data were taken (2011).[364]

178. The Agencies countered that annual and seasonal averages comprise the degree of temporal resolution that "matters most for this proceeding" because the $PM_{2.5}$ mortality concentration-response functions are defined in terms of annual average levels. Thus, the Agencies reasoned, annual and seasonal averages are appropriate under the Boylan and Russell evaluation model guidance as well.[365] The Agencies reiterated this argument in response to Xcel's criticism of the Agencies' comparison between AP2 and CAMx for 2011.[366] The fact that the performance evaluation showed that AP2 performed as well as CAMx, which was calibrated to use 2011 weather and emissions data, supports the Agencies' argument that annual average weather patterns have not significantly changed since 1990, according to the Agencies.[367]

179. Xcel argued that EPA guidance limits the scope of a reduced form model, such as the AP2, that employs an air-quality model component using a steady-state Gaussian plume model formulation.[368] According to Xcel, EPA air quality modeling guidelines state that, when "relying on a steady-state Gaussian plume model, such as AP2, [it] is appropriate . . .when modeling impacts from a source to receptors located up to 50 kilometers away . . . ."[369] Contrary to the EPA guidance, the Agencies "used the

[361] Ex. 606 at 6-7 (Desvousges Rebuttal).
[362] *Id.* at 52.
[363] *Id.* at 6-7, 53-54.
[364] *Id.* at 51.
[365] Ex. 811 at 2-3 (Muller Surrebuttal).
[366] *Id.* at 4.
[367] *Id.*
[368] Ex. 606 at 19 (Desvousges Rebuttal).
[369] *Id.* at 21.

AP2 model to disperse emissions across the entire contiguous United States . . . ."[370] Xcel warned that the EPA's 50 kilometer limit is "because of gross overestimation bias at further downwind distances . . . ."[371]

180. In response to Xcel's comments about the Agencies' use of AP2 to model beyond 50 kilometers, the Agencies argued, in the first instance, that they were required by the Commission to use a reduced form model.[372] Beyond that, the Agencies claimed that the model would not have generated results that stood up to comparisons with CAMx if it were producing unreliable estimates beyond 50 kilometers. To the extent that Xcel claimed it was inappropriate for the Agencies to estimate damages outside of Minnesota because they are using a reduced form model, the Agencies challenged Xcel's unwillingness to model damages beyond the limited geographic scope Xcel chose, despite the ability of CAMx to model those impacts.[373] The Agencies chided Xcel for citing EPA guidance in this respect while failing to follow the EPA's approaches to the choice of VSL and concentration-response parameters.[374]

181. Based on comparisons between its own modeling results and the Agencies' results in the same counties where Xcel's hypothetical power plants are located, Xcel raised additional questions about the Agencies' approach and recommendations. Xcel noted that the Agencies' modeling of their Lyon County source produced changes in ambient $PM_{2.5}$ concentrations based on NO_x emissions in only 25 out of Minnesota's 87 counties and no increase in the majority of Minnesota counties. At the same time, the Agencies' modeling did show increases from Minnesota NO_x emissions in $PM_{2.5}$ concentrations in California, Arizona, Maryland, New Jersey, Florida, Utah, and Nevada.[375] The Agencies' modeling of their Sherburne County source demonstrated "essentially no impact on secondary $PM_{2.5}$ concentrations in Sherburne County as well as in some adjacent counties."[376] Xcel's own CAMx modeling of its Sherco plant indicated the highest secondary $PM_{2.5}$ in Sherburne County, and concentrations decreasing with distance.[377]

182. The Agencies challenged Xcel's comparisons on three bases. First, the Agencies claimed that Xcel's criticisms were focused mostly on NO_x emissions changes, and that NO_x is the least significant of the CPs in terms of damages. The Agencies reiterated its rebuttal testimony that "the population exposures predicted by [Xcel's] runs of CAMx and [the Agencies'] runs of AP2 are nearly perfectly positively correlated for $PM_{2.5}$ and SO_2, and strongly correlated for NO_x."[378] Therefore, the Agencies concluded, "in areas with large populations, the predictions of the two models are very much alike."[379] In addition, the Agencies maintained that Xcel failed to include population exposure in its

[370] *Id.*
[371] *Id.* at 22.
[372] Ex. 811 at 6 (Muller Surrebuttal).
[373] *Id.* at 15.
[374] *Id.* at 6.
[375] Ex. 606 at 7, 56 (Desvousges Rebuttal).
[376] *Id.* at 7.
[377] *Id.* at 7, 57-58.
[378] Ex. 811 at 7 (Muller Surrebuttal).
[379] *Id.*

calculations. The Agencies argued that population-weighted exposure is critical in this context because human health effects are such a significant portion of the damage cost.[380] Finally, Xcel was limited in its evaluation to its own three source locations, leaving it at a significant disadvantage in analyzing the spatial pattern of the impacts of NO_x emissions.[381] The Agencies again referred to their model performance tests, contending that "in Minnesota . . . the AP2-predicited total $PM_{2.5}$ levels were just one percent lower than CAMx predictions."[382] The Agencies asserted that, for NO_x, their predicted levels of ammonium nitrate were, on average, 16% lower than CAMx's ammonium nitrate levels in Minnesota and that these differences are "very small."[383]

183. Specifically addressing the question of AP2's estimate of no change in $PM_{2.5}$ levels in some Minnesota counties, the Agencies claimed that these results reflect low levels of ambient ammonium in those counties. NO_x requires ambient ammonium to form ammonium nitrate, which is required to form $PM_{2.5}$.[384]

184. The Agencies emphasized that the EPA's work with the Cross State Air Pollution Rule (CSAPR) demonstrates that the CAMx model can predict impacts from NO_x emissions on ambient $PM_{2.5}$ from Minnesota EGUs to places as far away as Colorado, Connecticut, Wyoming, Florida, and Texas.[385]

185. Because the Agencies modeled based on the marginal emission of just one ton of each pollutant, Xcel questioned the validity of the Agencies' estimates, which calculate marginal changes in $PM_{2.5}$ concentration to the hundredth thousandth's in micrograms per cubic meter.[386] Xcel argued that this level of detail essentially renders the estimates meaningless because, accounting for population density and taking uncertainty into consideration, "[i]t is feasible to say that each and every county receives somewhat the same impact" of increased $PM_{2.5}$ concentration.[387]

186. Xcel criticized the Agencies' choice of a VSL for several reasons. First, Xcel disagreed with the Agencies' decision to use the mean values from two studies for the high and low ends of a range for the VSL in contrast to Xcel's use of a Monte Carlo approach to incorporate data from three different meta-analyses.[388] Xcel also challenged the Agencies' choice of the EPA value for its high-end number, claiming that the EPA value is based on outdated studies. Xcel maintained that the *Viscusi and Aldy* study (*Viscusi*) on which it relied is both more recent and more comprehensive.[389] Finally, Xcel argued that the Agencies' low-end number was based on a subset of the *Kochi* study,

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[380] *Id.*
[381] *Id.*
[382] *Id.* at 8.
[383] *Id.*
[384] *Id.* at 9.
[385] *Id.* at 10.
[386] Ex. 606 at 39-40 (Desvousges Rebuttal).
[387] *Id.* at 40.
[388] *Id.* at 46-47.
[389] *Id.* at 47.

which included only results of stated-preference studies and completely disregarded the *Mrozek and Taylor* study, which offers lower VSL estimates than most other studies.[390]

187. The Agencies countered that their VSLs are drawn from meta-analyses, and the suggestion that they only used two studies is misleading. The Agencies noted that Xcel's VSL falls within the Agencies' recommended range and that the Agencies' upper bound is the same VSL that the EPA has often used.[391] The Agencies maintained that they intentionally chose a VSL that reflects only stated preferences for the lower bound of their range because the VSL at the upper bound reflects revealed preferences. In this way, the Agencies asserted they reflected both kinds of VSL measurements.[392]

188. Xcel disagreed with the Agencies' approach to updating the CP externality values. In addition to questioning the accuracy of the Agencies' underlying numbers, Xcel challenged the Agencies' decision to update their values by projecting changes in population and mortality rates but holding emissions constant.[393]

B. Xcel's Criticisms of CEOs' Recommendations

189. Xcel expressed concern about the InMAP model because it understands the model to still be in the developmental phase, and not complete.[394]

190. In Xcel's view, InMAP is a very unusual model, unlike other models generally used to estimate changes in ambient air quality and its costs. InMAP "does not fall into any EPA model category."[395] Xcel pointed out that InMAP has not demonstrated that it can reproduce either the observed ambient air quality concentrations or marginal changes which are expected of air quality models. Furthermore, Xcel reported that the CEOs applied two calibration factors in order to correlate InMAP results well with WRF-Chem results.[396]

191. Xcel acknowledged that InMAP models pollutants simultaneously. Furthermore, InMAP models emissions as an area source rather than a point source, the usual method for this kind of analysis.[397] Xcel explained that impacts from area sources, which are typically low-level sources emitting over a large geographic area with little or no plume rise, cover a greater area but with smaller ambient increases than point sources, such as a stack at an EGU from which flue gas is released. Point source impacts are more highly localized and impact smaller areas but in higher concentrations, according to

[390] *Id.* at 47-48 (citing J.R. Mrozek & L.O. Taylor, *What Determines the Value of Life? A Meta-Analysis,* 21 Journal of Policy Analysis and Management, 253 (2002)).
[391] Ex. 811 at 16 (Muller Surrebuttal).
[392] *Id.* at 17.
[393] Ex. 606 at 61 (Desvousges Rebuttal).
[394] *Id.* at 62.
[395] Ex. 606 at 62 (Desvousges Rebuttal).
[396] *Id.* at 62-63.
[397] *Id.* at 63.

Xcel.[398] Xcel maintained that, by modeling as an area source, InMAP overstates the O_3 and $PM_{2.5}$ impacts, producing inaccurate results.[399]

192. The CEOs corrected Xcel, stating that they modeled generic values as a point source "based on a weighted average of damages from emissions at the point locations of existing power plants."[400] The county-by-county emissions were modeled as area sources. The reason for this, the CEOs explained, is because the area source assumes a future power plant is "equally likely to be sited anywhere within the county."[401] The CEOs claimed that modeling as an area source is not likely to have a major effect on the impact of the emissions modeling, and that Xcel failed to present any evidence to the contrary.[402]

193. Xcel argued that the CEOs' three stack height approach provides a misleading impression of accuracy and specificity, when the results of the InMAP modeling are the opposite.[403] Given the other inaccuracies and uncertainties that Xcel claimed the CEOs introduced into their modeling process, the three stack height approach "only serves to increase the uncertainty of the values making them further impracticable for valid application."[404]

194. Xcel asserted that InMAP's use of annual average wind speed, direction and turbulence data, which it derives from averaging a year's output of hourly WRF-Chem model data, fails to account for seasonal and daily variations in O_3 and $PM_{2.5}$ formation. According to Xcel, the CEOs' use of annual meteorological data causes inaccuracies in the valuation process.[405] Xcel theorized that the CEOs' reliance upon annual, rather than hourly, meteorological data has a "large impact" on the modeling outcomes, resulting in overestimates in ambient concentrations to the east, and underestimates to the west.[406]

195. Xcel determined that the results from the CAMx modeling runs of several of its facilities were "significantly different" than the CEOs' results, as well as from the Agencies' results.[407] Xcel focused on the CEOs' reliance on annual meteorological data which tends to over-emphasize winds blowing from west to east. Xcel maintained that, if the CEOs' model were more realistic in modeling winds blowing to some extent from east to west, "ambient concentrations would be more dispersed . . . ."[408] Xcel asserted that "this is significant in that where the increased ambient concentrations occur is pivotal in the calculation of impacts."[409]

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[398] *Id.* at 63-64.
[399] *Id.* at 64.
[400] Ex. 119 at 22 (Marshall Surrebuttal).
[401] *Id.*
[402] *Id.* at 22-23.
[403] Ex. 606 at 65 (Desvousges Rebuttal).
[404] *Id.*
[405] *Id.* at 66.
[406] *Id.* at 9.
[407] *Id.*
[408] *Id.*
[409] *Id.* at 9-10.

196. The CEOs acknowledged that the use of annual rather than hourly meteorological data renders InMAP's illustration of pollutant transport to be "less realistic than a well-configured CAMx simulation . . . ."[410] But the CEOs insisted that the advantage of the reduced form model – the ability to explore the impact of plant location on damages – is much more important to predicting air-pollution-related damages from power plants than the hourly or daily weather specifics. This is because plant location is a larger source of variability than choice of air quality model, according to the CEOs.[411]

197. Xcel disagreed with the CEOs' reliance on a single study to estimate the risk of premature mortality, and especially with using the point estimate from that study. While recognizing that the Lepeule study is an important and recent study, Xcel claimed that, as analyzed by the CEOs, it provided an estimate more than twice as high as the mean value from the Hoek study included in Xcel's analysis.[412]

198. The CEOs asserted that they relied on both Lepeule and Krewski to arrive at their concentration response recommendation.[413]

199. Xcel criticized the performance evaluation of InMAP on several bases, including that InMAP results were compared to results for 11 WRF-Chem control scenarios. These scenarios were developed for measuring emissions from mobile sources, which are very different in nature from EGUs.[414]

C. Xcel's Criticisms of Agencies' and CEOs' Recommendations

200. Xcel criticized both the InMAP and AP2 models because they had not completed the peer-review process as of the time of this proceeding.[415]

201. The CEOs stated that InMAP should be judged based on its model performance and accuracy, not on the fact that it is a new model.[416]

202. Xcel disagreed with the Agencies' and CEOs' choice to model sources for every county within Minnesota, plus sources and source locations for each county within 200 miles of Minnesota's borders, for a total of almost 500 sources. Xcel estimated that, because the reduced form model requires separate runs for $PM_{2.5}$, SO_2, and NO_x, the Agencies are required to run the AP2 model at least 1,500 times, or 3,000 times including the additional runs necessary to develop the low- and high-ends of the Agencies' proposed ranges.[417] According to Xcel, the CEOs had to do approximately 4,500 model runs for each end of their range, because in addition to each pollutant, the CEOs did separate model runs for each of three stack heights. Therefore, Xcel presumed the CEOs

[410] Ex. 119 at 23 (Marshall Surrebuttal).
[411] Ex. 119 at 24 (Marshall Surrebuttal).
[412] Ex. 606 at 74 (Desvousges Rebuttal).
[413] Ex. 119 at 16 (Marshall Surrebuttal).
[414] Ex. 606 at 9 (Desvousges Rebuttal).
[415] *Id.* at 23. Xcel also alleged that InMAP and AP2 are considered trade secret and not publicly available, but that changed by the time of the evidentiary hearing. *See* Tr. Vol. 6 at 125 (Marshall).
[416] Ex. 119 at 25-26 (Marshall Surrebuttal).
[417] Ex. 606 at 24 (Desvousges Rebuttal).

were required to do approximately 9,000 model runs to arrive at their recommended CP cost values.[418]

203. The Agencies responded that it is necessary to model sources outside the state if the Commission wishes to know what the impacts are from emissions produced outside the state. The Agencies maintained that it is insufficient to presume that a rural location in Minnesota will "accurately represent impacts from out-of-state sources."[419] Such an approach arises out of the use of the cumbersome CAMx model because CAMx cannot practically be used to run many separate sources, according to the Agencies.[420]

204. The Agencies suggested three different approaches to using the cost values for their out-of-state sources. One would be to calculate the average environmental cost by pollutant for all out-of-state sources. A second approach would be to subdivide the out-of-state sources into quantiles. The third suggestion the Agencies made would be to group the out-of-state sources based on land use – rural, metro-fringe, or urban.[421]

205. Xcel agreed that, when such a large number of model runs are required, a reduced form model is needed to conduct the runs in a timely fashion. Xcel maintained that, by choosing to make so many model runs, the Agencies and CEOs traded speed for accuracy.[422] However, Xcel strongly disagreed that there is any "reasonable justification or need to estimate county-by-county values for SO_2, NO_x and $PM_{2.5}$."[423] Xcel speculated that the Agencies and CEOs "spent more time and resources to calculate the values for out-of-state sources than for Minnesota sources."[424]

206. Xcel attacked the Agencies' and CEOs' county-by-county damages approach because, in addition to being burdensome to develop, Xcel claimed the approach gives a false illusion of precision and accuracy, and is a departure from the precedent established by the Commission in the First Externalities case.[425] Xcel maintained that the process of developing CP damage costs "is inherently uncertain, and depends on the accuracy of the models as well as the modeling parameters chosen, such as characteristics of emissions sources, meteorological data, estimation of mortality and morbidity risk, and estimation of VSL."[426] Because of the subjectivity required in the selection of inputs made by the modeler, and because the outputs depend on the subjectively chosen inputs, Xcel argued that "uncertainty is compounded with each choice made."[427] By using their less-accurate reduced form model, the Agencies and CEOs have compounded that uncertainty, Xcel claimed.[428] Xcel pointed out that the Commission established the three-tiered urban, metropolitan fringe, and rural structure

[418] *Id.* at 24-25.
[419] Ex. 811 at 26 (Muller Surrebuttal).
[420] *Id.* at 26-27.
[421] *Id.* at 26.
[422] Ex. 606 at 25 (Desvousges Rebuttal).
[423] *Id.*
[424] *Id.* at 31.
[425] *Id.* at 26.
[426] *Id.*
[427] *Id.*
[428] *Id.*

for CP values in the First Externalities case, applying it to all locations within Minnesota as well as to locations within 200 miles of the state border. Xcel asserted that that structure is now established Commission precedent which has been used for nearly 20 years and that the Agencies and CEO failed to articulate a basis to change this "well-functioning, long-standing practice."[429]

