414 Nicollet Mall
Minneapolis, MN 55401

March 15, 2016

—Via Electronic Filing—

The Honorable LauraSue Schlatter,
Office of Administrative Hearings
P.O. Box 64620
St. Paul, MN 55164-0620

RE: INITIAL POST-HEARING BRIEF REGARDING CRITERIA POLLUTANTS
INVESTIGATION INTO ENVIRONMENTAL AND SOCIOECONOMIC COSTS
MPUC DOCKET NO. E999/CI-14-643
OAH DOCKET NO. 80-2500-31888

Dear Judge Schlatter:

Northern States Power Company, doing business as Xcel Energy, submits this Initial Post-Hearing Brief related to Criteria Pollutants in the above-referenced docket.

This response has been filed in eDockets and thereby served on the parties to this proceeding. Consistent with the First Prehearing Order, we are also providing a printed version via U.S. mail to your office.

Please contact me at james.r.denniston@xcelenergy.com or (612) 215-4656 if you have any questions regarding this filing.

Sincerely,

/s/

JAMES R. DENNISTON
ASSISTANT GENERAL COUNSEL

Enclosures
c: Service Lists

STATE OF MINNESOTA
BEFORE THE OFFICE OF ADMINISTRATIVE HEARINGS
FOR THE
MINNESOTA PUBLIC UTILITIES COMMISSION

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3	OAH Docket No. 80-2500-31888 MPUC Docket No. E-999/CI-14-643

XCEL ENERGY'S INITIAL POST-HEARING BRIEF REGARDING CRITERIA POLLUTANTS ($PM_{2.5}$, SO_2, AND NO_x)

March 15, 2016

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INTRODUCTION

Northern States Power Company, doing business as Xcel Energy, respectfully provides this Brief in support of its proposed methodology to estimate the environmental cost of $PM_{2.5,}$ SO_2, and NO_x. We recommend that the Commission adopt a range of environmental values for each pollutant for three locations: rural, metropolitan-fringe, and urban areas. Our proposed values are based on an extensive damage cost study conducted by Dr. William Desvousges and his research team, including advanced air quality modeling by Ramboll Environ.[1]

The Company believes that the externality values should be based on the best and most accurate method that accounts for the majority of air quality changes and impacts from $PM_{2.5}$, SO_2, and NO_x emissions generated in Minnesota. In addition, the externality values should be practicable, meaning that they provide useful information and can in fact be applied for their intended purpose.

[1] Dr. Desvousges' Direct Testimony included two detailed reports, one describing his complete damage cost approach for developing environmental values (Schedule 2) and the other detailing Ramboll Environ's air quality modeling (Schedule3). *See* Ex. 604 (Desvousges Direct), Schedules 2 and 3.

Throughout this proceeding, we have identified numerous shortcomings with the air quality models and modeling parameters used by the experts representing the Department of Commerce and the Pollution Control Agency (the Agencies) as well as the Clean Energy Organizations (CEO). We do not believe that their air quality modeling results are reliable or reasonably accurate, and therefore the externality values should not be based on their models or modeling results. The Agencies and CEO proposed county-specific values for all 87 Minnesota counties and nearly 400 counties outside Minnesota, which is unnecessary and impracticable. Neither is it practicable or reasonable to estimate nationwide damages from $PM_{2.5}$, SO_2, and NO_x emissions generated in Minnesota, as the Agencies and CEO have recommended.

The Parties to this proceeding have proposed to use three different air quality models to develop externality values – AP2 (the Agencies), InMAP (CEO), and CAMx (Xcel Energy). AP2 and InMAP are both reduced-form models that use simplified chemistry equations based on annual average data, while CAMx is a photochemical grid model that incorporates hourly wind speed and direction as well as full-science chemistry algorithms. Not surprisingly, the three modeling efforts produced very different results. Considering that all three modeling approaches show vast differences in the predicted air quality changes and resulting externality values, it is simply not possible that they are all getting it right.

Both the Agencies and CEO have attempted to downplay the importance of the air quality model choice, and instead claim that some other decisions are more critical, such as the concentration-response function, value of a statistical life, geographic scope of damages, and development of county-by-county values.[2] We respectfully disagree. If the air quality model cannot predict ambient air concentration

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[2] Ex. 813 (Muller Opening Statement) at 2; Ex. 120 (Marshall Opening Statement) at 1-2.

changes reasonably accurately and instead produces results that are clearly flawed, the results should not be used as the basis for estimating and monetizing damages.

Predicting air quality changes from emissions is the first step in each Party's methodology, and the subsequent steps attempt to estimate and monetize the impacts. If this first step – air quality modeling – is flawed, it does not matter what the assumptions in the following steps are, because they will all be based on the underlying, but incorrect, air quality modeling results. Xcel Energy has strongly questioned the accuracy and credibility of the AP2 and InMAP air quality modeling results, and demonstrated why they are incorrect.

There is no doubt that Xcel Energy's damage cost study was more comprehensive, thorough, and scientifically robust than Dr. Muller's (the Agencies) or Dr. Marshall's (CEO) analyses. We predicted impacts from direct $PM_{2.5}$, SO_2, and NO_x emissions, including impacts from ozone and the secondary formation of $PM_{2.5}$; monetized damages for premature mortality and morbidity, agriculture, materials, and visibility; used a full-science photochemical grid model CAMx; modeled emissions profiles and other parameters based on a real power plant; and used Monte Carlo simulations to address uncertainty and create a combined distribution of concentration-response functions and the value of a statistical life.

The purpose of this proceeding is to examine the need for updating the existing externality values. We agree much has changed – the state of science has improved over the 20 years since the values were originally established. With the assistance of Dr. Desvousges, Xcel Energy has presented credible results using the most accurate air quality model and incorporating current science from the most recent epidemiological and economic studies. Xcel Energy respectfully recommends that the Commission adopt its proposed methodology and values as reasonable, practicable, and the best available measure to estimate environmental values for $PM_{2.5}$, SO_2, and NO_x.

STATEMENT OF THE ISSUES AND RULES

On February 10, 2014, the Commission reopened its investigation into environmental and socioeconomic costs,[3] and on October 15, 2014, the Commission referred the issues of the appropriate values for $PM_{2.5}$, SO_2, and NO_x to the Office of Administrative Hearing for a contested case proceeding.[4] The relevant statute in this proceeding, Minn. Stat. §216B.2422 subd. 3(a), states the following regarding environmental costs:

> "The commission shall, to the extent practicable, quantify and establish a range of environmental costs associated with each method of electricity generation. A utility shall use the values established by the commission in conjunction with other external factors, including socioeconomic costs, when evaluating and selecting resource options in all proceedings before the commission, including resource plan and certificate of need proceedings."