207. The CEOs responded that the county-by-county values will be easily referenced by the Commission as needed based on the location of an existing or proposed emission source. This would alleviate the need for the Commission to determine whether a particular emission source should be categorized as urban, metro-fringe, or rural. The CEOs' recommendations provide generic values for the occasions when the county is unknown. The CEOs disagreed that geographically-specific values compound uncertainty. Unlike the Agencies, the CEOs did not agree that their values fit easily into Xcel's three-tiered categories. The CEOs asserted that an attempt to group the values in that way results in a loss of information.[430]

208. Xcel challenged the Agencies' and CEOs' proposals to base CP values on potential damages across the contiguous U.S. for three primary reasons. First, Xcel asserted that estimating damages on a national scale is a significant departure from the precedent the Commission established in the CP portion of the First Externalities case.[431] Second, Xcel argued that "it is widely recognized that unlike damages from CO_2, impacts from SO_2, NO_x, and $PM_{2.5}$ are mostly regional and local in nature."[432] In addition, Xcel maintained that the federal government has addressed the issue of interstate transport of pollution through its own regulatory requirements and that Minnesota's compliance with the federal requirements demonstrates that it is "not significantly contributing to ambient air concentrations" of CPs in other states.[433] Finally, Xcel challenged the capacity of AP2 or InMAP to estimate changes in ambient air concentrations across the contiguous U.S. In addition to the concerns regarding the AP2 model to predict ambient concentrations beyond a 50 kilometer range, Xcel argued that InMAP "skews changes in ambient concentrations to the east based upon annual meteorological data and has results significantly higher than those obtained by [Xcel's and the Agencies'] modeling. . . ."[434]

209. The Agencies denied that there is any basis in either "the literature or policy context" for the claim that impacts from the CPs are mostly regional and local.[435] The Agencies referred to the EPA's reporting on the effect of emissions from Minnesota on ambient concentrations across the country, noting the CAMx, as run by the EPA, predicted impacts from NO_x from Minnesota on ambient $PM_{2.5}$ in Colorado, Connecticut, Wyoming, Florida, and Texas, among other states.[436] Furthermore, the Agencies computed and prepared a spreadsheet showing "the total change in $PM_{2.5}$ associated

[429] *Id.* at 27.
[430] Ex. 119 at 20-22 (Marshall Surrebuttal).
[431] Ex. 606 at 27-28 (Desvousges Rebuttal).
[432] *Id.* at 28.
[433] *Id.* at 29.
[434] *Id.*
[435] Ex. 811 at 24 (Muller Surrebuttal).
[436] *Id.* at 10, 24.

with NO_x emissions produced by power plants in Minnesota, for the time period simulated in the EPA's modeling runs . . . ."[437] That total is 31.96 μg/m^3. The Agencies computed the total change a second time after dropping the Minnesota receptor sites. The total after this adjustment is 21.01 μg/m^3. The Agencies argue that this demonstrates that "two-thirds of the impact on concentrations of $PM_{2.5}$ from NO_x emissions produced by power plants in Minnesota occurs outside of the state.[438]

210. In response to Xcel's argument based on the federal standards, the CEOs countered that Xcel acknowledges that emissions do travel beyond Minnesota's boundaries. Whether Minnesota is "significantly contributing" to another state's non-attainment of the federal standards is not relevant, the CEOs argued.[439] All that is relevant is a calculation of the externality damage costs of Minnesota's emissions. The CEOs assert that such a calculation does "not involve calculating what percentage of the air pollution in a particular state comes from Minnesota."[440]

211. Xcel criticized the Agencies' and CEOs' approach to addressing uncertainty in estimating CP damages. Xcel determined that areas of uncertainty in this process include: "meteorological data, emission sources modeled, modeling of chemical reactions, selection of human health studies, determination of a VSL, determination of dose-response functions, crop damages evaluated, visibility impacts, conversion rates, deposition rates, and population densities."[441] Xcel claimed that the Agencies and CEOs did not adequately account for these uncertainties because they used reduced form models, and failed to "use any standard statistical methods to minimize uncertainty" for their estimations of damages to human health.[442] In addition, Xcel asserted the Agencies and CEOs failed to adequately explain why they chose the studies they relied on for their damage costs analyses.[443]

212. The Agencies responded to the criticisms regarding accounting for uncertainty in estimations of damages to human health, asserting that, in addition to relying on meta-analyses for their VSLs, the *Krewski* and *Lepeule* studies "are the most widely used set of results in this area."[444] Xcel's approach, the Agencies argued, is not consistent with standard practice in the field.[445] Furthermore, the Agencies pointed out that they spent 14 pages of their primary witness's direct testimony explaining the Agencies' approach to these studies. Therefore, according to the Agencies, Xcel's suggestion that the Agencies failed to articulate the reasons for selecting the studies they did is "disingenuous."[446]

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[437] *Id.* at 24.
[438] Ex. 811 at 24 (Muller Surrebuttal).
[439] Ex. 119 at 15 (Marshall Surrebuttal).
[440] *Id.*
[441] Ex. 606 at 31 (Desvousges Rebuttal).
[442] *Id.*
[443] *Id.* at 32.
[444] Ex. 811 at 21 (Muller Surrebuttal).
[445] *Id.* at 20-21.
[446] *Id.* at 21.

213. In addition, the CEOs challenged the notion that Xcel's Monte Carlo analysis served as a valuable addition to its concentration response calculation. The CEOs argued that Xcel's subjective weightings produced inappropriate results, the end results of Xcel's concentration-response analysis were "nearly entirely derived from one concentration-response function," and straightforward averaging of Xcel's three chosen studies would have yielded "a more useful and representative result."[447]

214. Xcel prepared an analysis comparing its CP externality values to those proposed by the Agencies and the CEOs. For purposes of this comparison, Xcel standardized the approaches used by the three parties. Xcel incorporated its value assumptions into the Agencies' and the CEOs' estimates. For example, Xcel used the results of its Monte Carlo analysis, substituting its numbers for the risk of premature mortality, morbidity, agricultural and materials impacts. In that way, Xcel was able to present "the magnitude of the influence attributable to the predicted changes in ambient concentrations" for the CPs among the models.[448] In addition, Xcel applied the Minnesota (plus) geographic damages scope from its own analysis, summarized on its 3-tier county level. Xcel used the predicted changes in ambient concentrations for SO_2, NO_x and $PM_{2.5}$ as provided by the Agencies and the CEOs. Xcel also used the 25^{th} and 75^{th} percentiles, along with the mean values that resulted from using the changes in ambient concentrations and Xcel's valuations. Xcel theorized that the resulting values could be compared based on the assumption that differences are attributable to how the different models predict changes in ambient air concentrations.[449] Xcel provided comparisons of its values in the following table:[450]

[447] Ex. 119 at 16 (Marshall Surrebuttal).
[448] Ex. 608 at 18 (Desvousges Surrebuttal).
[449] *Id.*
[450] *Id.* at 19.

Summary Table Comparing Damage Results for CAMx , AP2 and InMAP Data Based on Xcel Modeling Domain and Valuation Process

Dollars/Ton of Emissions INMAP									
	Rural			**Metro Fringe**			**Urban**		
	Low	**Mean**	**High**	**Low**	**Mean**	**High**	**Low**	**Mean**	**High**
OPM* InMapa	6,134	11,130	15,197	11,080	20,151	27,698	56,491	102,905	141,807
AP2 (Actual)	**	**	**	6,299	11,437	15,639	7,588	13,784	18,870
AP2 (Hypothetical)	7,516	13,604	18,471	24,691	44,884	61,851	47,318	85,984	118,350
CAMx	3,437	6,220	8,441	6,450	11,724	16,078	10,063	18,305	25,137
NOx InMap	1,060	3,303	4,418	3,098	6,500	8,913	10,529	19,694	27,033
AP2 (Actual)	**	**	**	239	1,309	1,805	244	1,250	1,771
AP2 (Hypothetical)	238	1,606	2,092	1,191	3,049	4,208	2,125	4,625	6,391
CAMx	1,985	4,762	6,370	2,465	5,347	7,315	2,760	5,755	7,893
SO2 InMap	8,100	14,450	19,511	1,794	3,254	4,492	2,472	4,474	6,205
AP2 (Actual)	**	**	**	1,850	3,354	4,621	1,870	3,378	4,695
AP2 (Hypothetical)	2,207	3,944	5,332	5,204	9,463	13,058	8,471	15,389	21,254
CAMx	3,427	6,159	8,352	4,543	8,245	11,317	5,753	10,439	14,382

[a] Rural is hypothetical Lyon County high stack height. Metro Fringe and Urban are actual plants.
*OPM is the same as direct emissions of $PM_{2.5}$ in this table.
** No actual data available from Dr. Muller (Agencies).

215. Based on its analysis as reflected in the table above, Xcel concluded that the Agencies' and CEOs' modeling results cannot be accurate. Xcel maintained that the CEOs, through the InMAP model, consistently overestimate the CP externality values. Among other unexpected results, Xcel pointed out that the InMAP model predicted the greatest impacts from SO_2 in the rural, rather than either the metro or the metropolitan fringe scenarios, despite the fact that InMAP was the only model that did not include agricultural impacts.[451]

[451] Ex. 608 at 19-20 (Desvousges Surrebuttal).

216. Xcel maintained its comparison demonstrates that the AP2 model underestimates NO_x impacts and concentrations, but overestimates $PM_{2.5}$ and SO_2 values for the Agencies' hypothetical plant, even compared to its own values based on actual plants.[452]

D. CEOs' Criticisms of Agencies' Recommendations

217. The CEOs disagreed with the Agencies' approach to adopting a cost for the VSL. While both parties looked to the EPA's recommended VSL, the CEOs criticized the Agencies for using the EPA's VSL of $9.5 million (2011 dollars) as the high-end of a range rather than adopting the EPA value as their single VSL value, as the CEOs did. The Agencies used the EPA's number, while using the *Kochi* stated-preference estimate for their low end number.[453] The CEOs criticized the Agencies' choice to pair the EPA number with the *Kochi* number. The EPA number is derived from a distribution including both hedonic wage and stated preference studies. The *Kochi* stated preference estimate is based entirely on stated preference studies. According to the CEOs, using these two studies together to form the ends of a range "compares apples and oranges, and is not an appropriate use of these studies."[454]

218. The CEOs maintained that they are confident of their single-value approach "because the EPA derived its value by investigating many studies and then taking the central tendency of those studies."[455] Nonetheless, the CEOs recognized that the Commission might prefer to adopt a range of values for the VSL. Should the Commission choose to adopt such a range of values, the CEOs offered two alternative VSL estimates in response to the Agencies' estimate. As an alternative single point estimate, the CEOs recommended the *Kochi* combined estimate, adjusted for income growth, which is $7.7 million. If the Commission prefers a VSL range, the CEOs recommended reporting the damage cost estimates separately, based on a hedonic wage VSL and a stated preference VSL, using the two *Kochi* meta-analysis results ($13.6 million for hedonic wage and $4.0 million for stated preference).[456]

219. The CEOs calculated their dose-response function values using the same two EPA studies that the Agencies used.[457] For the high end of the dose-response function, the CEOs and the Agencies use the same value taken from the *Lepeule* study, 14% increased mortality risk per 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentrations. While both the CEOs and the Agencies derive their low-end values from the *Krewski* study, the CEOs criticized the Agencies' low-end value of a 6% concentration response, as opposed to the CEOs' low-end value of 7.8% concentration response.[458] The CEOs explained that their 7.8% figure takes into account ecologic covariates, while the Agencies' 6% figure does

[452] *Id.* at 19-20, 23-32.
[453] Ex. 119 at 4-5 (Marshall Surrebuttal). The Agencies used the Kochi study for the low number of $3.7 million (2011 dollars) for their range. *See* Ex. 808 at 41-42 (Muller Direct).
[454] Ex. 118 at 8 (Polasky Rebuttal).
[455] Ex. 119 at 5 (Marshall Surrebuttal).
[456] Ex. 118 at 8 (Polasky Rebuttal).
[457] Ex. 116 at 3 (Marshall Rebuttal).
[458] *Id.*

not.[459] The CEOs stated that *Krewski* defined ecologic covariates as "variables or factors known or suspected to influence mortality that represent the social, economic, and environmental settings . . . at community and neighborhood levels where individuals live, work, or spend time."[460] Ecologic covariates include: [461]

- percentage of homes with air conditioning;
- percentage of adults with less than a grade 12 education;
- percentage of self-reported white or non-white persons;
- percentage of persons over the age of 16 years who are unemployed;
- median household income;
- a measure of the inequality of income (Gini coefficient); and
- percentage of people with income < 125% of the poverty level.

220. The CEOs asserted that it can be important to adjust for ecologic covariates. Some can cause a concentration response function to skew high, others will cause it to skew low, while others, such as air conditioners, "have a more complicated relationship with the concentration of $PM_{2.5}$ in the atmosphere."[462] While finding it difficult to determine "whether an adjusted or unadjusted concentration response function is more or less accurate" in this case, the CEOs ultimately recommended using adjusted data.[463] However, given the "relatively small" difference in values, the CEOs acknowledged that the ecologic covariates did not have a significant effect.[464] The CEOs considered the 7.8% figure to be "somewhat more likely" to be correct than the 6% figure used by the Agencies, although they did not consider the Agencies' choice to be unreasonable.[465] The CEOs acknowledged that which number to use is a matter of professional judgment.[466]

221. While the Agencies continued to disagree with the CEOs' choice of 0.78 for the concentration-response value, the Agencies agreed that this is a matter of professional judgment and noted that the CEOs value falls within the range recommended by the CEOs. Therefore, the Agencies did not fundamentally disagree with the CEOs' recommended value.[467]

222. The CEOs recalculated the Agencies' damage results, adjusting for the ecologic covariate in the concentration-response number and using a single number of

[459] *Id.*
[460] Ex.117 at 6 (Jacobs Rebuttal). Krewski also took 44 individual covariates into account, but the CEOs did not discuss the significance of these in the present context. *Id.*
[461] *Id.*
[462] *Id.* at 7.
[463] *Id.*
[464] *Id.*
[465] Ex. 117 at 7 (Jacobs Rebuttal).
[466] Ex. 116 at 3 (Marshall Rebuttal).
[467] Ex. 811 at 30-31 (Muller Surrebuttal).

$9.8 million for the VSL.[468] The CEOs provided the results based on generic power plant damages in 2015 dollars:[469]

	$PM_{2.5}$ low	$PM_{2.5}$ high	SO_2 low	SO_2 high	NO_x low	NO_x high
CEOs	**$125,000**	**$218,000**	**$16,000**	**$28,000**	**$14,000**	**$24,000**
Agencies Direct	$ 26,010	$140,102	$11,820	$64,180	$1,183	$6,218
Agencies VSL correction	$ 68,891	$144,526	$31,307	$66,207	$3,133	$6,414
Agencies covariate correction	$ 33,813	$140,102	$15,366	$64,180	$1,538	$6,218
Agencies all adjustments	**$ 89,559**	**$144,526**	**$40,699**	**$66,207**	**$4,073**	**$6,414**

223. After these adjustments, the CEOs acknowledged that the Agencies' estimates for $PM_{2.5}$ and NO_x damages range from about 30% to 70% lower than the CEOs, while the Agencies' damages for SO_2 emissions are about two and a half times larger than the CEOs.[470] The CEOs contended that, in the air quality modeling context, "differences of these amounts are not necessarily considered unacceptably large. In contrast, the location of the emissions can cause differences in damages by up to a factor of 100."[471]

E. CEOs' Criticisms of Xcel's Recommendations

224. While acknowledging the CAMx is "an excellent tool for answering many questions" the CEOs maintained that Xcel's choice of CAMx as the model to use in this proceeding is "the wrong tool for this job."[472] The focus of the CEOs' criticism of CAMx is the "computational intensity of the model."[473] The CEOs alleged that Xcel only had enough time to run the CAMx model three times in this proceeding, with the third time only a week before the rebuttal testimony was due. The CEOs also claimed that CAMx's

[468] $9.8 million is the 2015 equivalent of the 2011 EPA figure of $9.5 million. Ex. 116 at 4, fn 2 (Marshall Rebuttal).
[469] *Id.* at 3-4.These adjustments are for illustrative purposes only. The CEOs did not rerun the AP2 model to arrive at these numbers. *Id.* at 4-5.
[470] *Id.* at 5.
[471] Ex. 116 at 5 (Marshall Rebuttal).
[472] *Id.* at 7.
[473] *Id.*

computational intensity prevented Xcel from engaging in a suitable level of investigation of "how the location of emission affects impacts and . . . they were apparently unable to quantify health impacts occurring outside of Minnesota and its immediately (sic) surrounding area."[474] The CEOs also expressed concerns about assumptions made by the Xcel modelers.[475]

225. According to the CEOs, the two problems with the computational intensity of CAMx "to set the values that will be used for all possible plant locations in Minnesota going forward" are that only a limited number of emissions locations can be modeled, and that the model cannot be easily updated, or rerun to test assumptions.[476]

226. Xcel responded to the criticisms concerning the computational intensity of CAMx and the cumbersome nature of the model by agreeing that the model takes longer to run, but asserting that the results are more reliable than reduced form models. Xcel stated that an annual CAMx run is made up of four quarter simulations. Each quarterly simulation takes about four-and-a-half days to run. Xcel commented that, with sufficient central processing unit (CPU) capacity to run four quarters at once, an annual simulation could be completed in four-and-a-half days. The costs associated with running CAMx are the cost to set up the model and the CPU run time. Xcel noted that the Agencies and CEOs "each completed nearly 3,000 runs" compared to Xcel's four runs – two initial scenarios and two additional scenarios.[477] Xcel again pointed out CAMx's long history of public accessibility, and claimed that CAMx is no more difficult to learn, and to evaluate, than InMAP and AP2 are.[478]

227. The CEOs criticized Xcel's decision to model the Sherburne County and Marshall locations simultaneously. The CEOs argued that Xcel's simultaneous modeling is inadequate to provide enough information "about the range of damages expected from emission sources across Minnesota" along with the reasons for the variation in damages, ultimately providing damage values of limited usefulness to the Commission.[479]

228. The CEOs cautioned that running the two models at two locations simultaneously could cause distorted results.[480] According to the CEOs, when Xcel was challenged on this question and stated it was running the model a third time as a control, Xcel reported its results one week later than it initially stated it would, and then only answered the question of whether the results from the Marshall plant had affected the Sherburne plant, but did not answer the inverse question. This set of circumstances, the CEOs concluded, demonstrates "how using a model with such a long computing time in this manner threatens the integrity of the results."[481] In addition, the CEOs asserted that

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[474] *Id.*
[475] *Id.*
[476] *Id.*
[477] Ex. 609 at 5 (Desvousges Surrebuttal).
[478] *Id.* at 5-6.
[479] Ex. 116 at 8 (Marshall Rebuttal).
[480] *Id.*
[481] *Id.* at 9.

the computational demands of the CAMx model prevented the other parties from independently verifying Xcel's results.[482]

229. The CEOs disputed Xcel's statement that CAMx is "much more accurate and reliable" in assessing air quality impacts than a reduced form model.[483] While agreeing that "[i]f used appropriately, the CAMx model can be reliable and accurate," the CEOs contended that there is also the question of "the overall approach" as to CAMx's reliability.[484] Furthermore, because it is not practical to run many test cases, according to the CEOs, it is difficult to answer questions that may arise in the future about the CAMx model and how it was used.[485] The CEOs concluded that CAMx's logistical challenges overwhelm any advantages it may provide by virtue of its complexity. [486]

230. The CEOs challenged Xcel's decision to limit the geographic scope of its estimated damages to Minnesota and an approximately 100-mile band around Minnesota's borders.[487] The CEOs argued that, of the damages from a generic power plant of the type described in the CEOs' direct testimony located within Minnesota, 26% of the $PM_{2.5}$ damages, 67% of the SO_2 damages, and 27% of the NO_x damages would occur outside of Xcel's geographic scope for damages.[488] According to the CEOs, Xcel relied on a CAMx continental U.S. pollution model to create the Minnesota model predictions in this proceeding. The CEOs pointed out that, just a week before surrebuttal testimony was filed in this proceeding, Xcel provided to the CEOs results for a larger geographic damages domain than what Xcel ultimately used.[489]

231. The CEOs acknowledged that the continental U.S. CAMx modeling results provided by Xcel are at a lower spatial resolution of 36 km grid cells than the Minnesota modeling results, which are at a resolution of 12 km grid cells. No performance evaluation was performed on this configuration in this proceeding, so the CEOs also acknowledged that its accuracy is unknown. Nevertheless, the CEOs used the data provided by Xcel to estimate how Xcel's limitation of the geographic scope of damages to Minnesota affected its damage estimates.[490] The following tables show the results of the CEOs' analysis:[491]

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[482] *Id.*
[483] *Id.*
[484] *Id.*
[485] *Id.* at 9-10.
[486] *Id.* at 10.
[487] *Id.* at 11.
[488] *Id.* at 12.
[489] Ex. 119 at 9-10 (Marshall Surrebuttal).
[490] Ex. 119 at 11-12 (Marshall Surrebuttal).
[491] *Id.* at 14.

Table 1. CAMx and InMAP Estimates of Damage Costs per Ton Emissions for the Sherburne County Generator

	Primary $PM_{2.5}$	NO_x	SO_2
CAMx MN domain	$24,000	$7,000	$12,000
CAMx U.S. domain	$60,000	$20,000	$51,000
InMAP U.S.domain	$57,000	$9,000	$14,000

Table 2. CAMx and InMAP Estimates of Damage Costs per Ton Emissions for the Black Dog Generator

	Primary	NO_x	SO_2
CAMx MN domain	$38,000	$8,000	$16,000
CAMx U.S. domain	$78,000	$23,000	$57,000
InMAP U.S. domain	$223,000	$24,000	$21,000

Table 3. CAMx and InMAP Estimates of Damage Costs per Ton Emissions for a Generator in Marshall, MN

	Primary $PM_{2.5}$	NO_x	SO_2
CAMx MN domain	$13,000	$6,000	$9,000
CAMx U.S. domain	$49,000	$19,000	$46,000
InMAP U.S. domain	$62,000	$12,000	$37,000

232. The CEOs asserted that their calculations show that less than half of Xcel's CAMx damages occur in Minnesota (and the 100-mile surrounding area). In almost all cases, the CEOs claim that "the difference between the CAMx results for the Minnesota domain and the CAMx results for the continental U.S. domain is larger than the difference between InMAP and CAMx results."[492]

[492] *Id.* at 13.The exception to this statistic is the $PM_{2.5}$ emissions from the Black Dog generator, according to the CEOs. *Id.* at fn 10.

233. Based on these calculations, the CEOs recommended that it is more appropriate to consider Xcel's low-resolution U.S. model results than to assume that there are no damages outside of Minnesota.[493]

234. At the evidentiary hearing, Xcel witness, Dr. William Desvousges, opined that he did not believe CAMx could predict damages throughout the contiguous U.S. with sufficient reliability to be used in this proceeding.[494]

235. According to the CEOs, Xcel's choices of both VSL and concentration-response values resulted in significant underestimates of the externalities costs in this proceeding. As to the VSL, the CEOs reported that, rather than utilizing a value recommended by the EPA Scientific Advisory Board or another "commonly used and reliable" number, Xcel calculated its own values distribution meant to represent "the product of the excess mortality risk from particulate matter multiplied by the value of statistical life."[495] The CEOs criticized that portion of Xcel's modeling process that involved multiplying the concentration response functions by the VSL, then creating a distribution by performing a Monte Carlo analysis on the resulting product. In its modeling, Xcel used the 25th and 75th percentiles of this distribution, which was separate from the VSL or the concentration response distribution.[496]

236. The CEOs found Xcel's use of the Monte Carlo approach inappropriate because using it effectively excluded the values from two of the three epidemiological studies Xcel stated it included in its concentration response number.[497]

237. The CEOs rejected Xcel's VSL calculation because it incorporates negative VSL estimates, which the CEOs found an "unjustifiable" decision that lowered the VSL estimate.[498]

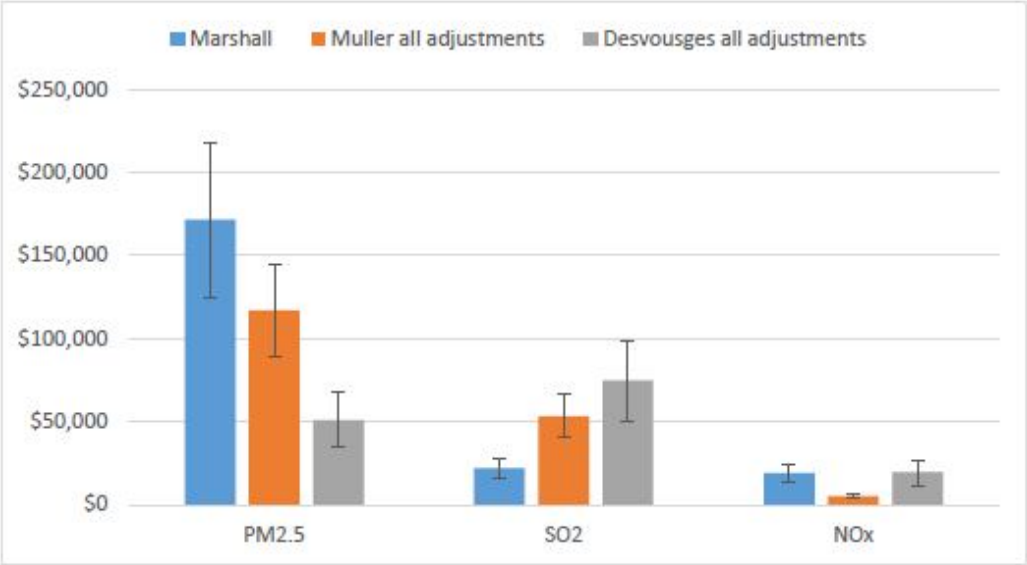
238. The CEOs stated that Xcel's interpretation of the CEOs' damage values is misleading because it uses the highest and lowest of all of the CEOs' county-specific values (inside and outside of Minnesota), then presents them as ranges of damage estimates alongside the CEOs' generic range. The CEOs maintained that this presents a damage range that is "misleadingly large" and not helpful.[499]

239. The CEOs criticized Xcel's illustration of distribution of emissions from the Sherco plant.[500] The CEOs claimed that Xcel's non-linear scale on the map, using a single bright-red color to represent a range of concentrations from 0.009 through 17.2 μg/m^3, distorted the spatial pattern of pollution concentrations. The CEOs provided a

[493] Ex. 119 at 11-12 (Marshall Surrebuttal).
[494] Tr. Vol. 7 at 61-62 (Desvousges).
[495] Ex. 116 at 13-14 (Marshall Rebuttal).
[496] *Id.* at 14.
[497] *Id.* at 14-15.
[498] *Id.* at 17.
[499] *Id.*
[500] *Id.* at 18.

version of the map with a "linear" color scale which differentiates among the concentrations more clearly.[501]

240. The CEOs adjusted Xcel's results to compare the generic values of each of the parties' models. For the CEOs' and Agencies' generic values, the CEOs took a weighted average of impacts from the Sherburne County and Black Dog locations, based on the total impacts of those plants as calculated for the Direct Testimony in this case.[502] The CEOs adjusted the weighted average results to correct both the VSL and concentration response assumptions for the high and low estimates. In addition, the CEOs adjusted Xcel's results to account for an expanded geographical scope of impacts outside of Minnesota.[503] The CEOs provided a graphic presentation of the comparison:[504]



Note: Marshall = CEOs, Muller = Agencies, Desvousges = Xcel.

241. The CEOs noted that these results are not precise, or the same as they would have been had the models themselves been rerun. The adjustments were made for illustrative purposes.[505]

F. Agencies' Criticisms of Xcel's Recommendations

242. The Agencies agreed that Xcel's VSL value of $5.9 million is reasonable, noting that it falls "nearly directly in the center" of the Agencies' range of VSL values.[506] The Agencies disagreed with the use of one central VSL rather than a range of values,

[501] Ex. 119 at 18 (Marshall Surrebuttal).
[502] Ex. 116 at 18 (Marshall Rebuttal). The CEOs did not use the Marshall location based on Xcel's testimony that there is no power plant currently located in Marshall. *Id.*
[503] *Id.* at 18-19.
[504] *Id.* at 20.
[505] *Id.*
[506] Ex. 810 at 18 (Muller Rebuttal).

but stated that, as to Xcel's approach, that criticism is reduced because Xcel used a Monte Carlo analysis to reflect uncertainty in the choice of VSL value.[507]

243. The Agencies also agreed with Xcel's choice of a 6% concentration response function because that value falls within the Agencies' recommended range. But Xcel chose only a single value rather than a range of values, which would have been more consistent with current epidemiological research, according to the Agencies.[508]

244. Like the CEOs, the Agencies disagreed with Xcel's choice to calculate the CP externalities values in this proceeding based on a geographic area that included just Minnesota and a band extending approximately 100 miles from the state's borders.[509] The Agencies asserted that Xcel's geographic scope of damages made Xcel's externalities values "inaccurately low."[510]

245. The Agencies provided a table comparing the raw estimated marginal damages reported by Xcel, the Agencies and the CEOs for the City of Marshall (rural), Sherburne county (metro fringe) and the Black Dog plant location (urban), the three locations Xcel modeled:[511]

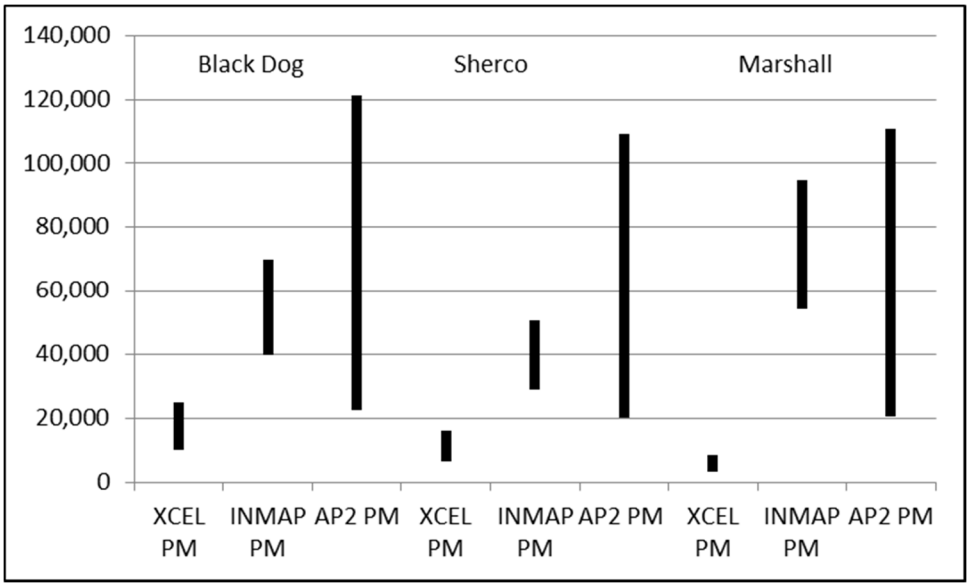
Marginal Damage Estimates for Sherburne County, Black Dog, and City of Marshall Sources ($/ton)[C]

Source	Damage Scenario[A]	$PM_{2.5}$			SO_2			NO_x		
		Xcel	InMAP	AP2	Xcel	InMAP	AP2	Xcel	InMAP	AP2
Black Dog (Urban)[B]	High	25,137[C]	69,794	121,277	14,382	39,381	64,250	7,893	12,729	5,490
	Low	10,063	40,007	22,440	5,753	22,574	11,804	2,760	7,296	1,040
Sherburne County (Metro Fringe	High	16,078	50,672	109,237	11,317	25,429	61,534	7,336	8,324	5,314
	Low	6,450	29,046	20,200	4,543	14,576	11,313	2,467	4,771	1,008
City of Marshall, Lyon County	High	8,441	94,577	110,651	8,352	52,722	61,679	6,370	17,917	5,278
	Low	3,437	54,213	20,400	3,427	30,221	11,329	1,985	10,271	999

A = For InMAP and AP2, damage scenarios denote high and low damage estimates. For Xcel, these correspond to the 25th and 75th percentiles from the damage distributions.
B = For Xcel, the source locations correspond to the hypothetical plants modeled.
C = These are values reported by each expert witness. The corrections for differences in year-dollars make very little impact on their relative magnitudes.

[507] Ex. 810 at 17-18 (Muller Rebuttal).
[508] *Id.* at 18-19.
[509] *Id.* at 19-20.
[510] *Id.* at 20.
[511] *Id.* at 21.

246. In addition, the Agencies illustrated the results for emissions of primary $PM_{2.5}$ demonstrating that the Agencies' and CEOs' ranges overlap, while Xcel's range remained below both of the other ranges:[512]



All values in dollars per U.S. short ton. For InMAP and AP2, the endpoints of each line correspond to the high and low damage estimates. The topmost point of the line reflects high-end damage assumptions. The bottommost point of the lines reflects low-end damage assumptions. For Xcel, the top and bottom of the lines reflect the 75th and 25th percentiles of the damage distributions, respectively.

247. Because the Agencies calculated that nearly 40% of their estimated damages for $PM_{2.5}$ and NO_x emissions and about 15% of their estimated damages from SO_2 emissions occur within Minnesota, they concluded that Xcel's "spatially limited analysis may dramatically understate actual damages."[513]

[512] Ex. 810 at 21-22 (Muller Rebuttal).
[513] *Id.* at 22.

248. The Agencies compared their Minnesota-only damages to Xcel's damages, with the following results:[514]

Comparison of Damage Estimates when AP2 Damages are Limited to Counties in Minnesota ($/ton)

		PM2.5		SO2		NOx	
Source[B]	Scenario[A]	Xcel	AP2	Xcel	AP2	Xcel	AP2
Black Dog (Urban)	High	25,137	26,382	14,382	5,046	7,893	1,081
	Low	10,063	4,976	5,753	1,081	2,760	194
Sherco (Metro Fringe)	High	16,078	23,374	11,317	5,529	7,336	1,203
	Low	6,450	4,405	4,543	1,042	2,467	236
City of Marshall, Lyon County (Rural)	High	8,441	30,119	8,352	7,522	6,370	1,135
	Low	3,437	5,618	3,427	1,410	1,985	225

A =For AP2, damage scenarios denote high and low damage estimates. For Xcel, these correspond to the 25th and 75th percentiles from the damage distributions.
B =For Xcel, the source locations correspond to the hypothetical plants modeled. For the AP2 values the Agencies use the specific values calculated for Sherburne County (Sherco) facility and for the Black Dog facility, and the county value for Lyon County which includes the City of Marshall.