The Commission in this proceeding further ordered that the Parties must use a damage cost approach to estimate the environmental costs[5] and that if the Department of Commerce uses an expert consultant, any such consultant must use reduced-form modeling.[6]

After providing an opportunity for the Parties to present written Memoranda and Responsive Memoranda on burden of proof issues, the ALJ issued an Order

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

[4] *In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. §216B.2422, Subdivision 3*. Docket No. E-999/CI-14-643. NOTICE AND ORDER FOR HEARING. October 15, 2014. Order Point 3. Hereafter, documents in this Docket will be referred to by name and date only.

[5] NOTICE AND ORDER FOR HEARING, October 15, 2014, Order Point 4.

[6] NOTICE AND ORDER FOR HEARING, October 15, 2014, Order Point 5.

Regarding Burdens of Proof on March 27, 2015.[7] In essence, the ALJ ordered that any Party proposing that the Commission adopt a new value for $PM_{2.5}$, SO_2, and NO_x bears the burden of showing, by a preponderance of the evidence, that the value is "reasonable, practicable, and the best available measure of the criteria pollutant's cost."[8] In addition, the ALJ ordered that if a Party wishes to propose an externality value, it must file Direct Testimony in support of its proposal. If a Party did not propose an environmental value in Direct Testimony, a value may be offered in Rebuttal Testimony, but only if it is offered as a response to a cost value proposed in another Party's Direct Testimony.[9]

In an Order regarding MLIG and Peabody's motion to strike CO_2 testimony, the ALJ confirmed that the appropriate rule of evidence to apply in this case is the rule of the Office of Administrative Hearing.[10] This rule permits the admission of all evidence that has probative value, including hearsay, if it is the type of evidence on which reasonable, prudent persons are accustomed to rely in the conduct of their serious affairs (Minn. R. 1400.7300, subd. 1). The rule excludes evidence that is incompetent, irrelevant, immaterial, or unduly repetitious.[11]

ARGUMENT

I. CRITERIA FOR DECISION-MAKING

The Parties have made proposals based on three different methodologies and air quality models, which in turn produced very different estimates of the environmental cost of $PM_{2.5}$, SO_2, and NO_x. Because of this variety, it is important to

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[7] ORDER REGARDING BURDENS OF PROOF, March 27, 2015.
[8] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order point 2.
[9] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order points 6 and 8.
[10] ORDER ON MOTIONS BY MINNESOTA LARGE INDUSTRIAL GROUP AND PEABODY ENERGY CORPORATION TO EXCLUDE AND STRIKE TESTIMONY, September 15, 2015.
[11] ORDER ON MOTIONS BY MINNESOTA LARGE INDUSTRIAL GROUP AND PEABODY ENERGY CORPORATION TO EXCLUDE AND STRIKE TESTIMONY, September 15, 2015, Memorandum at 12-13.

establish decision-making criteria, which will give the ALJ and the Commission guidance on how to sort and evaluate the diverse proposals.

Xcel Energy clearly articulated in its Direct Testimony reasonable standards for the methodology to develop the environmental cost of $PM_{2.5}$, SO_2, and NO_x under Minn. Stat. §216B.2422 subd. 3(a) and proposed that the methodology should be based on a balanced consideration of the following:[12]

- 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.

Dr. Desvousges evaluated each Party's proposal against Xcel Energy's recommended standard of review criteria in his Rebuttal and Surrebuttal Testimonies.[13] Table 1 below summarizes how well each Party's recommendation meets the proposed review criteria, with green indicating a criterion is met, yellow that a criterion is met partially, and red that a criterion is largely not met.

[12] Ex. 604 (Desvousges Direct) at 4.
[13] Ex. 605 (Desvousges Rebuttal) at 15-16; Ex. 608 (Desvousges Surrebuttal) at 64-65.

Table 1. Updated Matrix Comparing all Parties' Proposals to Company's Criteria[14]

Criterion	Dr. Muller, DOC	Dr. Marshall, CEO	Dr. Desvousges, Company
Uses damage costs approach	[green]	[green]	[green]
Accurate	[red]	[red]	[yellow]
Credible	[red]	[red]	[green]
Addresses Uncertainty	[red]	[red]	[green]
Based on sound science and economics	[red]	[red]	[green]
Minimizes subjective judgments	[yellow]	[yellow]	[yellow]
Transparent	[yellow]	[yellow]	[green]
Replicable	[yellow]	[red]	[green]
Updateable	[green]	[red]	[yellow]
Practicable	[red]	[red]	[green]

Xcel Energy believes that the most important review criteria are that the environmental values are established based on credible and accurate estimates, which means that the models and methods must rely on sound science and economics. In addition, the environmental values should be practicable so that they can be used for their intended purpose and provide useful information in their application.[15] These criteria are reflected in the ALJ's Order Regarding Burden of Proof, which states that the environmental values selected for $PM_{2.5}$, SO_2, and NO_x must be "reasonable, practicable, and the best available measure of the criteria pollutant cost."[16] Throughout this proceeding, Xcel Energy has demonstrated how its proposal meets the recommended standard of review criteria, and why its proposal meets these criteria better than any other Party's proposal.

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[14] Reproduced Table 3 from Ex. 608 (Desvousges Surrebuttal) at 65.

[15] Ex. 605 (Desvousges Rebuttal) at 15.

[16] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order Point 2.

II. IS THE GEOGRAPHIC SCOPE OF ENVIRONMENTAL DAMAGES A LEGAL OR POLICY DECISION?

As directed by the ALJ during the evidentiary hearings,[17] we researched the legislative history and intent regarding the geographic scope of environmental costs. The purpose of this research was to examine if there is legislative history or intent to determine whether the geographic scope of damages estimated is a matter of law or if it is a policy decision for the Commission. The legislative history of Minn. Stat. § 216B.2422, Subd. 3 does not explicitly address whether the environmental costs should be measured based on their impact within Minnesota or nationwide, but the legislature's focus in the committee hearing was on Minnesota's need for the legislation. Ultimately, we believe the geographic scope of criteria pollutant damages is a policy decision for the Commission.