249. The Agencies noted that, with the exception of SO_2 damages from the Black Dog facility, the $PM_{2.5}$ and SO_2 damages in this analysis tend to overlap, while the NO_x damages do not. The Agencies pointed out that Sherco and Black Dog are both in the eastern third of Minnesota, meaning that "any methodology that fails to accurately incorporate the pollutants' dispersal would bias downward the results of these eastern sources for which a large portion of emissions travel out of state."[515] According to the Agencies, the comparison is not exact in part because Xcel's model domain included some areas beyond Minnesota's boundaries while, for purposes of this comparison the Agencies limited their damages to Minnesota only.[516]

250. The Agencies concluded that their Minnesota-only damages comparison showed the following: a) the range for $PM_{2.5}$ overlaps for all of the locations; b) for two of the three source locations, the range of values for Xcel's SO_2 value and the Agencies' SO_2 value overlap; and c) for NO_x the ranges do not overlap but are quite close.[517] When the Agencies considered that the NO_x range was based on the 25th and 75th percentiles, they determined that it is "very likely that the absolute ranges do overlap."[518]

[514] *Id.* at 23.
[515] Ex. 810 at 23 (Muller Rebuttal).
[516] *Id.*
[517] *Id.* at 25-26.
[518] *Id.* at 26.

251. The Agencies contended that there is no scientific or practical reason for Xcel's decision to limit its damages modeling domain.[519] Xcel's decision to truncate the geographic scope of its damages calculation resulted in impacts being missed or omitted from the cost analysis, according to the Agencies.[520] The Agencies asserted that Xcel's decision to limit the geographic scope of damages it included is inconsistent with the modeling approach it used to estimate baseline concentrations, which included emissions from far outside Minnesota.[521]

252. The Agencies noted that Xcel's justification for limiting its damages calculation geographically was to be consistent with the Commission's approach in the First Externalities proceeding. The Agencies found this justification was inconsistent with other aspects of Xcel's approach in this proceeding, which are different from the First Externalities proceeding based on updated research.[522]

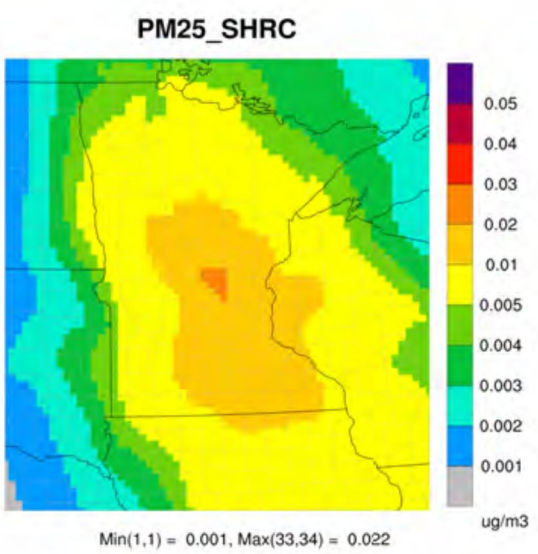
253. The Agencies criticized Xcel's decision to combine the hypothetical Sherco and Marshall EGUs into a single CAMx run. Xcel justified its choice based on the rationale that:

> Sherco and Marshall EGUs are far enough away from each other that they would likely have minimal influence on each other's air quality impacts. However, to check this a third scenario will be run with only the Sherco EGU and compared with Sherco's impacts from the Sherco/Marshall scenario at a later stage in the study.[523]

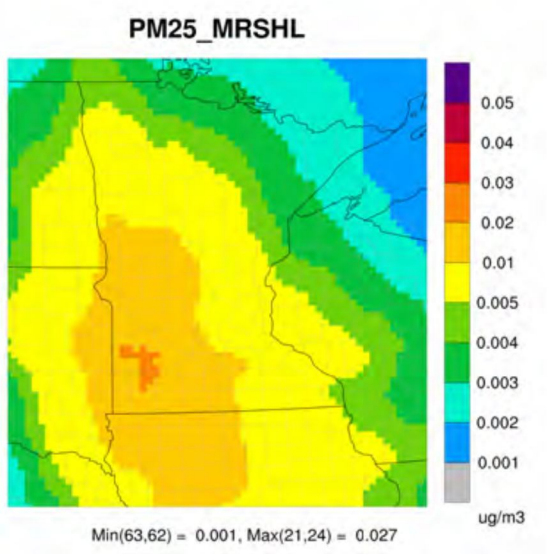
254. The Agencies alleged that the combined run rendered separating any impacts one plant had on the other impossible "because of the extent to which the dispersion of emissions is co-mingled."[524] The Agencies pointed to Xcel's maps of $PM_{2.5}$ emissions dispersions, arguing that those maps demonstrate that the "plumes of emitted pollution from these two facilities overlap"[525]:

[519] *Id.* at 26-27.
[520] *Id.* at 29.
[521] *Id.* at 30-31.
[522] Ex. 810 at 32 (Muller Rebuttal).
[523] *Id.* at 33.
[524] *Id.*
[525] *Id.* at 28, 33.

Sherco Facility



Marshall Facility



255. Furthermore, the Agencies argued that the flaw in Xcel's modeling in this respect taints the comparisons the Agencies make among the parties' reported cost values.[526]

256. Xcel acknowledged that emissions from one of the EGUs could change the background chemistry of the other, affecting the modeled $PM_{2.5}$ and ozone impacts attributed to the second EGU. Xcel reiterated that it relied on the distance between Sherco and Marshall to assure no significant impact would occur from one to the other.[527] Xcel explained that CAMx contains ozone and particulate matter source apportionment technology (OSAT and PSAT) which can isolate individual separate contributions from multiple hypothetical EGUs.[528] According to Xcel, in order to verify the question of emission sources, the source apportionment simulations were first run in two scenarios for use in Xcel's Direct Testimony. The first scenario located the EGUs at Sherco and Marshall, run together, with the impacts tracked separately for each EGU. The second scenario modeled the EGU at Black Dog by itself. Following the filing of Direct Testimony, a third scenario was run with only the Sherco site and the results were compared with the Sherco results from the first scenario. The results of the third scenario were "essentially the same as those from the first, according to Xcel.[529] This confirmed Xcel's original assumption that the Marshall and Sherco EGUs would not have significant impacts on one anothers' emissions.[530]

[526] *Id.* at 33.
[527] Ex. 609 at 6-7 (Desvousges Surrebuttal).
[528] *Id.* at 7.
[529] *Id.* at 8.
[530] *Id.*

257. Following the rebuttal testimony, Xcel ran a fourth scenario, which was the Marshall EGU alone.[531] Xcel maintained that the results of that scenario also showed that running Sherco and Marshall together originally had little effect on the externality calculations.[532]

258. The Agencies rejected Xcel's three hypothetical source locations for CP emissions because the Agencies disagreed with Xcel's underlying premise that three categories of damages (urban, metro-fringe, and rural) can adequately represent the variety of sources of CP emissions across the state.[533] The Agencies disagreed that the Marshall location was representative of rural locations across the state, considering the distances that emissions travel and the differing impacts those emissions might have depending on wind, dispersal and geographic location.[534]

259. The Agencies theorized that Xcel's true reason for choosing only three source locations mostly had to do with the time and expense associated with running the CAMx model. The Agencies noted that Xcel admitted that it would have ideally separated the CAMx runs for Sherco and Marshall. "However, performing separate runs for each EGU would take additional time, of which we were limited for this study. Each model simulation takes approximately three weeks to run."[535]

260. The Agencies criticized Xcel's accidental substitution of annual $PM_{2.5}$ emissions data from its gas-fired Riverside facility in the emissions data it used for the modeling for its hypothetical power plants. The Agencies stated that Xcel's error, reporting emissions of 9.4 tons of $PM_{2.5}$ per year (based on Riverside plant emissions) rather than 341 to 359 tons of $PM_{2.5}$ per year (based on the actual Sherco plant emissions) "seriously undermines the ability to draw inferences about environmental cost values from [Xcel's] modeled hypothetical power plants."[536]

261. Xcel recognized that if the SO_2 or NO_x emissions from Riverside had been modeled for its hypothetical Sherco plant, that would have affected the values because the chemistry for those compounds forms in a nonlinear manner. However, Xcel maintained that, because there is a direct, linear relationship between the amount of direct $PM_{2.5}$ emissions and the ambient concentration of $PM_{2.5}$, the mistake in the number of tons of $PM_{2.5}$ emitted for the purposes of the Sherco modeling calculations would not have affected the ultimate externalities values.[537]

262. Xcel asserted that much of the Agencies' criticism of the hypothetical Sherco plant is based on the Agencies' misunderstanding and misconstruction of Xcel's data. Xcel explained it filed corrected emissions data, but that the Agencies failed to incorporate the changes, and that the Agencies misread Xcel's tables concerning a single

[531] *Id.* at 7.
[532] *Id.* at 9-10.
[533] Ex. 810 at 34 (Muller Rebuttal).
[534] *Id.*
[535] *Id.* at 35.
[536] Ex. 810 at 37-38 (Muller Rebuttal).
[537] Ex. 609 at 12 (Desvousges Surrebuttal).

unit versus tables comparing multiple units, in addition to misunderstanding the differing sources of information about hourly emissions.[538]

263. The Agencies disagreed with Xcel's assertion that photochemical models are more accurate predictors of air pollution than reduced form models. The Agencies reiterated that the AP2 model performed satisfactorily "according to common air quality model performance tests."[539]

264. The Agencies noted that, on average, across all of the counties in Xcel's geographic area, AP2's predicted CP concentration changes were higher by 7 to 37 percent than those predicted by CAMx. The Agencies attributed most of this difference to Xcel's limited geographic damage area as opposed to the Agencies' choice to measure damages across the contiguous U.S. The Agencies came to this conclusion for $PM_{2.5}$, SO_2, and NO_x.[540]

265. Xcel criticized the Agencies' approach of modeling just one incremental of ton of each criteria pollutant, in isolation, unlike a real plume, because of the unrealistic impact that approach has on the formation of secondary PM2.5., and for the Agencies' alleged failure to model a representation of an actual facility.[541]

G. Agencies' Criticisms of CEOs' Recommendations

266. The Agencies agreed with the CEOs approach to modeling and calculating CP externalities damages generally in this proceeding. Like the Agencies, the CEOs used a reduced form model, included sources from a 200 mile radius outside of Minnesota and measured damages based on the contiguous U.S.[542]

267. The Agencies approved of the CEOs' choice of a VSL amount of $9.8 million in 2015 dollars, based on the VSL range the Agencies recommended, which had a high end, in 2015 dollars, of $10.1 million.[543] However, the Agencies asserted that the use of a single VSL instead of a range fails to recognize the uncertainty that arises from the varied approaches to estimate the VSL. The Agencies maintained that using a single value for the VSL yields a damage estimate with a false sense of precision.[544]

268. The CEOs preferred their single-point VSL, but offered alternatives, for a single-point or for an alternative range. The alternatives are described in Finding 218 of this report.[545]

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[538] *Id.* at 12-13.
[539] Ex. 810 at 39 (Muller Rebuttal).
[540] *Id.* at 41-43.
[541] Ex. 609 at 14-15 (Desvousges Surrebuttal).
[542] Ex. 810 at 3-7 (Muller Rebuttal).
[543] *Id.* at 7.
[544] *Id.* at 16.
[545] Ex. 119 at 6 (Marshall Surrebuttal).

269. The Agencies agreed with the CEOs' choice of concentration response function studies, which are the *Lepeule* and *Krewski* studies – the same studies used by the Agencies.[546]

270. The Agencies compared their recommended externalities value for the CPs in this matter with those of the CEOs, after adjusting the CEOs' VSL input to match the Agencies. The Agencies' concluded that, with this adjustment, the two parties' sets of recommendations had significant overlap for $PM_{2.5}$ and SO_2.[547] Although the CEOs reported NO_x values fall outside the range of the Agencies' NO_x values, the Agencies expressed confidence that the CEOs values for NO_x are still within a range recognized in recent literature.[548]

271. The Agencies expressed concern that the CEOs incorporated only the effects of exposure to $PM_{2.5}$ on adult mortality rates into their damage estimates. The Agencies asserted that this limited analysis omitted O_3 as well as other environmental and social consequences of exposure, including the effects on rates of illness and reductions in yields of agricultural crops. According to the Agencies these impacts should have been included; they are included in the EPA's regulatory impact analyses. However, the Agencies observed, the result of not including these other effects is likely to be small. In the empirical analysis the Agencies conducted, morbidity effects contributed less than five percent of total impacts.[549]

272. The CEOs did not disagree that there is value in including non-mortality $PM_{2.5}$ and O_3 impacts as the Agencies suggested. The CEOs excluded them from their modeling because the damages are relatively minor (5-10% of the total damages) and to keep the analysis as understandable as possible. The CEOs assert that excluding these damages causes their estimate to be conservative. The CEOs are amenable to including these impacts and stated the InMAP approach could be used to do so.[550]

273. The Agencies clarified that the CEOs' statement that the AP2 model assumes a constant wind speed and direction was incorrect. AP2 estimates the "likelihood that the wind blows in each of sixteen different directions at each source" based on empirical weather data.[551] Thus, AP2 demonstrates that emissions move in multiple directions.[552] The CEOs agreed with this clarification.[553]

274. The Agencies also provided a comparison of $PM_{2.5}$ prediction concentrations by InMAP and AP2 models to demonstrate that AP2 is at least as reliable as InMAP.[554]

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[546] Ex. 810 at 8 (Muller Rebuttal).
[547] *Id.* at 9-10.
[548] *Id.* at 10 -11.
[549] *Id.* at 11-12.
[550] Ex. 119 at 5-6 (Marshall Surrebuttal).
[551] Ex. 810 at 12 (Muller Rebuttal).
[552] *Id.* at 12-13.
[553] Ex. 119 at 6 (Marshall Surrebuttal).
[554] Ex. 810 at 13-15 (Muller Rebuttal).

275. The CEOs recommended that the Commission not rely on the model comparisons to determine which model to choose in this proceeding, or even whether to choose more than one model. Instead, the CEOs suggested that the Commission decide the appropriate approach with regard to VSL, concentration response function and geographic domain.[555]

VI. MLIG Arguments and Responses

A. MLIG Arguments

276. MLIG did not offer affirmative values for the Criteria Pollutants, but instead called into question the foundation of the testimony offered by the CEOs, Xcel, and the Agencies and used to calculate their proffered values. MLIG did this by offering rebuttal testimony from Dr. Roger McClellan.[556]

277. MLIG acknowledged that some of the human health effects associated with exposure to sufficiently high levels of $PM_{2.5}$ include premature death, aggravation of respiratory and cardiovascular disease, as well as chronic respiratory disease.[557] However, MLIG asserted that the bulk of these diseases are attributable to factors other than $PM_{2.5}$. MLIG identified a failure in the field of air pollution to "clearly describe that baseline occurrence of disease" so that the public can "appreciate the small portion of the common diseases that may be attributed to air pollution."[558]

278. MLIG demonstrated that the ambient air concentration of $PM_{2.5}$ in Minnesota and Wisconsin has generally been below the NAAQS of 12 $\mu g/m^3$.[559] For example, MLIG provided data showing average levels of $PM_{2.5}$ in 2012-2014 in several Minnesota cities ranged between 4.6 and 10 $\mu g/m^3$.[560]

279. MLIG noted that Xcel, the CEOs, and the Agencies "all assume a linear association between any incremental increase in the ambient concentrations of the pollutant and increased health risks."[561] Furthermore, MLIG claimed that the CEOs and the Agencies "assume the statistical association represents a causal link."[562] MLIG criticized the CEOs and the Agencies for their presumption of a causal link between any increased level of $PM_{2.5}$ and increase in disease, whatever the baseline $PM_{2.5}$ in the ambient air.[563]

280. MLIG emphasized that Dr. Marshall, the CEOs' witness, "was unable to explain that causation is different from mere mathematical association and that it requires

[555] Ex. 119 at 7 (Marshall Surrebuttal).
[556] *See* Ex. 441 (McClellan Rebuttal).
[557] Tr. Vol. 7 at 172 (McClellan).
[558] *Id.*
[559] Ex. 441, App. 2 at 6-7, 18 (McClellan Rebuttal).
[560] Ex. 443 at 3-10 (McClellan Resp. to Info. Request).
[561] Tr. Vol. 7 at 174 (McClellan).
[562] *Id.*
[563] *Id.*

ruling out other explanations of premature mortality."[564] Furthermore, MLIG noted that it is unaware of any study showing "the presence of particulate matter preceding premature mortality and correlation in the absence of other explanations for mortality at $PM_{2.5}$ concentrations below 12 micrograms per cubic meter, as would be required to show causation at these concentrations." [565]