H.F. No. 1253 was introduced to the Minnesota House of Representatives on March 18, 1993 and was delegated to the Committee on Regulated Industries and Energy.[18] During the April 13, 1993 committee hearing, Representative Alice Hausman explained that the proposed amendment was a compromise between parties and was in response to the Public Utilities Commission's difficulties in quantifying externalities. Representative Hausman's remarks focused on the impact of the bill on Minnesota, especially Minnesota's economy and the hidden cost of energy sources that Minnesotans do not see in their electric bills. Representative Hausman further noted that "Our current patterns of energy production and use threaten both our environment and future economic growth."[19] Both the Committee and the legislature

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[17] Hearing Transcript, Vol. 8 at 157-159.
[18] *See* H. JOURNAL, 78th Sess., at 580 (Minn. 1993).
[19] *See Hearing on H.F. No. 1253 Before the H. Comm. on Regulated Indus. and Energy*, 1993 Leg. 78th Sess. (Minn. Apr. 13, 1993); statement of Rep. Alice Hausman, Member, H. Comm. On Regulated Indus. and Energy, available at Minnesota History Center Reference Library, Box 619, Tape Recording #5 of H. Comm. on Regulated Indus. and Energy Meeting on Apr. 13, 1993.

unanimously approved the amendment.[20] The legislature's emphasis on Minnesota is consistent with the Commission's original decision to estimate externality values for criteria pollutants based on concentration changes in Minnesota.

Minnesota courts grant deference to administrative interpretations of statutes unless that interpretation is arbitrary and capricious, or in conflict with the express purpose of the act and the intention of the legislature.[21] The level of deference increases when the agency, as here, is construing a statute which it administers and the construction is longstanding.[22] The original Commission interpretation, which estimated criteria pollutant impacts in Minnesota, is consistent with the legislative intent discussed above, which emphasized the protection of Minnesota's economy and environment. At the same time, the Commission has estimated externality values for CO_2 on a global basis. Considered together, this indicates that the geographic scope of criteria pollutants is a policy decision for the Commission.

It is our position that the geographic scope of criteria pollutant damages is a policy question, but there is a strong preference in the legislative history and Commission's long-standing precedent to focus on criteria pollutant impacts within Minnesota and their effects on Minnesotans.

III. DEVELOPMENT OF THE ORIGINAL EXTERNALITY VALUES

The current externality values for $PM_{2.5}$, SO_2, and NO_x were established nearly 20 years ago and they have been used since then by the Commission and Minnesota utilities without much controversy. The values were based on a state-of-the-science damage cost study by Triangle Economic Research (TER), whose lead author was Dr.

[20] *See* H. JOURNAL, 78th Sess., at 3745 (Minn. 1993).
[21] *See, e.g.*, *Mankato Citizens Tel. Co. v. Commr. of Taxn.*, 145 N.W.2d 313, 317 (Minn. 1966).
[22] *See McAfee v. Dept. of Revenue*, 514 N.W.2d 301, 304 (Minn. App. 1994).

Desvousges. The TER study used the best air quality model and science available at that time, examined criteria pollutant impacts in Minnesota, and developed environmental costs for three geographic locations.[23] It is worth noting that since the original proceeding, there have been no changes to the underlying statute, Minn. Stat. §216B.2422 subd. 3(a). In that proceeding, the ALJ and the Commission agreed on certain fundamental principles on how to establish the externality values, and we believe these principles can ultimately be characterized as policy decisions.

First, the ALJ and the Commission recognized the need for geographically sensitive criteria pollutant values and the ALJ recommended "that the Commission adopt geographically sensitive values *to the extent practicable*." [24] [emphasis added] Both the ALJ and the Commission concluded that three different value categories – rural, metro-fringe, and urban – were appropriate, practicable, and satisfied the need to consider the geographic location of the emission source. No Party proposed or suggested that a separate externality value should be established for each Minnesota county.

Second, the focus on estimating criteria pollutant values was clearly on Minnesota damages and costs to Minnesotans, which was stated many times by the ALJ: "Environmental values must reflect damages in Minnesota," "the ALJ's recommended proposed environmental cost values are based on damages that would occur in Minnesota," and "the ALJ accepts the Department's focus on damages occurring in Minnesota because any assessment of a resource option for providing

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[23] Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* FINDINGS OF FACT, CONCLUSIONS, RECOMMENDATION, AND MEMORANDUM. March 22, 1996 at 24; Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* ORDER ESTABLISHING ENVIRONMENTAL COST VALUES. January 3, 1997 at 17. The TER Study was also published as a book, *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method* by William H. Desvousges, F. Reed Johnson, H. Spencer Banzhaf, 1998, Edward Elgar Publishing Limited.

[24] Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* FINDINGS OF FACT, CONCLUSIONS, RECOMMENDATION, AND MEMORANDUM. March 22, 1996 at 20.

power to Minnesotans should consider the environmental cost to Minnesotans."[25] Similarly, the Commission undeniably confirmed that damages from criteria pollutants emissions should be estimated in Minnesota:

> 4. General Focus on Damage Occurring in Minnesota
>
> With the exception of the values adopted for CO_2, which causes damages globally rather than regionally or locally, the Commission has quantified the costs of environmental damage occurring in Minnesota. This is consistent with the approach recommended by the Department and found reasonable by the Commission that the Commission focus on the effects of by-products that cause the most significant costs. With respect to CO_2, this means assessing damage globally; for all other pollutants for which values are established in this Order it means quantifying the damage they cause in Minnesota. [26]

Third, the ALJ and the Commission concluded that it was practicable to estimate damages from sources located up to 200 miles from the state border, and hence the fourth category of values "within 200 miles of Minnesota" was created. However, no separate values were estimated or sources modeled outside of Minnesota, instead, the rural values were used as such, unchanged.[27]

Xcel Energy's proposed methodology to establish externality values follows the fundamental principles that were adopted in the original proceeding: we recommend estimating values for rural, metro-fringe, and urban scenarios based on damages occurring predominantly in Minnesota (and within 100 miles from the Minnesota border). We have revised the externality values using the best modeling and science available today, based on the need to incorporate improved scientific knowledge, to

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[25] Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* FINDINGS OF FACT, CONCLUSIONS, RECOMMENDATION, AND MEMORANDUM. March 22, 1996 at 20.

[26] Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* ORDER ESTABLISHING ENVIRONMENTAL COST VALUES. January 3, 1997 at 15.