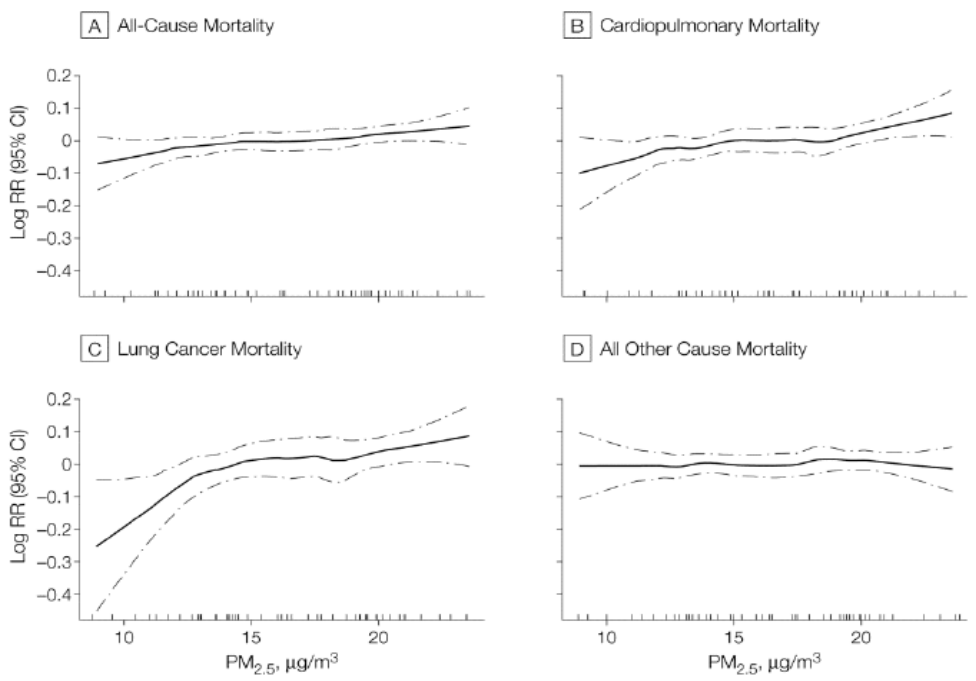
281. MLIG cautioned that it is critical to keep in mind that there are substantial differences in ambient, outdoor air across the United States and around the world, that the population throughout life breathes a complex mixture of gases and particulate matter, and that what is in the air varies considerably between homes, schools, work places and other environs where people live and work over a lifetime.[566]

282. MLIG further warned that evaluation of any airborne pollutant requires consideration of emissions from particular sources, transport and potential transformations in the atmosphere, exposure of receptor populations, uptake and translocation of the inhaled material by individuals, mechanisms of detoxification, damage and repairs, and occurrence of disease over and above that occurring naturally or from other causative factors.[567]

283. MLIG's witness, Dr. McClellan, interpreted the ACS results, and published his interpretations in a book chapter, referred to in this Report as the "Hazard and Risk chapter."[568] Based on Dr. McClellan's observations, MLIG asserted that "there is a small, but statistically significant, effect on all-cause mortality observed for $PM_{2.5}$, an even smaller effect for sulfate and SO_2, and no effect for NO_2."[569] In addition, MLIG noted the effects of one pollutant could confound the observations on the other pollutants.[570]

284. MLIG offered the following figure, reproduced from the Hazard and Risk chapter, to support its conclusion that "there is no medical evidence of any excess deaths associated with these low ambient concentrations of $PM_{2.5}$"[571]:

[564] *Id.*
[565] *Id.*
[566] Ex. 441, App. 2 at 3 (McClellan Rebuttal).
[567] *Id.*
[568] *Id.* at 2 (citing R.O. McClellan et al, Textbook of Environmental Medicine Chapter 4 (Hodder Education 1st ed. 2010).
[569] Ex. 441, App. 2 at 7 (McClellan Rebuttal).
[570] *Id.* at 7-8.
[571] *Id.* at 8, 16.



Vertical lines along x-axes indicate rug or frequency plot of mean fine particulate pollution; $PM_{2.5}$, mean fine particles measuring less than 2.5 µm in diameter; RR, relative risk; and CI, confidence interval.

Non-parametric smoothed exposure-response relationship. Vertical lines along the x-axes indicate a rug or frequency plot of mean fine particulate pollution. CI, confidence interval; RR, relative risk.

285. MLIG described the significance of the diagram, discussing Panels D and A, as follows:

> [S]tart with . . . all other cause mortality [panel D]. Now you see that straight line that's fit to it, that's a fit to the data and we have confidence intervals around it. Now that's essentially a flat line and it's law (sic) relative risk zero, that means one. That means [it] didn't matter what level of PM you're looking at, all other cause mortality wasn't associated with it and we wouldn't have expected it to. . . . .
>
> Now let's go to the all cause mortality up here in the left-hand corner [panel A]. And there, again, if we're to draw a straight line across at zero, we'd see that you have to get up here at about 15 before the relative log rounded risk starts to go up, but we still have error bars around it, it's uncertain. But what's most significant is that we look to the left side of this in that range of around 10 to 12 micrograms. And those error bars are very substantial. That's a measure – statistical measure of the uncertainty.[572]

[572] Tr. Vol. 7 at 205 (McClellan).

286. MLIG also asserted that the information available regarding morbidity and mortality attributed to $PM_{2.5}$ supports acknowledgment of "a high degree of uncertainty in any linear ambient air concentration morbidity or mortality function used for annual concentrations of $PM_{2.5}$ above 12 $\mu g/m^3$."[573]

287. MLIG focused on the increased protections established in 2012 by the EPA when it lowered the annual NAAQS for $PM_{2.5}$ from 15 to 12 $\mu g/m^3$. According to MLIG, the primary NAAQS standards must be set so that "the attainment and maintenance of [the standard], in the judgment of the [EPA] administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect public health."[574]

288. MLIG provided an overview of the kinds of expertise the EPA took into consideration in making its decision to lower the NAAQS standard, including review of the information it considered by the EPA's Clean Air Scientific Advisory Committee (CASAC).[575] MLIG maintained that, while the EPA, supported by CASAC, "found a causal relationship between ambient $PM_{2.5}$ and increased health risks at some level above 12 micrograms per cubic meter," they also stated "that the strength of the association, that mathematical association between ambient $PM_{2.5}$ at low concentrations and increased health risk is so uncertain they do not view the association as causal at ambient concentration of $PM_{2.5}$ below 12 micrograms per cubic meter."[576]

289. MLIG pointed to the EPA's final publication in the January 15, 2013 *Federal Register*, which was the final step in the review process,[577] where the EPA announced that "[t]his action provides increased protection for children, older adults, persons with pre-existing heart and lung disease, and other at-risk populations against an array of $PM_{2.5}$-related adverse health effects that include premature mortality, increased hospital admissions and emergency department visits, and development of chronic respiratory disease."[578]

290. MLIG noted that, in preparing the 2013 $PM_{2.5}$ NAAQS, the Administrator of the EPA recognized that the Clean Air Act:

> requires her to reach a public health policy judgment as to what standards would be requisite—neither more nor less stringent than necessary—to protect public health with an adequate margin of safety, based on scientific evidence and technical assessments that have inherent uncertainties and limitations. This judgment requires making reasoned decisions as to what weight to place on various types of evidence and assessments, and on the related uncertainties and limitations. Thus, in selecting the final standards, the

[573] Ex. 441, App. 2 at 9 (McClellan Rebuttal).
[574] Tr. Vol. 7 at 173 (McClellan).
[575] *Id.* at 170-171.
[576] *Id.* at 177.
[577] Ex. 444A at 3088 (Fed. Reg. Vol. 78, No. 10).
[578] Ex. 444A at 3088 (Fed. Reg. Vol. 78, No. 10).

> Administrator is seeking not only to prevent fine particle concentrations that have been demonstrated to be harmful but also to prevent lower fine particle concentrations that may pose an unacceptable risk of harm, even if the risk is not precisely identified as to nature or degree."[579]

291. MLIG explained that the EPA explored ways to take into account additional information from epidemiological studies.[580] Following those studies, the EPA and its scientific and epidemiological advisors determined that considering $PM_{2.5}$ concentrations down to the lowest concentration observed in a study would be "a highly uncertain basis for selecting alternative standard levels."[581] According to MLIG, notwithstanding this concern, the EPA took into consideration "studies that were very much towards the low end of the $PM_{2.5}$ ambient air concentrations."[582]

292. MLIG provided the EPA's graphic display of the most important studies, which showed, for all studies suggestive of a causal or likely causal relationship *and* all studies merely suggestive of a causal relationship, a 3-year average mean ambient air $PM_{2.5}$ concentration above 12 $\mu g/m^3$.[583]

293. MLIG acknowledged that the EPA Administrator's decision in setting the NAAQS standard is "a policy judgment based on [a] very substantial body of science."[584] That includes, for the EPA Administrator, exercising her judgment to determine the acceptability of the level of risk associated with the NAAQS level sufficient to be "protective of public health with an ample margin of safety."[585]

294. Dr. McClellan opined, with what he described as a "reasonable degree of medical certainty," that the current and projected levels of $PM_{2.5}$ in Minnesota will not cause additional mortality over and above that occurring naturally and from other causes.[586] For this reason, MLIG took the position that it is not appropriate to estimate damages for $PM_{2.5}$ in Minnesota.[587]

295. MLIG maintained that Xcel, the CEOs and the Agencies all failed to demonstrate, by a preponderance of the evidence, that there is "a causal link between any increase in the pollutant and increased disease regardless of the baseline of $PM_{[2.5]}$ in the ambient air."[588]

296. Ultimately, MLIG asserted that because the damages calculations presented by each expert witness retained by the CEOs, Xcel, and the Agencies are

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[579] Ex. 444A at 3097 (Fed. Reg. Vol. 78, No. 10).
[580] *Id.*
[581] Ex. 444A at 3129 (Fed. Reg. Vol. 78, No. 10).
[582] Tr. Vol. 7 at 106 (McClellan); Ex. 444A at 3135 (Fed. Reg. Vol. 78, No. 10).
[583] Ex. 444A at 3131-3133, 3135 (Fed. Reg. Vol. 78, No. 10).
[584] Tr. Vol. 7 at 184 (McClellan).
[585] *Id.*
[586] Ex. 441, App. 2 at 9 (McClellan Rebuttal).
[587] *Id.*
[588] Tr. Vol. 7 at 174 (McClellan).

based on national data related to ambient air concentration of $PM_{2.5}$ rather than local data, and none of the opinions consider lack of a linear relationship between mortality levels and lower $PM_{2.5}$ air concentrations, the calculations are inadequate and invalid.[589]

B. Responses to MLIG's Arguments

297. The Agencies cited to the *Lepeule* and *Krewski* studies, stating that the relationship between chronic exposure to $PM_{2.5}$ and all-cause, cardiovascular, and lung-cancer mortality is linear without a threshold.[590] The Agencies also highlighted two EPA studies using no-threshold models to estimate mortality functions.[591] In reviewing one of the EPA studies, the Health Effects Subcommittee of the EPA's Science Advisory Board proclaimed that using a no-threshold model is "supported by the data, which are quite consistent in showing effects [of $PM_{2.5}$] down to the lowest measured levels."[592]

298. The Agencies disagreed with MLIG's argument that the parties must show causation in the medical sense between increased CPs and health impacts. The Agencies maintained that the epidemiological literature, as well as studies by the EPA, have concluded that increased concentrations of air pollution are correlated with increased health impacts.[593]

299. The Agencies pointed out that MLIG's witness recognized that the EPA Administrator sets the NAAQS standards based on a mixture of "policy judgments as to acceptable levels of risk if the science does not identify a threshold level below which there are no identifiable risks."[594] Quoting Dr. McClellan, the Agencies argued

> [S]cience alone cannot identify an acceptable level of health risk, since such levels inherently represent a policy judgment call. Sound science can only inform what are ultimately policy judgments or political decisions. This is especially the case for the setting of NAAQS, in the absence of a clearly defined threshold, which involve decisions as to acceptable health risks which are linked to the level (and form) of the Standard.[595]

300. Furthermore, the Agencies pointed out the EPA has lowered the NAAQS over time as scientific evidence has revealed health risks at increasingly lower levels of $PM_{2.5}$ and O_3.[596]

301. According to the CEOs, MLIG's position that "there is no increased risk at [$PM_{2.5}$] concentrations below the national standards is incorrect and not supported by the

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[589] MLIG Initial Post-Hearing Brief (MLIG Initial Br.) at 4.
[590] Ex. 811 at 33 (Muller Surrebuttal); Agencies Initial Post-Hearing Brief (Agencies Initial Br.) at 41-42.
[591] Ex. 811 at 33-34 (Muller Surrebuttal).
[592] *Id.* at 34.
[593] Tr. Vol. 8 at 17-18 (Muller).
[594] Ex. 441, App. 2, Ex. A at 243 (McClellan Direct).
[595] Ex. 441, App. 2, Ex. A at 254 (McClellan Direct).
[596] *See* https://www3.epa.gov/ttn/naaqs/standards/pm/s_pm_history.html ($PM_{2.5}$) and https://www.epa.gov/ozonepollution/table-historical-ozone-national-ambient-air-quality-standards-naaqs (ozone) (EPA tables showing NAAQS standards over several decades).

scientific literature."[597] The CEOs asserted that Dr. McClellan's testimony "runs counter" to the testimony of each of the other parties' witnesses: Dr. Marshall, Dr. Muller, Dr. Desvousges, Dr. Polasky, and Dr. Jacobs.[598] The CEOs cited Lepeule for the proposition that "[i]ncluding recent observations with $PM_{2.5}$ exposures well below the U.S. annual standard of 15 $\mu g/m^3$ and down to 8 $\mu g/m^3$, the relationship between chronic exposure to $PM_{2.5}$ and all-cause, cardiovascular, and lung-cancer mortality was found to be linear without a threshold."[599]

302. The CEOs also pointed out that the NAAQS provides a margin of safety to protect public health as determined by the EPA Administrator, but does not define the boundaries of accurate scientific data available regarding an association between exposure to $PM_{2.5}$ and adverse health effects.[600] The CEOs asserted that MLIG's attempt to invoke the NAAQS as a basis for discounting quantifiable environmental and public health costs should be rejected.[601]

303. The CEOs maintained that "the literature shows that there is no threshold below which the relationship between $PM_{2.5}$ and mortality is not linear; or below which there is no relationship…. Instead, the linear relationship exists at all observed concentrations."[602]

304. Both the CEOs and the Agencies stated unambiguously that there is a linear relationship between $PM_{2.5}$ air concentration and mortality.[603]

CONCLUSIONS OF LAW AND FACT

I. Conclusions of Law

1. The Public Utilities Commission and the Administrative Law Judge have jurisdiction to consider this matter pursuant to Minn. Stat. §§ 14.50, 216B.01-.82 (2014), and Minn. R. 7829.1000 (2015).

2. The public and the parties received proper and timely notice of the hearings and the Commission and all parties complied with all procedural requirements of statute and rule.

3. The Administrative Law Judge concludes that the following burdens of proof apply in this proceeding:

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[597] Ex. 119 at 28 (Marshall Surrebuttal).
[598] *Id.*
[599] Ex. 117, Schedule 3 at 970 (Jacobs Rebuttal); *see also* CEOs Initial Post-Hearing Brief (CEOs Initial Br.) at 48.
[600] Tr. Vol. 7 at 184-89 (McClellan); CEOs Initial Br. at 49-50; CEOs Reply Post-Hearing Brief (CEOs Reply Br.) at 20.
[601] CEOs Reply Br. at 22.
[602] Ex. 117, Schedule 2 at 119, Schedule 3 at 967-68 (Jacobs Rebuttal).
[603] Ex. 117, Schedule 3 at 967-68 (Jacobs Rebuttal); Ex. 811 at 33 (Muller Surrebuttal).

a. A party or parties proposing that the Commission adopt a new environmental cost value for $PM_{2.5}$, CO_2, or NO_x, bears the burden of showing by a preponderance of the evidence that the value being proposed is reasonable, practicable, and the best available measure of the environmental costs of $PM_{2.5}$, CO_2, or NO_x

b. A party or parties proposing that the Commission retain any environmental cost value as currently assigned by the Commission bears the burden of showing by a preponderance of the evidence that the current value is reasonable and the best available measure to determine the applicable environmental cost.

c. A party or parties opposing a proposed environmental cost value must demonstrate that the evidence offered in support of the proposed values is insufficient to amount to a preponderance of the evidence.

4. Minnesota Statutes, section 216B.2422, subdivision 3 requires that the Public Utilities Commission "shall, to the extent practicable, quantify and establish a range of environmental costs associated with each method of electricity generation."[604]

5. The Administrative Law Judge concludes that the Commission's Notice and Order for Hearing in this docket requires the parties to evaluate the environmental cost values using a damage cost, as opposed to market-based or cost-of-control approach. The Commission found the damage cost approach superior to a market-based or cost-of-control approach "because it appropriately focuses on actual damages from uncontrolled emissions."[605]

6. The Administrative Law Judge concludes that the Commission found that quantification of environmental values "necessarily involves the consideration of scientific evidence that generally does not provide definitive answers. The statute . . . here requires the Commission to establish a range of values. Using a range appropriately acknowledges the uncertainty attending the quantification of environmental costs."[606]

7. The Administrative Law Judge concludes that the Commission required any consultant retained by the Agencies to use reduced form modeling to estimate damage costs in this proceeding.[607]

[604] Minn. Stat. § 216B.2422, subd. 3 (2014).
[605] NOTICE AND ORDER FOR HEARING at 4 (Oct. 15, 2014) (eDocket No. 201410-103872-02).
[606] 93-583 PUC ORDER 1 at 10.
[607] NOTICE AND ORDER FOR HEARING at 5 (Oct. 15, 2014) (eDocket No. 201410-103872-02).

II. Conclusions of Fact

A. InMAP Model

8. The Administrative Law Judge concludes that the CEOs failed to demonstrate by a preponderance of the evidence that the InMAP model is reasonable, practicable and the best model to measure the CP externalities. The CEOs did not present evidence that InMAP has been accepted for publication following peer review.