[27] Ex. 605 (Desvousges Rebuttal) at 27.

update health and other impacts, and to reflect current economic studies. We do not, however, believe it is appropriate or reasonable to change some of the fundamental principles that were relied on to establish the original values. Our understanding is that this docket was re-opened because the current values were no longer reflecting the most recent scientific knowledge and studies, however, other Parties are now proposing to change significant principles that are, by nature, policy decisions, not questions of science.

IV. SUMMARY OF PARTIES' PROPOSALS

A. The Agencies

Dr. Muller testified for the Agencies. His analysis evaluated direct and secondary $PM_{2.5}$, SO_2, and NO_x (also ozone from NO_x emissions) and estimated damages for mortality, morbidity, and agriculture. Dr. Muller used a reduced-form model, AP2, to estimate county-by-county values for each criteria pollutant based on damages in the contiguous United States.[28] AP2 uses an air quality model component that is based on a source-receptor (S-R) matrix developed 20 years ago using a steady-state Gaussian plume model formulation. AP2 relies on annual average wind speed and direction data and assumes a constant wind speed and direction to transport emissions from the source to the receptors.[29] Dr. Muller modeled one incremental ton each of $PM_{2.5}$, SO_2, and NO_x in isolation of one another and did not account for any chemical interaction among the pollutants to resemble a point source plume. In addition to modeling one ton of each pollutant in each Minnesota county (87 counties), he also modeled an incremental ton of each pollutant in every county

[28] Ex. 808 (Muller Direct) at 14-15.
[29] Ex. 811 (Muller Surrebuttal) at 6; Ex. 605 (Desvousges Rebuttal) at 5, 33-35.

within 200 miles from the Minnesota border (368 counties), assuming that the emissions are dispersed from the county centroid (geometric center).[30]

Dr. Muller also modeled six named existing power plants (Sherco, High Bridge, Clay Boswell, Riverside, Black Dog, and A.S. King) in Minnesota as well as 26 large power plants located within 200 miles of the Minnesota border, based on their actual location and stack height, and one incremental ton of each pollutant.[31] The externalities values Dr. Muller reported for each county are inconsistent, because they are based on different sources—some existing, some hypothetical, and some a combination of both. Dr. Muller proposed specific values for nearly 500 different counties and existing power plants, but he did not propose a generic value.

B. CEO

Dr. Marshall testified for CEO. He used a brand new reduced-form model, InMAP, developed by his research team at the University of Minnesota. Similarly to Dr. Muller, Dr. Marshall also developed specific values for nearly 500 counties, and estimated damages in the contiguous United States. Dr. Marshall's modeling of hypothetical facilities assumed that 1,000 incremental tons of each pollutant were evenly emitted over each county, which means that a generating source was modeled as an area source rather than as a point source.[32] InMAP uses gridded annual average wind speed, direction, and turbulence data by averaging Weather Research Forecast WRF-Chem data over 12 months. In addition to modeling a hypothetical source in nearly 500 counties, Dr. Marshall modeled existing power plants in Minnesota, based

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[30] Ex. 808 (Muller Direct) at 18-20; Ex. 605 (Desvousges Rebuttal) at 5-6, 37-38.
[31] Ex. 808 (Muller Direct) at 18-21, Schedule 2 at 29; Ex. 605 (Desvousges Rebuttal), Schedule 1 at 15 (DOC Response to Xcel Energy IR No. 14). Dr. Muller also modeled all other smaller, existing power plants located in Minnesota and within 200 miles of the Minnesota border, assuming each was located in the county centroid.
[32] Ex. 605 (Desvousges Rebuttal) at 63-64; Ex. 608 (Desvousges Surrebuttal), Schedule 3 at 3 (CEO Supplemental Response to Xcel Energy IR No. 11).

on their actual location, stack height, and emissions.[33] He proposed a generic value based on the weighted average results from the existing Minnesota power plants.[34] Dr. Marshall's analysis did not include impacts from direct emissions of SO_2 and NO_x, ozone impacts from NO_x emissions, or any damages other than premature mortality due to direct and secondary emissions of $PM_{2.5}$.[35]

Dr. Jacobs testified to support Dr. Marshall's selected values for concentration-response functions (7.8 percent and 14 percent per every 10 μg/m^3 increase in $PM_{2.5}$), but also stated that Dr. Muller's values (6 percent and 14 percent) would be reasonable.[36]

Dr. Polasky testified to support Dr. Marshall's value of a statistical life (VSL) of $10.1 million ($2014, adjusted for income), but also stated that a VSL value of $7.7 million ($2014, combined hedonic wage and stated preference estimate, adjusted for income) from the Kochi study (Kochi et. al. 2006) would be appropriate.[37]

C. MLIG

Dr. McClellan testified for the Minnesota Large Industrial Group (MLIG). He stated that epidemiological studies do not show medical evidence of any excess mortality caused below $PM_{2.5}$ concentrations of 12 μg/m^3, the current level of National Ambient Air Quality Standards (NAAQS), and therefore it is inappropriate to establish externality values or estimate any damages from $PM_{2.5}$ for areas that are in attainment with NAAQS and where the annual level of exposure to $PM_{2.5}$ is less than 12 μg/m^3. According to Dr. McClellan, current levels of ambient $PM_{2.5}$ in Minnesota

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[33] However, because InMAP assumes that concentrations change linearly with marginal changes in emissions, the amount of emissions does not ultimately affect the results. *See* Ex. 608 (Desvousges Surrebuttal), Schedule 3 at 3 (CEO Supplemental Response to Xcel Energy IR No. 11).
[34] Ex. 115 (Marshall Direct) at 18; Ex. 608 (Desvousges Surrebuttal), Schedule 3 at 3 (CEO Supplemental Response to Xcel Energy IR No. 11).
[35] Ex. 115 (Marshall Direct) at 28.
[36] Ex. 117 (Jacobs Rebuttal) at 5-7.
[37] Ex. 118 (Polasky Rebuttal) at 4-8.

and nearby states are below the levels that would cause additional mortality on top of natural causes. In addition, he argued that Dr. Desvousges, Dr. Muller, and Dr. Marshall all failed to provide an adequate scientific basis for their linear treatment of concentration-response function – a purely mathematical exercise – and that there is no medical evidence of linearity at very low $PM_{2.5}$ concentrations.[38]