9. The Administrative Law Judge concludes that significant departures from the more typical reduced form models embodied in InMAP are the kind of innovations that call for support through peer review and some demonstration that InMAP has some history of having been relied upon in other settings for purposes analogous to the present proceeding.[608] Evidence of such support is not part of the record in this docket.

10. In addition to the general concern about InMAP as a model, the Administrative Law Judge concludes that several aspects of the CEOs' implementation of InMAP cast doubts on the CEOs' modeling results. The Administrative Law Judge concludes that the CEOs' choice to model counties as area sources rather than point sources may have led to inaccurate results.[609] While the CEOs provided the reason they chose to model counties as area sources, they did not respond to the underlying, substantive concern about the resulting inaccuracies that may have resulted from their choice. Thus, the CEOs did not meet their burden of demonstrating that modeling counties as area sources was reasonable.

11. The Administrative Law Judge concludes that the CEOs did not meet their burden of demonstrating that the performance evaluation comparing their results to 11 WRF-Chem control scenarios was valid because the CEOs failed to respond to Xcel's criticism that the WRF-Chem control scenarios were developed for measuring emissions from light-duty mobile vehicles, which are very different in nature from EGUs.[610]

12. The Administrative Law Judge concludes that the complexities that InMAP claims make it more accurate and realistic, such as calculating movement within a grid of hundreds of thousands of cells, and modelling pollutants moving from gas to particulate matter then back to gas, make InMAP much less transparent than a typical reduced form model. The Administrative Law Judge concludes that the CEOs did not show, by a preponderance of the evidence, that InMAP is a reliable reduced form model.

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[608] Although InMAP is a reduced form IAM, it is complex in some ways. For example, the CEOs stated that InMAP can model transformations of the individual pollutants from gas-phase to particulate matter and back to gas-phase "using reaction properties that vary from location to location." Ex. 115 at 13 (Marshall Direct). The CEOs asserted that this modeling is more realistic than other reduced form models because other models "generally assume chemical reactions only occur in one direction at a rate that does not vary." *Id.* Similarly, the CEOs claim InMAP is designed to calculate both dry and wet deposition of pollutants in a spatially explicit manner, using a combination of theoretical information and data from WRF-Chem. *Id.*

[609] *See* Findings 191-192 of this Report.

[610] Ex. 606 at 9 (Desvousges Rebuttal).

B. AP2 Model

13. The Administrative Law Judge concludes that the Agencies demonstrated by a preponderance of the evidence that the AP2 model has been peer-reviewed and that AP2 and its predecessor model, APEEP, have substantial history of being utilized for purposes similar to AP2's use in this proceeding.

14. The Administrative Law Judge concludes that the Agencies demonstrated by a preponderance of the evidence that it is reasonable to make annual estimates of O_3 and $PM_{2.5}$ values, as opposed to daily estimates, for the purpose of developing inputs to calculate the mortality concentration-responses.

15. The Administrative Law Judge concludes that the Agencies failed to demonstrate by a preponderance of the evidence that modeling individual pollutants separately is an approach commonly used in this field. The Administrative Law Judge further concludes, based on Xcel's comparative damage results, that AP2's modeling of pollutants separately did not appear to result in overstatement of nitrate formed.[611]

16. The Administrative Law Judge concludes that the Agencies demonstrated, by a preponderance of the evidence, that population-weighted exposure is an important measure in the context of this proceeding because human health effects are a large portion of the damage cost.

17. The Administrative Law Judge concludes that the Agencies' proposal to update the CP externalities values by using a formula that projects changes in populations and mortality rates but holds emissions constant is not a reasonable approach. There is no reason to believe that emissions will remain constant. Given that emissions drive mortality rates in this context, and that mortality rates have the largest impact on damages, the Administrative Law Judge concludes that the Agencies' update proposal will not result in reliable updates for CP externalities.

18. The Administrative Law Judge concludes that the Agencies failed to demonstrate by a preponderance of the evidence that the modeling of their hypothetical plants is reasonable. The Agencies assert the purpose of the hypothetical plants is to predict what the impacts would be if a plant were to be located in a county in a particular location. On one hand, the Agencies stated the hypothetical plants are intended to replace the values for the "largest emitters in the state"[612] but the Agencies' hypothetical replacement plants result in far higher damage costs than the Agencies' damage costs for the largest emitters.[613]

19. The Administrative Law Judge concludes that the Agencies did not demonstrate how or to what extent the damages attributed to the hypothetical plants were or were not included in any of the recommendations the Agencies made for total CP externalities costs in this proceeding.

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[611] *See* Finding 214 of this Report.
[612] Ex. 811 at 22 (Muller Surrebuttal).
[613] Ex. 606 at 6 (Desvousges Rebuttal).

20. The Administrative Law Judge concludes that the Agencies failed to demonstrate by a preponderance of the evidence that the AP2 model, when evaluated according to the Boylan and Russell performance standards, generally performs at the highest standards of the performance goals when compared to CAMx and generally performs at adequate standards of the performance criteria when compared to real ambient monitor data available from the EPA.

21. The Administrative Law Judge concludes that Xcel demonstrated by a preponderance of the evidence that the Agencies' performance evaluations are not reliable. The Agencies argued that, under the Boylan and Russell evaluation model guidance, annual and seasonal averages are appropriate because they are the degree of temporal resolution that is most significant for this proceeding. The Agencies asserted that annual and seasonal averages are most appropriate because the mortality concentration-response functions are based on annual data.[614] The Administrative Law Judge concludes that it is not the purpose for which the evaluated data will be used that is significant for establishing the temporal resolution of the evaluated data. Rather, it is the nature of the evaluated data itself. The EPA modeling guidance speaks of "evaluating a model by using the observed native averaging times . . . ."[615] The model should produce accurate results, regardless of the use to which the data will be put. To interpret the Boylan and Russell model instructions to allow annual and seasonal data based on the inputs for concentration-response functions as the Agencies have done does not follow logically. Therefore, the Administrative Law Judge concludes that by using annual rather than 24-hour averages, the Agencies have compromised the validity of the Boylan and Russell performance evaluations.

22. The Administrative Law Judge concludes that the Agencies failed to respond substantively to many of Xcel's additional concerns about the way in which the Agencies conducted the Boylan and Russell evaluations. Xcel raised specific and detailed questions, including:

- why the Agencies failed to use graphical displays to validate performance evaluations;
- why CAMx was presented in an annual average by grid and county;
- why the Agencies relied on the EPA CAMx run, the hourly predictions of which were collapsed into annual average values;
- why the comparisons were not presented in ambient concentration changes rather than absolute levels of ambient concentrations;
- why no separate analyses were made to account for concerns that AP2 suffers as a model in its ability to measure such impacts beyond 50 kilometers; and

[614] *See* Finding 178 of this Report.
[615] Ex. 606 at 52 (Desvousges Rebuttal).

- why use of 1990 meteorological data would not render the entire evaluation invalid.[616]

23. With the exception of the response that meteorological data does not vary much when averaged over years, the Agencies' primary response to these issues was that the positive evaluations themselves were proof that none of the irregularities mattered. The Administrative Law Judge concludes that the Agencies' responses in this vein are circular and unpersuasive. If the evaluations were conducted at least in part outside the established guidelines, then it is not clear to what extent the results can be relied upon. Thus, the Administrative Law Judge concludes that the Agencies failed to demonstrate by a preponderance of the evidence that the results of the AP2 Boylan and Russell performance evaluations provided in this proceeding are reliable.

C. CAMx Model

24. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that it took Xcel approximately four-and-a-half days to run a single quarterly simulation on CAMx. Given the computational demands of CAMx, the Administrative Law Judge concludes that it would not be practicable to use CAMx for approaches similar to those the Agencies and the CEOs used regarding the number of sources and source locations.

25. The Administrative Law Judge concludes that the preponderance of the evidence demonstrated that the CAMx model is capable of predicting impacts from CP emissions on ambient $PM_{2.5}$ including states at least as distant from one another as Minnesota is to Florida, based on information available on the EPA's CSAPR information website.[617] The Administrative Law Judge further concludes that different CAMx models are configured at different spatial resolutions which affect the accuracy of the models' predictions.[618] Therefore, the Administrative Law Judge is not able to draw any conclusions regarding the degree of accuracy CAMx models are able to achieve when predicting the impact of emissions over long distances.

26. The Administrative Law Judge concludes that, although Xcel's decision to combine its CAMx runs of the Sherco and Marshall plants cast some doubt on the results of that analysis, Xcel's later testing of each plant alone confirmed Xcel's theory that the two plants did not have significant impacts on one another's damage costs.

27. The Administrative Law Judge concludes that Xcel failed to demonstrate the reliability of its CP damages costs because Xcel failed to recalculate those costs following the discovery of its accidental use of $PM_{2.5}$ emissions data from its gas-fired Riverside facility in the emissions data used for the modeling of its hypothetical power plants. The Administrative Law Judge is unconvinced by Xcel's explanation that this error does not have an impact on the $PM_{2.5}$ externality values proposed by Xcel because of the

[616] *See* Finding 177 of this Report.
[617] Ex. 620 (EPA CSAPR spreadsheet).
[618] Ex. 119 at 14 (Marshall Surrebuttal).

linear nature of increased ambient concentrations of $PM_{2.5}$ from direct $PM_{2.5}$ emissions.[619] Specifically, the Administrative Law Judge concludes that Xcel failed to demonstrate why the simultaneous discharge of SO_2 and NO_x, which were reported in the correct quantities, and their mingling with the $PM_{2.5}$, which was reported in a greatly diminished amount, would not have altered the results of the modeling in question.[620]

28. The Administrative Law Judge concludes that CAMx is a reliable, established PGM, and would be appropriate to use in this matter, if the Commission chooses to limit the sources and source locations.

D. Spatial Sensitivity: Sources and Source Locations

29. The Administrative Law Judge concludes that the Agencies demonstrated by a preponderance of the evidence that Xcel's choice to model just three emission source locations within Minnesota put Xcel at a disadvantage in analyzing the spatial impact patterns of NO_x.[621]

30. The Administrative Law Judge concludes that the Agencies' statement that it is necessary to model sources outside the state if the Commission wishes to know what the impacts are from emissions produced outside the state does not require the Commission to adopt externalities values in this proceeding which include almost 400 sources and source locations outside Minnesota's borders, a number which makes including outside sources and source locations cumbersome and potentially confusing.

31. The Administrative Law Judge concludes that sources and source locations that are situated considerably southeast of Minnesota, such as in the vicinity of Milwaukee and Chicago, appear less likely to capture many emissions that will impact Minnesota locations than sources and source locations that are to Minnesota's west, south, southwest and northwest.[622]

32. The Administrative Law Judge concludes that the Commission's understanding of impacts from emissions produced outside the state does not require modeling of source locations outside of Minnesota where there are currently no active plants. Should such a plant be built in the future, the Administrative Law Judge concludes that the Commission can substitute the emissions costs from an existing (or hypothetical) source to estimate the effect of a new plant.

33. The Administrative Law Judge concludes that, in suggesting three approaches to using the damage costs for the out-of-state sources, the Agencies have not demonstrated how they will prevent the CP externalities values for these locations from including damages to out-of-state locations caused by out-of-state sources, should the Commission choose to include out-of-state impacts as well as out-of-state sources. For example, the Agencies have not demonstrated how damages in a Chicago receptor

[619] Ex. 609 at 12 (Desvousges Surrebuttal).
[620] *Id.*
[621] *See* Findings 180-182 of this Report.
[622] *See* Finding 43 of this Report.

location attributed to a source location in Wisconsin will not be included in Minnesota CP externalities numbers.

34. The Administrative Law Judge concludes that the Commission's decision in the First Externalities case to establish the three-tiered urban, metropolitan fringe and rural structure for all locations within Minnesota as well as to locations within 200 miles of the Minnesota border was made as the most reasonable, practicable decision at the time. This proceeding is the first opportunity the Commission has had to reconsider externality values or the structure of sources and source locations since it made that decision. As the parties have demonstrated in this proceeding, the science and the modeling capabilities have matured significantly since the First Externalities proceeding. Therefore, the Administrative Law Judge concludes that it would be reasonable for the Commission to choose some other means of structuring source locations, should it decide that another structure is practicable and necessary to provide additional useful information for resource planning, certificate of need, or other proceedings before the Commission.

35. The Administrative Law Judge concludes that the Agencies and the CEOs did not demonstrate, by a preponderance of the evidence, that their county-by-county source approach within Minnesota is a reasonable approach. It is not reasonable because nothing in the record indicates the Commission requires or has expressed a need for this level of detail in resource planning or certificate of need or related proceedings.

36. The Administrative Law Judge concludes that the Agencies' claim that the EPA's CAMx modeling run of the effect of Minnesota NO_x emissions on ambient concentrations of $PM_{2.5}$ across a number of states showed, for the time period included in the CAMx simulation, that approximately "two-thirds of the impact on concentrations of $PM_{2.5}$ from NO_x emissions produced by power plants in Minnesota occurs outside of the state"[623] is not supported by a preponderance of the evidence. While the mathematics behind the Agencies' statement appears to be straightforward on its face, the calculation was based on ambient monitoring receptor locations in the states involved.[624] There is no dispute that there is no relationship between the size of the state and the number of receptors. States choose to site receptors for a variety of reasons.[625] The Agencies' witness, Dr. Muller, acknowledged "If I were to design an experiment to glean this information, I would not do it this way. I was working with the best information that I had available, which is the network of monitoring sites . . . ."[626] Dr. Muller continued "that this is a suboptimal way to show that . . . ."[627] The Agencies relied on data that is unreliable for the present purpose.

37. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that primary $PM_{2.5}$ causes damages which are mostly local and regional. The Administrative Law Judge concludes that the preponderance of the

[623] Ex. 811 at 24 (Muller Surrebuttal).
[624] Tr. Vol. 8 at 104-110 (Muller).
[625] *Id.*
[626] *Id.* at 110.
[627] Tr. Vol. 8 at 110 (Muller).

evidence demonstrates that SO_2, and NO_x can travel significant distances, forming secondary $PM_{2.5}$ hundreds of miles from the source from which they were emitted.[628] The Administrative Law Judge concludes that the preponderance of the evidence failed to demonstrate the percentage of SO_2, and NO_x emitted in Minnesota that cause impacts and damages outside the state of Minnesota because the Agencies relied on skewed data to demonstrate that two-thirds of NO_x emissions from Minnesota cause damages outside of Minnesota.[629]

38. The Administrative Law Judge respectfully recognizes that the Commission may decide that it would be useful to have county-level CP externalities costs available to it. This is a policy decision most appropriately made by the Commission. The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated by a preponderance of the evidence that the computational intensity of CAMx would make it impracticable to use if the Commission were to determine that it prefers to adopt an approach involving many more sources and source locations than the approach taken by Xcel in this proceeding. The number of data runs required to accomplish the Agencies' and CEOs' approach renders the possibility of using a photochemical model impracticable. The Administrative Law Judge concludes that, should the Commission choose the county-by-county approach, the AP2 model would be the best reduced form model for such an approach.

39. The Administrative Law Judge concludes that, if the Commission determines that an approach to sources and source locations similar to that proposed by Xcel will meet its needs, then CAMx is the most reliable and accurate model of the three models presented in this proceeding. Whether CAMx is practicable in that situation is a question that the Administrative Law Judge respectfully concludes is best determined by the Commission, based on the Commission's evaluation of the time and expense involved in re-running the CAMx model.

E. Geographic Scope of Damages

40. The Administrative Law Judge concludes that the CEOs and the Agencies demonstrated by a preponderance of the evidence that emissions from Minnesota EGUs travel beyond Minnesota boundaries.

41. The Administrative Law Judge concludes that the CEOs did not meet their burden of demonstrating that InMAP is sufficiently accurate to rely on its estimates of CP externality values, including damages occurring within the entire contiguous U.S. The Administrative Law Judge's conclusion is based on the issues discussed at Conclusions 8 through 12 above, and the additional concern that the InMAP model "skews changes in ambient concentrations to the east based upon annual meteorological data and has

[628] Ex. 620 (EPA CSAPR spreadsheet); Ex. 621 (EPA CSAPR map).
[629] See Finding 38 of this Report.

results significantly higher than those obtained by [Xcel's and the Agencies'] modeling . . . ."[630]

42. The Administrative Law Judge concludes that the CEOs and the Agencies demonstrated, by a preponderance of the evidence, why they chose the studies they relied upon for their damage cost analyses.

43. The Administrative Law Judge concludes that neither the CEOs nor the Agencies have proved by a preponderance of the evidence that their respective InMAP or AP2 models can reliably predict CP externality values across the contiguous U.S. As stated in Conclusions 8 and 9, the CEOs failed to demonstrate that, at this time, InMAP is generally recognized as reliable. In addition to the general concerns about InMAP's reliability, the Administrative Law Judge concludes that the CEOs failed to rebut Xcel's statements that InMAP "skews changes in ambient concentrations to the east based upon annual meteorological data and has results significantly higher than those obtained by [Xcel's and the Agencies'] modeling . . . ."[631]

44. The Administrative Law Judge concludes that the Agencies failed to overcome the questions raised by Xcel concerning application of the AP2 model to predict CP impacts at distances significantly beyond the 50 kilometers recommended by the EPA. The Agencies' failure is particularly troublesome in light of the twin concerns posed by the AP2 model's Gaussian plume and the nature of AP2's design that models individual pollutants separately, rather than leaving the stack simultaneously.