D. Xcel Energy

Dr. Desvousges testified for Xcel Energy. He estimated externality values for $PM_{2.5}$, SO_2, and NO_x for rural, metropolitan fringe, and urban locations, consistent with the practice established in the original externalities proceeding. $PM_{2.5}$ can be emitted directly (primary $PM_{2.5}$), but can also be formed secondarily from emissions of SO_2 (ammonium sulfate, $AmmSO_4$) and NO_x (ammonium nitrate, $AmmNO_3$). The effects of secondary $PM_{2.5}$ were attributed to NO_x and SO_2 as appropriate. In addition, ozone is formed in the atmosphere through a set of complex, non-linear photochemical reactions involving emissions of NO_x and volatile organic compounds. Ozone impacts were attributed to NO_x in Dr. Desvousges' analysis.[39]

For each location, Dr. Desvousges modeled one hypothetical, new, coal-fired power plant for each hour of the year to estimate changes in atmospheric chemistry over baseline concentrations. He used the photochemical grid model CAMx (Comprehensive Air Quality Model with Extensions) to model a hypothetical Black Dog facility in Dakota County, a hypothetical Sherco facility in Sherburne County, and a hypothetical Marshall facility in Lyon County. The hypothetical facility was modeled as a point source, based on Sherco Unit 1 operational data from 2014, using hourly-calculated plume rise, representative emission rates[40], representative stack

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[38] Ex. 441 (McClellan Rebuttal) at 12-20; Hearing Transcript, Vol. 7 at 174-178 (McClellan).
[39] Ex. 604 (Desvousges Direct) at 16.
[40] The Riverside emission rate of 9.4 tons was mistakenly used for $PM_{2.5}$. This was later identified and clarified; the results were not affected.

parameters (e.g., height, stack gas exit flow velocity, and temperatures), and hourly-varying meteorological conditions.[41]

Ambient air quality changes were estimated in Minnesota and parts of Iowa, Wisconsin, Michigan, Illinois, Nebraska, South Dakota, and North Dakota for each hypothetical source. Dr. Desvousges integrated post-processed, county-level CAMx results[42] into separate economic models to estimate the potential effects of these air quality changes on human health (premature mortality and morbidity, based on populations exposed), agriculture (crop production), materials (corrosion and soiling), and visibility.[43] Therefore, unlike Dr. Muller claims,[44] Dr. Desvousges did assess the criteria pollutant impacts based on the populations exposed at the county-level. The impacts were then monetized by estimating damages for each type of environmental cost for each location (urban, metropolitan-fringe, and rural).

Dr. Desvousges conducted an extensive literature review of current studies (e.g., health impacts, mortality risk evaluation, value of a statistical life) and explained the reasons why studies were included in or excluded from his damage cost analysis. In order to address the uncertainty in estimating human health impacts, he used an advanced Monte Carlo simulation to estimate and monetize potential mortality effects from increased concentrations of $PM_{2.5}$ by creating a combined distribution of concentration-response functions and VSL. Dr. Desvousges estimated human health damages based on the populations exposed to the air quality changes, and finally selected the 25th percentile and the 75th percentile from the combined mortality risk/VSL distribution to represent the low and high value estimates.[45]

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41 Ex. 604 (Desvousges Direct) at 18, Schedule 2 at 18-24, Schedule 3 at 20.
42 Hourly air quality data was post-processed to generate county-level concentration changes.
43 Ex. 604 (Desvousges Direct) at 19-21, Schedule 3 at 6; Ex. 605 (Desvousges Rebuttal) at 20, 29-30.
44 Ex. 811 (Muller Surrebuttal) at 7.
45 Ex. 604 (Desvousges Direct) at 21-25; Schedule 2 at 25-73.

Xcel Energy's recommended externality values are presented in Table 1 below (per short ton in 2014 dollars).

Table 2. Recommended Environmental Values (per Short Ton in $2014)[46]

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

For this proceeding, Dr. Desvousges' original analysis consisted of two CAMx modeling runs: Scenario 1 combined the hypothetical Sherco and Marshall facilities and Scenario 2 included the hypothetical Black Dog facility. The CAMx model includes source apportionment technology that can isolate the separate contributions from multiple hypothetical facilities. Running the Sherco and Marshall hypothetical facilities together in one CAMx source apportionment simulation (Scenario 1) did not affect the results. This was tested and demonstrated later by running Scenario 3 (including only the hypothetical facility located at Sherco) and Scenario 4 (including only the hypothetical facility located in Marshall).[47] The difference in the externality values between the original combined scenario and the latter separate scenarios was a mere 0.06 percent for the Sherco facility and 0.03 percent for the Marshall facility.[48]

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[46] Table 1 from Ex. 604 (Desvousges Direct) at 6.
[47] CEO describes the CAMx modeling scenarios in the Issues List, but omits the fourth scenario, which included the Marshall facility only. *See* Issues List at 8, 13-14.
[48] Ex. 605 (Desvousges Surrebuttal) at 2, 6-11, Schedule 5 (Xcel Energy Supplemental Response to CEO IR No. 6, including a detailed Memorandum, October 23, 2015), Schedule 6 (Memorandum, November 30, 2015).

The CAMx modeling used Sherco Unit 1 operational data and emissions data for SO_2 and NO_x from 2014, and inadvertently the Riverside 2014 emission rate for modeling direct emissions of $PM_{2.5}$. As explained several times in Dr. Desvousges' testimony, the use of Riverside $PM_{2.5}$ rate did not have an impact on the $PM_{2.5}$ externality values because of the linear nature of increased ambient concentrations of $PM_{2.5}$ from direct $PM_{2.5}$ emissions. All other necessary operating parameters, such as stack height, flue gas exit velocity and temperature, and MBtu consumption rate, were correctly based on Sherco Unit 1 data for $PM_{2.5}$, SO_2, and NO_x.[49]

V. ACCURACY OF MODELS AND RESULTS

A. The Values Proposed by Dr. Muller and Dr. Marshall Are Not Similar

Dr. Muller has indicated that there is broad agreement between the AP2 and InMAP models and that the estimated environmental cost values tend to be very similar.[50] In the same manner, Dr. Marshall believes that the choice between AP2 and InMAP is not very significant and seems to suggest that either of the models could be chosen because the results are comparable and presently there is no "robust evidence regarding whether AP2 or InMAP is more accurate."[51] Dr. Marshall goes as far as proposing that the Commission could adopt damage values based on the average results of AP2 and InMAP modeling.[52]

Xcel Energy respectfully disagrees. It is simply not true that the AP2 and InMAP modeling results are comparable, similar, or in any kind of agreement. All