45. The Administrative Law Judge concludes that, regardless of the specific standards established by the federal Cross State Air Pollution Rule, the extent to which the CP damage costs for a receptor located in another state is fueled by sources outside of Minnesota is relevant to determining how much Minnesota sources are contributing to the other state's CP damage costs. For example, if a power plant in Wisconsin injects significant amounts of O_3 or NO_x into the Chicago area, and the Sherco plant contributes a small additional amount of NO_x to the Chicago area, the Sherco plant is not increasing the ambient concentration of $PM_{2.5}$ in Chicago to the same extent it is likely increasing the ambient $PM_{2.5}$ in Chicago. Put another way, but for the pollutants coming from Wisconsin, the NO_x traveling to the Chicago area from Sherco might result in much smaller increases in ambient $PM_{2.5}$ concentration. Therefore, the Administrative Law Judge concludes that, if damages are based on ambient concentrations at receptor sites outside of Minnesota based on Minnesota sources and source locations, then any out-of-state sources of pollution must be excluded from the Minnesota damage costs.

46. The Administrative Law Judge concludes that the question of whether the geographic scope of damages should extend beyond Minnesota's borders (or, if Xcel's CAMx model is used, beyond Xcel's CAMx model's range) is a policy question which is

[630] Ex. 606 at 29 (Desvousges Rebuttal). In general, when the parties presented estimates for the externalities values adjusted to reflect consistent parameters and inputs for illustrative purposes to compare the models, the InMAP model produced significantly higher results for $PM_{2.5}$ and NO_x and generally lower results for SO_2. *See* Findings 214, 222, 231 of this Report.
[631] Ex. 606 at 29 (Desvousges Rebuttal).

properly answered by the Commission. The Administrative Law Judge concludes that Minn. Stat. § 216B.2422, subd. 3, is silent as to whether or not the legislature expected the Commission to include damages outside of Minnesota.

47. The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that Minnesota's compliance with the standards established by CSAPR reduces cross-border CP damages to zero.

F. VSL and Concentration-Response Function

48. The Administrative Law Judge concludes that although Xcel, the CEOs and the Agencies' criticized one anothers' approaches to establishing recommended VSL and concentration-response functions, the parties ranges of acceptable values overlapped. The recommended ranges for dose concentration-response percentages and VSL amounts are as follows:

	Xcel[632]	CEOs[633]	Agencies[634]
VSL (in $millions)	$4.1-$7.9 $5.9 mean	$9.8 Alternative $7.7 (2015 $)	$3.7 - $9.5 (2011$)
Dose-Concentration Response	5.3%-7.3% 6.8% mean	7.8% (6% not unreasonable)	6%-14% (7.8% not fundamentally disagreeable)

49. The Administrative Law Judge concludes that $7.70 million is a reasonable VSL value which is within the recommended range for Xcel, the Agencies and the CEOs.[635]

50. The Administrative Law Judge concludes that 6.8% - 7.3% is both reasonable, and an acceptable dose-concentration response function range for Xcel, the Agencies and the CEOs.[636]

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[632] Ex. 604 at 24; WHD-1, Schedule 2 at 38 (Desvousges Direct).
[633] Ex. 115 at 22, 25 (Marshall Direct); Ex. 117 at 7 (Jacobs Rebuttal); Ex. 118 at 8 (Polasky Rebuttal).
[634] Ex. 808 at 41-42 (Muller Direct); Ex. 809, NZM-2 at 11-12 (Muller Direct Attachments); Ex. 811 at 30 (Muller Surrebuttal).
[635] Ex. 115 at 25 (Marshall Direct); Ex. 117 at 7 (Jacobs Rebuttal); Ex. 604 at 24 (Desvousges Direct); Ex. 808 at 41-42 (Muller Direct). The Administrative Law Judge notes that $7.70 would be $7.31 in 2011 dollars, still within the Agencies' range. Xcel did not specify the year for which its recommended range was expressed, but it referred to its study as a "2015 Study." Ex. 604 at 24 (Desvousges Direct). For purposes of this conclusion, the Administrative Law Judge presumes that $7.70 falls within Xcel's recommended range as well.
[636] Ex. 117 at 7 (Jacobs Rebuttal); Ex. 118 at 8 (Polasky Rebuttal); Ex. 604, WHD-1, Schedule 2 at 38 (Desvousges Direct); Ex. 809, NZM-2 at 11-12 (Muller Direct Attachments); Ex. 811 at 30 (Muller Surrebuttal).

G. Ambient Concentration of $PM_{2.5}$ Relative to Mortality

51. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the ambient air concentration of $PM_{2.5}$ in Minnesota and Wisconsin was generally under 12 $\mu g/m^3$ from 2012 to 2014.[637]

52. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the EPA NAAQS standard for $PM_{2.5}$ is currently 12 $\mu g/m^3$.[638]

53. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the EPA Administrator's decision regarding the NAAQS standards is based on a combination of science and policy judgments, through which she weighs an acceptable level of risk against an adequate level of protection of public health.[639]

54. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates the relationship between chronic exposure to $PM_{2.5}$ and all-cause cardiovascular and lung-cancer mortality is linear without a threshold.[640]

55. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the CEOs, the Agencies and Xcel all met their burdens of demonstrating that it is appropriate to calculate mortality and morbidity damages for emissions of $PM_{2.5}$ in Minnesota, even if the ambient concentration of $PM_{2.5}$ is below 12 $\mu g/m^3$.[641]

56. The Administrative Law Judge concludes that a preponderance of the evidence that Minnesota's compliance with the NAAQS does not reduce CP damages associated with human mortality to zero.[642]

57. Any Findings of Fact more properly designated as Conclusions of Law or Fact are hereby adopted as such.

Based upon these Conclusions of Fact and Law, the Administrative Law Judge makes the following:

RECOMMENDATIONS

1. The Administrative Law Judge respectfully recommends that the Commission approach this matter by first addressing the following issues:

a. What is the most appropriate value for the VSL?

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[637] See Finding 278 of this Report.
[638] See Findings 287-288 of this Report.
[639] See Findings 288-290 of this Report.
[640] See Findings 297, 299, 301, 303-304 of this Report.
[641] See Finding 301 of this Report; Minn. Stat. § 216B.2422, subd. 3.
[642] See Finding 302 of this Report.

b. What is the most appropriate concentration-response function?

c. What sources and source locations should be included?

d. What is the proper geographic scope of damages?

2. The Administrative Law Judge respectfully recommends, consistent with the parties' various recommendations, that the Commission adopt a VSL of $7.7 million.

3. The Administrative Law Judge respectfully recommends, consistent with the parties' various recommendations, that the Commission adopt a concentration-response function of 6.8 percent, or if the Commission prefers to adopt a concentration-response range to reflect uncertainty, a range of 6 percent to 7.3 percent.

4. The Administrative Law Judge respectfully recommends that the Commission choose one of the following options to determine the costs of CP Externalities:

a. Adopt a model configuration that provides a five- or six-tiered version of Xcel's three-tiered proposed sources and source locations. The Administrative Law Judge recommends that the additional tiers incorporate factors such as nearby topography, vegetation, buildings, etc. consistent with the Agencies' recommendations. The tiers could accomplish this by including variations on the rural category to account for rural settings that are isolated versus rural settings that are less so, and possibly a "small town" category. This would enable the Commission to gain additional information beyond the three categories Xcel proposed. If the Commission chooses this option, the Administrative Law Judge respectfully recommends that the Commission choose the CAMx model, if the Commission finds that the CAMx model would be practicable to use with this somewhat expanded scope. The Administrative Law Judge recommends the CAMx model because it is more reliable than AP2.

b. Adopt a model configuration that includes all 87 counties in Minnesota, but only out-of-state sources that reflect active EGUs in the out-of-state locations. The Administrative Law Judge recommends that county-specific information not be combined or averaged, but used as the CEOs recommended it be used. In addition, the Administrative Law Judge recommends that the Commission exclude out-of-state sources located in eastern Wisconsin, Michigan and Illinois. If the Commission chooses this option, or some variation of it that is similar in scope and size, the Administrative Law Judge recommends that the Commission choose the AP2 model, which is generally recognized as a reliable model and would be capable of modeling the much larger number of modeling runs needed with this configuration.

5. As explained in Conclusion 46, the Administrative Law Judge concludes that the question of geographic scope of damages is a policy matter to be decided by the Commission. If the Commission chooses to include the contiguous U.S. or some substantial area outside of Minnesota in the CP externalities costs, the Administrative Law Judge respectfully recommends the CAMx model as the most reliable model to calculate those externalities costs.

Dated: June 15, 2016

LAURASUE SCHLATTER
Administrative Law Judge

Court Reporter: Janet Shaddix

NOTICE

Notice is hereby given that exceptions to this Report, if any, by any party adversely affected must be filed under the timeframes established in the Commission's rules of practice and procedure, Minn. R. 7829.2700, .3100 (2015), unless otherwise directed by the Commission. Exceptions should be specific and stated and numbered separately. The Commission will make the final determination of the matter after the expiration of the period for filing exceptions, or after oral argument, if an oral argument is held.

The Commission may, at its own discretion, accept, modify, or reject the Administrative Law Judge's recommendations. The recommendations of the Administrative Law Judge have no legal effect unless expressly adopted by the Commission as its final order.

MEMORANDUM

I. Externalities Costs: Models

The parties explored the issues in this portion of the proceeding in depth and at length. In the end, however, the Administrative Law Judge cannot recommend to the Commission a specific externality value or range of such values proposed by any of the parties. As is apparent from reviewing the parties' externalities estimates, the numbers vary widely, if not wildly. Looking at $PM_{2.5}$ for example, the parties' ranges of recommended cost values include the following (values provided in short tons):

- Agencies (2015): $26,574 - $143,108
- CEOs' generic (2015): $125,000 - $218,000
  CEOs' Ramsey County: $31,384 - $54,929 (high stack height) to
  $339,329 - $591,975 (low stack height)
- Xcel's (2014): $3,437 - $8,441 (rural) $10,063 - $25,137 (urban).

Nothing in these widely disparate numbers provides a sense of precision or reliability. Once the parties attempted to control for inputs and parameters for the purpose of comparing their models, the results became less consistent and more difficult to explain. The Agencies recommended the Commission refrain from trying to make a decision based on the comparisons.

There are flaws with each of the models, or their implementations, or both. InMAP is innovative, but its results are so dramatically higher than the other parties' results that, given InMAP's lack of peer review and track record, the Administrative Law Judge cannot recommend it. AP2 has been successfully peer reviewed; and it and its predecessor, APEEP, have a positive history of being utilized. But the flaws in AP2's performance evaluation in this case rendered the evaluation unreliable. In combination with the doubts raised by the EPA's guidance regarding limitations on models that incorporate a Gaussian plume and Xcel's criticisms based on AP2's separately modeled pollutants, the Administrative Law Judge cannot recommend AP2 if the Commission chooses to estimate damages beyond Minnesota. The Administrative Law Judge is more inclined to recommend AP2 as long as the damages are confined to Minnesota, particularly if the Commission chooses many sources and source locations, making CAMx impractical to use. This recommendation is based on APEEP and AP2's recognition as generally reliable, and on AP2's more moderate cost damage estimates.

None of the parties criticized CAMx as a model, except to state that it is too cumbersome to use with the amount of detail the Agencies and CEOs claim is needed for the Commission's purposes. The other criticisms had to do with the implementation of CAMx, and with Xcel's handling of uncertainty as it applies to the VSL and the concentration-response function. The Administrative Law Judge views CAMx as the most reliable of the models, but is aware that the Commission explicitly preferred a reduced form model in the Notice and Order for Hearing in this matter. Should the Commission

choose CAMx, the Administrative Law Judge assumes it would have to be run again, adjusting for the incorrect modeling data (assuming the Commission chooses to retain Xcel's hypothetical plants), and using new inputs and parameters based on the Commission's other decisions in this case. Based on the comments at the hearing, the Administrative Law Judge presumes that would take at least a month of computer run time, in addition to necessary changes to the model. The record is silent as to what the cost of such a choice would be. Should the Commission choose to use the AP2 model, that might also require that the model be run again depending on how the Commission adjusts the inputs and parameters for the model. According to the testimony at the hearing, such a task is more quickly and easily accomplished than modifying and rerunning CAMx.

II. Externalities Costs: Parameters

The question of what number and configuration of sources and source locations will best serve the Commission is a question the Commission is most suitably positioned to answer. The Commission understands how it uses the externalities numbers and whether it is more useful to have 500 ranges of CP externalities numbers than it is to have three such ranges. Nothing in the law directs the Commission or the Administrative Law Judge how to make this determination, except that the decision should be practicable and lead to numbers that carry some indicia of reliability in what is an uncertain area. The Administrative Law Judge agrees with the CEOs that, if the Commission chooses the county-by-county model, it would be counterproductive to average or otherwise group the county numbers together. Such a choice would result in a loss of information, undermining the purpose of undertaking the more detailed analysis.

Similarly, the question of whether the Commission believes that CP externalities should include damages from the contiguous U.S. is a question of policy. It appears that CAMx can perform this estimate, although questions linger about CAMx's accuracy at significant distances, depending on the grid size that is used. Pollutants do not stop at state borders. On the other hand, the CSAPR provides safeguards to alert federal and state officials if damaging amounts of pollutants cross Minnesota's borders into other states. In the First Externalities case, the Commission chose to limit the damages geographically, based, at least in part, on the practicability of determining accurately what the damages are outside the state. It could make that choice again. Or, it could rely on the more sophisticated modeling techniques available to quantify the damages beyond Minnesota's borders to include a more complete estimate of the damages caused by Minnesota emissions.[643]

III. Externalities Costs: Inputs

The Administrative Law Judge is mindful that she made few conclusions regarding the parties' arguments about the correct values for the VSL and the concentration-

[643] As mentioned earlier in this Report, the Administrative Law Judge is concerned that if the Commission decides to use the broadest proposed sources and source locations as well as the contiguous U.S. damages scope, precautions will not be taken to refrain from counting damages both emitted and received outside Minnesota.

response function. Despite some differences regarding the best way to determine those values, the Agencies and the CEOs ultimately compromised and agreed on numbers acceptable to each. Although neither party dropped their strong criticisms of Xcel's method of reaching its values (nor did Xcel drop its criticisms of the other parties' methods of getting to their recommended values), in the end, there were ranges of numbers for both the VSL and the concentration-response function that were common among all three parties. The Administrative Law Judge recommends that the Commission adopt these values.

IV. MLIG: Human Health and Threshold Level of $PM_{2.5}$

The Administrative Law Judge finds several flaws in MLIG's argument that, because its expert found with a "reasonable degree of medical certainty"[644] that an ambient concentration of 12 $\mu g/m^3$ of $PM_{2.5}$ constitutes a floor below which causation of damages to human health damages can be shown, there should be no CP externalities costs applicable to human health in this proceeding.[645] First, the Administrative Law Judge finds, as a matter of law, that MLIG focused on the incorrect standard when it insisted that the parties advocating for damages costs based on effects on human health had to prove a causal link, as defined by the medical literature, between increased ambient concentration of CPs and increased mortality. The applicable statutory language requires the Commission, "to the extent practicable" to "quantify and establish a range of environmental costs *associated* with each method of electricity generation."[646] The language of the statute requires only that there be an association between the cost established and the pollutant emitted as a result of the electricity generation. Medical causation is not the statutory standard.

In addition, the Administrative Law Judge notes that the record demonstrated that researchers in the field currently have concerns about the long-term effects on human health of ambient concentration levels as low as 8 $\mu g/m^3$ of $PM_{2.5}$, and that the general trend over the years has been for the levels that are considered "safe" to be lowered. Therefore, neither the law nor the evidentiary record supports MLIG's arguments.

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[644] Tr. Vol. 7 at 173 (McClellan).
[645] It is not dispositive in this matter, but the Administrative Law Judge notes that MLIG's expert witness Dr. McClellan is not a medical doctor. He is a doctor of veterinary medicine. The Administrative Law Judge is willing to accept Dr. McClellan as an expert in the work relevant to this proceeding, but the Administrative Law Judge does not recognize Dr. McClellan's as an M.D. Therefore, he is not qualified to provide his opinion as to a "reasonable degree of medical certainty" regarding human health.
[646] Minn. Stat. § 216B.2422, subd. 3(a) (2014) (emphasis added).

STATE OF MINNESOTA
OFFICE OF ADMINISTRATIVE HEARINGS

FOR THE PUBLIC UTILITIES COMMISSION

In the Matter of the Further Investigation in to Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3	**ATTACHMENT A: LIST OF PARTIES AND THEIR EXPERT WITNESSES CRITERIA POLLUTANTS**

The parties in this proceeding sponsored the witnesses listed below. All of the witnesses' testimony was received. Witnesses whose hearing presence was waived by agreement of the parties are noted as such.

1. The Clean Energy Organizations (CEOs), sponsored the following witnesses:

- Dr. Julian Marshall: Dr. Marshall is an Associate Professor of Environmental Engineering in the Department of Civil, Environmental, and Geo-Engineering at the University of Minnesota. His research focuses on exposure to air pollution, with a focus on urban air pollution, air pollution and health impacts of transportation energy consumption, and measurement of $PM_{2.5}$ concentrations in developing countries. Dr. Marshall is an author or co-author on many peer-reviewed articles about exposure to air pollution, many of the articles incorporating modeling aspects.[647]

- Dr. David R. Jacobs: Dr. Jacobs is a Professor in the Division of Epidemiology and Community Health, School of Public Health at the University of Minnesota. He teaches epidemiology and community health. Dr. Jacobs is the local principal investigator for the MESA Air study of air pollution and its health effects, which is ancillary to the Multi-Ethnic Study of Atherosclerosis (MESA), a National Heart, Lung and Blood Institute contract ongoing since 1999 funded by the EPA. Dr. Jacobs' research encompasses, among many other areas, epidemiology, cardiovascular and chronic disease, lung function, air pollution and health.[648]

[647] Ex. 115 at 1-2 (Marshall Direct).
[648] Ex. 117 at 1-2 (Jacobs Rebuttal).