[49] This error was also corrected in an errata filed on October 13, 2015. Ex. 604 (Desvousges Direct) at 18; Ex. 604A (Errata to Exhibit 604); Ex. 605 (Desvousges Rebuttal) at 5, 39-40, 42; Ex. 608 (Desvousges Surrebuttal) at 2-3, 7-13; Ex. 811 (Muller Surrebuttal), Schedule 1 (Xcel Energy Supplemental Response to DOC IR No. 16).
[50] Ex. 810 (Muller Rebuttal) at 8-10.
[51] Ex. 119 (Marshall Surrebuttal) at 8.
[52] Ex. 119 (Marshall Surrebuttal) at 7.

three models produced very different results, both regarding the predicted ambient air concentration changes (air quality modeling component) and the proposed environmental values (estimating and monetizing impacts). We will address in more detail the differences in predicting air concentration changes in a later section that discusses the accuracy of AP2 and InMAP air quality modeling, and briefly give some examples of the vast differences in the proposed environmental values here.[53]

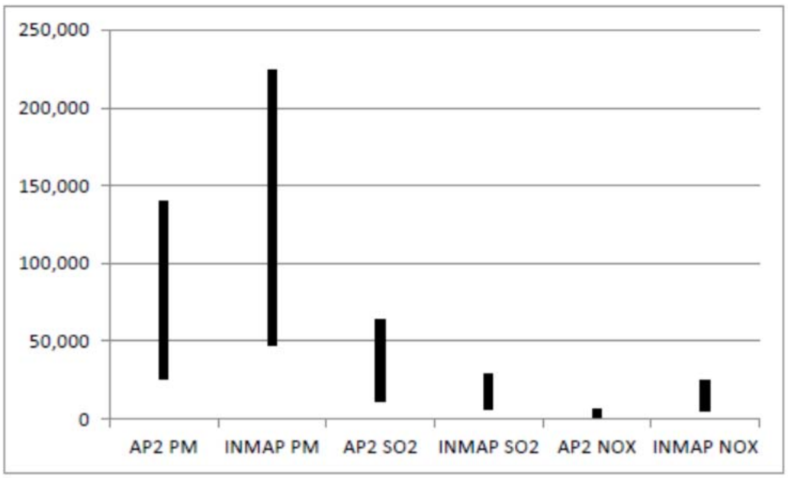
For example, Dr. Muller presented in his Rebuttal Testimony an analysis that compared AP2 and InMAP externality values after adjusting the VSL to the high and low VSL estimates used by himself.[54] Figure 1 below shows the average values from all sources modeled in Minnesota from AP2 and InMAP, using the high-end and low-end damage assumptions. It is clear from Figure 1 that Dr. Muller's and Dr. Marshall's externality values are not similar. AP2 predicts a range of $PM_{2.5}$ values from \$26,000 to \$140,000, while InMAP predicts a range of $PM_{2.5}$ values from approximately \$50,000 to \$225,000, double those of AP2's. InMAP's low and high $PM_{2.5}$ values are not only significantly higher than AP2's low and high $PM_{2.5}$ values, but the InMAP range is also substantially wider than the AP2 range. For SO_2, AP2 predicts significantly higher values, which are more than two times higher than the InMAP values (approximately \$10,000 to \$65,000 from AP2 versus \$5,000 to \$25,000 from InMAP). For NO_x, AP2 values are very low from almost zero to less than \$10,000, while InMAP values range from approximately \$8,000 to \$25,000.

53 Please note Figures 1 and 2 and Table 3 are not directly comparable to each other, because they are based on different adjustments and location sources.

54 Ex. 810 (Muller Rebuttal) at 8-10.

Figure 1. Comparison of AP2 and Adjusted InMAP Damage Values for $PM_{2.5}$, SO_2, and NO_x, Average Values for All Sources in Minnesota[55]

Figure 12. Comparison of External Cost Estimates Produced By InMAP and AP2 for All Sources in Minnesota



All values in $/U.S. short ton
Sources of information: Table 6 in DOC Ex.___ at 49 (Muller Direct) and CEO Ex.___ at 28 (Marshall Direct)

A second example of the different results between InMAP and AP2 is presented in Figure 2 below, which displays the estimated marginal damage values reported by each witness for direct $PM_{2.5}$ for the Black Dog, Sherco, and Marshall locations.[56] Figure 2, prepared by Dr. Muller, shows that there is little variation in the AP2 results by location, and that all three locations have a very wide range of $PM_{2.5}$ values, from about $20,000 up to $120,000. InMAP values include more variability by location and contrary to the previous example are significantly lower in this analysis than the AP2 values. For example, for the Sherco facility, InMAP values for $PM_{2.5}$ range from approximately $30,000 to $50,000, while AP2 values for $PM_{2.5}$ range from approximately $20,000 to $110,000.

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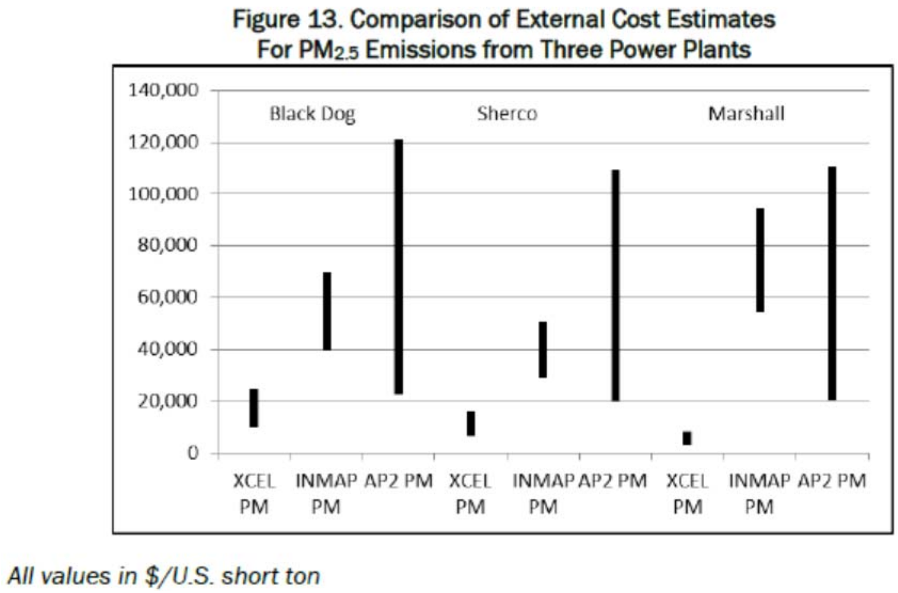
[55] Reproduced Figure 12 from Ex. 810 (Muller Rebuttal) at 9.
[56] Ex. 810 (Muller Rebuttal) at 21-22