- Dr. Stephen Polasky: Dr. Polasky is a Regents Professor and the Fesler-Lampert Professor of Ecological/Environmental Economics at the University of Minnesota, Department of Applied Economics. His research and publications focus on issues at the intersection of ecology and economics, including the impacts of land use and land management on the provision and values of ecosystem services and natural capital, biodiversity conservation, sustainability, environmental regulation, renewable energy, and common property resources.[649] Dr. Polasky was a Senior Staff Economist for Environment and Resources for the President's Council of Economic Advisors (CEA) in 1998-1999, during which time he reviewed benefit-cost studies of regulations designed to improve air quality, including VSL issues.[650]

2. MLIG sponsored:

- Dr. Roger O. McClellan: Dr. McClellan serves as an independent advisor to public and private organizations on issues of air quality in the ambient environment and in the work place. He also serves in an editorial role for a number of journals. Dr. McClellan serves on the Adjunct Faculty of Duke University Medical Center and the University of New Mexico Medical Center. His areas of expertise include inhalation toxicology, aerosol science, comparative medicine and human health risk analysis. Dr. McClellan is a Doctor of Veterinary Medicine, but was elected to membership in the National Academy of Medicine in 1990 based on his contributions to improving human health.[651]

3. Northern States Power Company, d/b/a Xcel Energy (Xcel), sponsored:

- Dr. William H. Desvousges: Dr. Desvousges is the President of WH Desvousges & Associates, an environmental and economic consulting firm established in 2005. He has conducted economic valuation studies for more than 35 years, including natural resource damage assessments, environment costing, property valuation, and benefit-csot analyses of regulatory programs. Dr. Desvousges was the lead author of the damage cost study that was conducted on behalf of Xcel in the First Externalities case.[652]

- Mr. Richard A. Rosvold is the Air Quality Manager for Xcel, a position he has held for 9 years. He has a Bachelor of Chemical Engineering degree from the University of Minnesota with an emphasis in pollution control technology. Mr. Rosvold has worked in the air

[649] Ex. 100 at 1 (Polasky Direct).
[650] Ex. 118 at 1 (Polasky Rebuttal).
[651] Ex. 441 at 1-2 (McClellean Rebuttal).
[652] Ex. 604 at 1 (Desvousges Direct).

quality field for 27 years, focusing on air quality dispersion modeling and permitting, as a corporate air quality expert for a global specialty chemical manufacturing company, and in air quality permitting and compliance for Xcel in Minnesota.[653]

4. The Department of Commerce and Minnesota Pollution Control Agency (Agencies) sponsored:

- Dr. Nicholas Z. Muller: Dr. Muller is an Associate Professor of Economics with tenure at Middlebury College, a Research Associate with the National Bureau of Economic Research and, at the time he filed his testimony, a Visiting Professor of Economics at Carnegie Mellon University. Dr. Muller's PhD is in environmental and natural resource economics. His dissertation focused on modeling damages from air pollution in the contiguous United States. He has served as a consultant to the National Academies of Science, the U.S. Department of Justice and environmental non-profit organizations.[654]

[653] Ex. 607 at 1 (Rosvold Rebuttal).
[654] Ex. 808 at 1 (Muller Direct).

STATE OF MINNESOTA
OFFICE OF ADMINISTRATIVE HEARINGS

FOR THE PUBLIC UTILITIES COMMISSION

In the Matter of the Further Investigation in to Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3

ATTACHMENT B:
SUMMARY OF PUBLIC COMMENT

1. On August 26, 2015, a public hearing was held in the large hearing room at the Commission's office in Saint Paul.

2. Kevin Lee appeared on behalf of DHE and made a statement on the record regarding DHE's involvement in the proceedings.[655]

3. Bruce Gerhardson appeared on behalf of the Utilities and made a statement on the record regarding the Utilities' involvement in the proceedings.[656]

4. Andrew Moratzka appeared on behalf of MLIG and made a statement on the record regarding MLIG's involvement in the proceedings.[657]

5. Ben Gerber appeared on behalf of MCC and made a statement on the record regarding MCC's involvement in the proceedings.[658]

6. Hudson Kingston appeared on behalf of the CEOs and made a statement on the record regarding the CEOs' involvement in the proceedings.[659] Mr. Kingston also posted a chart showing the CEOs' proposed externality values.[660]

7. Sean Stalpes, a Commission staff member, attended the public hearing and explained the Commission's role in the proceedings on the record.[661]

[655] Public Hearing Tr. at 14-16 (Aug. 26, 2015) (eDocket No. 20159-113775-01).
[656] *Id.* at 16-19.
[657] *Id.* at 19-22.
[658] *Id.* at 23-26.
[659] *Id.* at 26-29.
[660] Public Hearing Ex. 1 (Aug. 26, 2015) (eDocket No. 20159-113729-02).
[661] Public Hearing Tr. at 30-31 (Aug. 26, 2015) (eDocket No. 20159-113775-01).

I. Public Hearing Comments

8. Approximately 100 members of the public attended the hearing and 34 individuals spoke on the record.[662] All speakers were afforded a full opportunity to make a statement on the record and to ask questions. In addition to the oral comments, 14 exhibits were received as part of the public hearing record.[663]

9. Eight individuals spoke on the record in support of the position being taken by the CEOs in this matter.[664]

10. Fourteen members of the public specifically urged the Administrative Law Judge and the Commission to adopt the Federal Social Cost of Carbon.[665] However, Jim Horan, counsel for the Minnesota Rural Electric Association, specifically disagreed with the Federal Social Cost of Carbon and voiced his concern that energy prices will increase without any benefit to the state.[666]

11. Four individuals raised concerns about health problems caused by air pollution, especially asthma and pulmonary diseases.[667] A letter addressing the issue

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[662] Public Hearing Sign-In Sheet (Aug. 26, 2015) (eDocket No. 20159-113729-01).
[663] Public Hearing Tr. at 3 (Aug. 26, 2015) (eDocket No. 20159-113775-01).
[664] Comment by Amy Blumenshine (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Benjamin Bourgoin (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Alexis Boxer (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Rebecca Corruccini (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Carrie Johnson (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Beth Mercer-Taylor (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Grant Ruckhein (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Preeti Yonjon (Aug. 26, 2015) (eDocket No. 20159-113729-01).
[665] Comment by Amy Blumenshine (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Alexis Boxer (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Sally Downing (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Julie Drennen (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by James Hietala (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Faith Holschbach (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 14 (Aug. 26, 2015) (eDocket No. 20159-113759-01); Comment by Boise Jones (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Rachel Kerr (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Linda Kriel (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Beth Mercer-Taylor (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Jean Ross (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Grant Ruckhein (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Tammy Walhof (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Preeti Yonjon (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 6 (Aug. 26, 2015) (eDocket No. 20159-113729-07).
[666] Jim Horan, Minnesota Rural Electric Association (Aug. 26, 2015) (eDocket No. 20159-113729-01).
[667] Comment by Tess Ergen (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Kerry Felder (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Iresha Herath (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Carrie Johnson (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Boise Jones (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 5 (Aug. 26, 2015) (eDocket No. 20159-113729-06); Comment by Linda Kriel (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 3 (Aug. 26, 2015) (20159-113729-04); Comment by Beth Mercer-Taylor (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Katie Mercer-Taylor (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Karen Monahan (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Stephanie Spitzer (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Brady Steigauf (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Rose Thelen (Aug. 26,

and signed by 29 doctors and public health professionals from across Minnesota was entered into the record.[668] Some of the concerned individuals believe the profits of utilities are being put ahead of the protection of human health.[669]

12. Three individuals spoke specifically about the affects air pollution has on low income neighborhoods and people.[670] Kerry Felder, a resident of North Minneapolis and secretary for the Minneapolis NAACP, talked about low income people who struggle to pay utility bills and watch their children suffer from asthma, and asked for a progressive solution addressing both issues.[671]

13. Michael Troutman, a member of the nonprofit Bread for the World, a national organization fighting hunger and poverty globally, asked the Administrative Law Judge and the Commission to consider the moral cost of air pollution and climate change.[672]

14. Louis Asher and Dale Lutz highlighted a program used by 3M called Pollution Prevention Pays, and recommended consideration of the program as a model.[673]

15. Two members of the public voiced their belief that adoption of higher cost values will drive greater growth and use of sustainable energy sources.[674] Lea Foushee, the Environmental Justice Director for the North American Water Office, stressed that electric utility industry profits must be tied to the efficient use of their product.[675]

16. Julie Drennen, a member of the Sierra Club, submitted video statements from 25 individuals living in Minnesota describing their feelings about the true cost of

2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 13 (Aug. 26, 2015) (eDocket No. 20159-113730-04); Comment by William Waisbren (Aug. 26, 2015) (eDocket No. 20159-113729-01).

[668] Public Hearing Ex. 2 (Aug. 26, 2015) (eDocket No. 20159-113729-03).

[669] Comment by Brady Steigauf (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by William Waisbren (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Michael Troutman (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 12 (Aug. 26, 2015) (eDocket 20159-113730-02); Comment by John Landgraf (Aug. 26, 2015) (eDocket No. 20159-113729-01).

[670] Comment by Kerry Felder (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Boise Jones (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Carrie Johnson (Aug. 26, 2015) (eDocket No. 20159-113729-01).

[671] Comment by Kerry Felder (Aug. 26, 2015) (eDocket No. 20159-113729-01).

[672] Comment by Michael Troutman (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 12 (Aug. 26, 2015) (eDocket 20159-113730-02).

[673] Comment by Louis Asher (Aug. 26, 2015) (eDocket No. 20159-113729-01); Comment by Dale Lutz (Aug. 26, 2015) (eDocket No. 20159-113729-01).

[674] Comment by Tim Chapp (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 7 (Aug. 26, 2015) (eDocket No. 20159-113729-08); Comment by Diwin Daley (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 11 (Aug. 26, 2015) (eDocket No. 20159-113730-02).

[675] Comment by Lea Foushee, North American Water Office (Aug. 26, 2015) (eDocket No. 20159-113729-01); Public Hearing Ex. 4 (Aug. 26, 2015) (eDocket No. 20159-113729-05).

pollution.[676] All of the individuals urged the Commission to recognize the negative impacts of pollution and increase the cost values accordingly.[677]

17. The Sierra Club also submitted more than 2,000 petitions signed by individuals living in Minnesota who believe public officials should implement policies to support clean energy. The petitions, addressed "Dear Commissioner:" read as follows: [678]

> I urge you to recognize the true costs of pollution by updating pollution cost estimates for utility energy planning based on current, credible science. Pollution from fossil fuels costs Minnesotans $2.1 billion annually in health and environmental costs – 94 percent of this impact is from coal. Burning coal at Xcel Energy's Sherco plant in Becker contributes to an estimated 1600 asthma attacks, 150 heart attacks and 92 deaths each year.
>
> Scientists and health experts have made significant progress in the past 20 years in understanding just how damaging pollution is to our health and environment; yet, Minnesota hasn't updated its pollution cost estimates, except for inflation. In addition to our monthly electricity bill, when a utility chooses to continue to burn coal and other dirty fuel sources it is sticking us with the bill for increased health care expenses, missed work and school, and environmental damages. Please include the EPA's social cost of carbon and most up-to-date scientific costs for other pollutants in Minnesota's energy decision-making.
>
> It's time to count the true costs of pollution when making decisions about our energy future!

II. Written Public Comments

18. Three individuals submitted written comments via the Commission's SpeakUp website.[679] Two of the commenters voiced their support for adoption of the Federal Social Cost of Carbon, although both agreed the standard is a minimum starting point.[680]

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[676] Public Hearing Ex. 8 (Aug. 26, 2015) (eDocket No. 20159-113729-09); Public Hearing Ex. 9 (Aug. 26, 2015) (eDocket No. 20159-113729-10).
[677] Public Hearing Ex. 8 (Aug. 26, 2015) (eDocket No. 20159-113729-09); Public Hearing Ex. 9 (Aug. 26, 2015) (eDocket No. 20159-113729-10).
[678] Public Hearing Ex. 10 (Aug. 26, 2015) (eDocket Nos. 20159-114142-01, 20159-114143-01, 20159-114145-01, 20159-114148-01, 20159-114155-01, 20159-114156-01, 20159-114158-01, 20159-114159-01, 20159-114160-01, 20159-114161-01, 20159-114-162-01, 20159-114163-01, 20159-114164-01).
[679] Comment by Allan Campbell (Sept. 1, 2015) (SpeakUp) (eDocket No. 20159-114130-01); Comment by Barbara Draper (Sept. 15, 2015) (SpeakUp) (eDocket No. 20159-114130-01); Comment by Terrence Nayes (June 5, 2015) (SpeakUp) (eDocket No. 20159-114130-01).
[680] Comment by Allan Campbell (Sept. 1, 2015) (SpeakUp) (eDocket No. 20159-114130-01); Comment by Barbara Draper (Sept. 15, 2015) (SpeakUp) (eDocket No. 20159-114130-01).

19. On September 15, 2015, the Metropolitan Council submitted a written comment.[681] The Metropolitan Council "is responsible for coordinating regional transportation planning efforts" and has "adopted transportation plans [that] emphasize strategies and investments to reduce transportation-related greenhouse gas and criteria pollutant emissions."[682] The Metropolitan Council supports adoption of updated cost values and believes the updated values will help achieve "regional sustainability outcomes."[683]

20. On September 17, 2015, the Minnesota Rural Electric Association (MREA) submitted a written comment.[684] The MREA represents the interests of the state's 44 electric distribution cooperatives as well as the six generation and transmission cooperatives that supply them with power.[685] The MREA opposes an increase in externality cost values, "especially the use of an unrealistically high value of the federal Social Cost of Carbon for carbon dioxide emissions," based on its concern that higher externality costs will result in increased costs to its members.[686] Instead, the MREA urges the Administrative Law Judge and the Commission to consider the federal Environmental Protection Agency's Clean Power Plan to avoid burdening consumers with duplicative and potentially conflicting requirements.[687]

21. On September 17, 2015, the Minneapolis Health Department (MHD) submitted a written comment.[688] MHD believes that, as the largest city in Minnesota, Minneapolis "bear[s] a larger brunt of the burden of air pollution in [the] State."[689] MHD supports updating the cost values to reflect current scientific evidence on environmental externalities.[690]

22. On September 18, 2015, the Minnesota Division of the Isaak Walton League of America (MN-IWLA) submitted a written comment.[691] The MN-IWLA voiced its support for the position taken by the CEOs in the externality proceedings.[692] The MN-IWLA encouraged adoption of the Federal Social Cost of Carbon "as a transparent, well-vetted value for carbon dioxide."[693]

23. On September 18, 2015, Missouri River Energy Services (Missouri River) submitted a written comment.[694] Missouri River opposes adoption of the Federal Social

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[681] Comment by Metropolitan Council (Sept. 15, 2015) (eDocket No. 20159-114130-01).
[682] *Id.*
[683] *Id.*
[684] Comment by Minnesota Rural Electric Association (Sept. 17, 2015) (eDocket No. 20159-114087-01).
[685] *Id.*
[686] *Id.*
[687] *Id.*
[688] Comment by Minneapolis Health Department (Sept. 17, 2015) (eDocket No. 20159-114130-01).
[689] *Id.*
[690] *Id.*
[691] Comment by Minnesota Division of the Izaak Walton League of America (Sept. 18, 2015) (eDocket No. 20159-114120-01).
[692] *Id.*
[693] *Id.*
[694] Comment by Missouri River Energy Services (Sept. 18, 2015) (eDocket No. 20159-114102-01).

Cost of Carbon, and instead encourages the state "to create a single, centralized and consolidated state cost value for carbon dioxide rather than clinging to both regulatory and externality values applicable for matters governed by [the Commission] which results in multiple cost points."[695] Missouri River believes "it is premature for the Commission to adopt or modify a carbon dioxide value for externalities."[696]

[695] *Id.*
[696] *Id.*

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June 15, 2016

See Attached Service List

Re: In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3

OAH 80-2500-31888
MPUC E-999/CI-643

To All Persons on the Attached Service List:

Enclosed and served upon you is the Administrative Law Judge's **FINDINGS OF FACT, CONCLUSIONS, AND RECOMMENDATIONS: CRITERIA POLLUTANTS** in the above-entitled matter.

If you have any questions, please contact my legal assistant Katie Lin at (651) 361-7911 or katie.lin@state.mn.us, or facsimile at (651) 539-0310.

Sincerely,

LAURASUE SCHLATTER
Administrative Law Judge

LSS:kjl
Enclosure
cc: Docket Coordinator

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CERTIFICATE OF SERVICE

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3	OAH Docket No.: 80-2500-31888

Katie Lin, certifies that on June 15, 2016 she served the true and correct **FINDINGS OF FACT, CONCLUSIONS, AND RECOMMENDATIONS: CRITERIA POLLUTANTS** by eService, and U.S. Mail, (in the manner indicated below) to the following individuals:

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