Figure 2. $PM_{2.5}$ Values for Black Dog, Sherco, and Marshall Locations Based on AP2, InMAP, and CAMx (Xcel) Modeling[57]



The very wide range of AP2 values is the product of Dr. Muller's treatment of concentration response function and VSL. He chose a high and low value for each, and then combined the low concentration response function with the low VSL value to represent the low end of the range and the high concentration response function with the high VSL value to represent the high end of the range. This low/low and high/high approach dramatically increases the range of his externality values.[58]

Our third example is from Dr. Marshall's Rebuttal Testimony, where he adjusted Dr. Muller's modeling results to match his concentration-response function and VSL assumptions.[59] Table 3 below compares InMAP and adjusted AP2 damage values for $PM_{2.5}$, SO_2, and NO_x. It shows that the InMAP values for NO_x are nearly four times higher than the AP2 values for NO_x. On the other hand, the InMAP values for SO_2 are more than two times lower than the AP2 values for SO_2. For $PM_{2.5}$, the

[57] Reproduced Figure 13 from Ex. 810 (Muller Rebuttal) at 21.
[58] Ex. 604 (Desvousges Direct) at 50.
[59] Ex. 116 (Marshall Rebuttal) at 3-5.

InMAP values are once again higher, about 30 percent higher, than the AP2 values for $PM_{2.5}$.

Table 3. InMAP (Marshall) and Adjusted AP2 (Muller) Damage Values for $PM_{2.5}$, SO_2, and NO_x[60]

Table 1. Generic power plant damage costs adjusted to reflect recommended assumptions (currency year 2015).

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

Finally, based on their AP2 and InMAP modeling results, Dr. Muller and Dr. Marshall provided estimates of the proportion of the total damages from Minnesota sources occurring outside of Minnesota or beyond 100 miles from Minnesota. Dr. Muller stated that 60 percent of his calculated damages from $PM_{2.5}$ emissions occur outside of Minnesota, while Dr. Marshall reported that 26 percent of his calculated damages from $PM_{2.5}$ emissions are beyond 100 miles from Minnesota. Similarly, Dr. Muller stated that for NO_x, 65 percent of his calculated damages fall outside of Minnesota, while Dr. Marshall reported that 27 percent of his calculated damages from NO_x emissions are beyond 100 miles from Minnesota.[61]

While we dispute the accuracy of any of the AP2 and InMAP estimates presented above, these examples clearly show that the AP2 and InMAP modeling results are far from being alike or in agreement with one another. The results vary

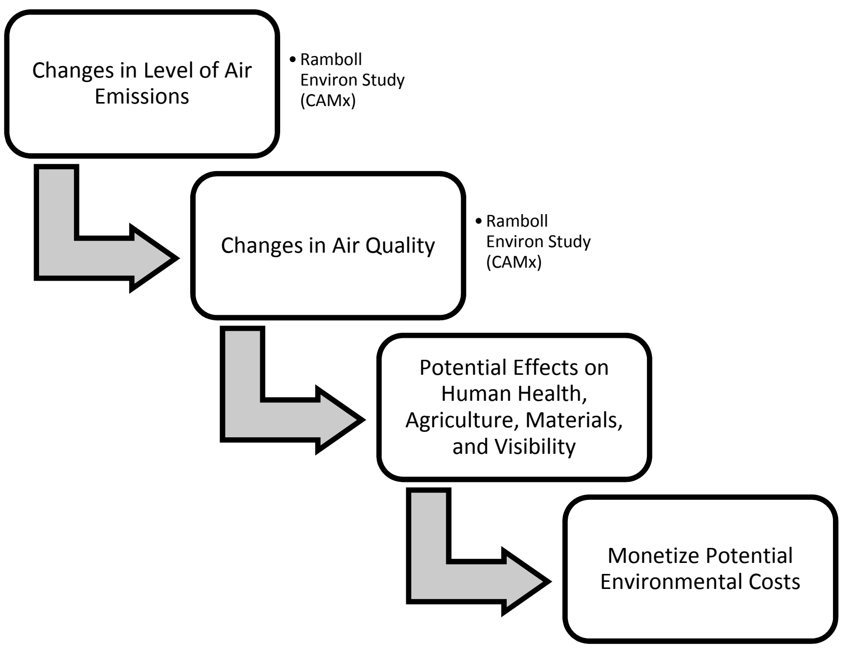
[60] Reproduced Table 1 from Ex. 116 (Marshall Rebuttal) at 4.
[61] See Ex. 605 (Desvousges Rebuttal), Schedule 1 at 29 (DOC Response to Xcel Energy IR No. 28); Ex. 810 (Muller Rebuttal) at 22; Ex. 116 (Marshall Rebuttal) at 12.

significantly, whether analyzed by pollutant, by individual source, or by geographic scope.

B. The Air Quality Models Used by Dr. Muller and Dr. Marshall Are Inappropriate for This Proceeding

All Parties have taken similar steps in their methodology to estimate criteria pollutant values and agree on the appropriate steps. For example, Xcel Energy presented the steps involved in the following way:

Figure 3. Estimating Environmental Costs from Air Pollution[62]



Dr. Muller and Dr. Marshall have both claimed that the air quality model that is used to estimate the first step in the process, air quality changes from emissions, is not as important as some of the other decisions that are made later, such as the geographic scope of damages estimated, the concentration response function, and the

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[62] Reproduced Figure 2 from Ex. 604 (Desvousges Direct) at 15.

VSL.[63] We disagree – if the underlying air quality modeling results are inaccurate, it does not matter what the choices in the next steps of the process are, because the results that follow will be incorrect as well.

1. The CAMx Model

CAMx incorporates hourly, varying, three-dimensional wind speeds and direction, temperature, humidity, and other conditions as well as full-science chemistry algorithms to model air quality changes. It is the only model in this proceeding that can accurately determine the dispersion of emissions throughout the year; includes chemistry in the point source plume; and accurately accounts for the chemical reactions in the atmosphere after the pollutants are emitted. Our CAMx modeling used realistic emission profiles and rates based on real power plants and modeled a representative ratio of each pollutant (1,169 tons of SO_2 per year, 3,508 tons of NO_x per year, and 9 tons of $PM_{2.5}$ per year), not the same incremental amount of each pollutant as Dr. Muller and Dr. Marshall did.[64]

CAMx was specifically designed to simultaneously model criteria pollutant emissions and is recommended by EPA for the modeling of ozone and secondary $PM_{2.5}$ formation. CAMx meets all of EPA's current and proposed air quality guidelines and guidance and it has been subject to hundreds of peer-reviewed journal articles and used in numerous EPA rulemakings such as the July 2011 Cross-State Air Transport Rule (CSPAR) and the July 2015 Transport for the March, 2008 Ozone National Ambient Air Quality Standards (NAAQS) analysis. Therefore, CAMx has been thoroughly tested and approved by the scientific and academic community. CAMx and all the supporting software have been publicly available for free for over ten years

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[63] Ex. 813 (Muller Opening Statement) at 2; Ex. 120 (Marshall Opening Statement) at 1-2.
[64] Ex. 604 (Desvousges Direct) at 16-18, Schedule 2 at 16-19; Ex. 605 (Desvousges Rebuttal) at 2-3, 20; Ex. 616 (Desvousges Opening Statement) at 1-5.

and the model has been downloaded more than 1,200 times in the last two years alone.[65]

2. The AP2 Model

There are several reasons why AP2's air quality modeling, as applied in this proceeding to estimate nationwide concentration changes, is not reliable. Since AP2 is a reduced-form model, it is based on simplified chemistry and air dispersion modeling, which assumes all emissions occur at the exact geographic center of the county; relies on annual average wind speed and direction data; and uses a constant wind speed and direction to transport emissions from the source to receptors. AP2 also relies on science and data that is outdated and from different time periods: it uses annual average meteorological data from 1990, emissions data from 2011, and is based on an air quality dispersion model approach that was developed more than 40 years ago in 1973.[66]

AP2 uses an air quality model component that is based on a source-receptor (S-R) matrix developed using a steady-state Gaussian plume model formulation, which assumes the instantaneous straight-line transport of emissions from the source to receptors. In reality, wind speed and direction are constantly changing both temporally and spatially, which impacts the dispersion of emissions and therefore changes in ambient concentrations.[67]

EPA publishes air quality modeling guidelines and guidance that detail their recommended modeling approaches for different applications. Current EPA air

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[65] Ex. 605 (Desvousges Rebuttal) at 18, 21-24, 35-37; Ex. 608 (Desvousges Surrebuttal) at 6; Ex. 616 (Desvousges Opening Statement) at 1.
[66] Ex. 605 (Desvousges Rebuttal) at 5, 19, 33-34, Schedule 1 at 8 (DOC Response to Xcel Energy IR No. 10); Ex. 811 (Muller Surrebuttal) at 3.
[67] Ex. 605 (Desvousges Rebuttal) at 19, 34.

modeling guidelines (40 CRF Part 51, Appendix W)[68] recommend that reduced-form models that rely on a steady-state Gaussian plume model formulation, such as AP2, should not be used when modeling SO_2, NO_x, and $PM_{2.5}$ impacts from a source to receptors located more than 50 kilometers away (equivalent to 31 miles). The EPA has set the 50 kilometer limit for steady-state Gaussian plume models because of gross overestimation bias at further downwind distances.[69]

In addition, AP2 uses highly simplified chemical transformation algorithms that cannot model ozone and secondary $PM_{2.5}$ concentrations reliably.[70] Ozone and secondary $PM_{2.5}$ formation have highly variable seasonal and daily variations that must be accounted for to accurately simulate the change in ambient concentrations, for example, ozone and secondary sulfate $PM_{2.5}$ formation is higher in the summer, whereas secondary nitrate $PM_{2.5}$ formation is higher during cooler periods.[71] EPA's current (2007)[72] and proposed (2014)[73] guidance for ozone and secondary $PM_{2.5}$ modeling recommend using photochemical grid models, such as CAMx, which incorporate full-science atmospheric chemistry.[74]

Since AP2 is a reduced-form model, it does not include flue gas chemistry and models SO_2, NO_x, and $PM_{2.5}$ in isolation from one another, unlike a real plume. Dr. Muller modeled an equal ratio of each pollutant – one incremental ton of each

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68 EPA 2005. "40 CFR Part 51: Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule." Federal Register, Vol. 70, No. 216, Wednesday, November 9, 2005. http://www3.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

69 Ex. 604 (Desvousges Direct), Schedule 3 at 2-3; Ex. 605 (Desvousges Rebuttal) at 21-22.

70 Dr. Muller himself acknowledges that AP2 models chemical reactions in the atmosphere "in a very simple way." Hearing Transcript, Vol. 8 at 29 (Muller).

71 Ex. 605 (Desvousges Rebuttal) at 34.

72 EPA 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze." April 2007. http://www3.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf

73 EPA 2014. "Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$ and Regional Haze." December 2014. http://www3.epa.gov/ttn/scram/guidance/guide/Draft_O3-PM-RH_Modeling_Guidance-2014.pdf

74 Ex. 605 (Desvousges Rebuttal) at 35-37.

separately – which may overestimate the impacts of SO_2 and NO_x on secondary $PM_{2.5}$ formation. As Dr. Muller himself characterized, if one ton of a particular pollutant is added to baseline admissions, "the change in concentration is strictly attributable to that ton."[75] However, in reality, power plants emit all three criteria pollutants together and they interact with each other.

AP2 is a later version of a well-known air quality model APEEP. However, the current version of AP2 used in this proceeding was designated as trade secret and undergoing peer-review.[76] The trade secret status was lifted on the first day of the evidentiary hearings, on January 12, 2016, but some aspects of AP2 are still not public.[77] Although Dr. Muller has stated that the current version of AP2 mostly updates emissions, population, and other input data to the year 2011,[78] the fact remains that the scientific community has not had a chance to review and test the accuracy of the current AP2 version.

Our strongest critique is not directed to the AP2 model itself, but to the manner in which it was applied in this proceeding. EPA does not recommend using a reduced-form model to estimate ozone and secondary $PM_{2.5}$ formation, and EPA clearly states that a steady-state Gaussian plume model should not be used to model SO_2, NO_x, and $PM_{2.5}$ impacts beyond a 50-kilometer distance from the source to the receptor. Regardless, Dr. Muller used AP2 to estimate ambient air concentrations from Minnesota sources across the contiguous United States, well beyond the 50-kilometer recommended limit.

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[75] Evidentiary Hearing Transcript, Vol. 8 at 10-11 (Muller).
[76] Ex. 605 (Desvousges Rebuttal) at 17.
[77] Hearing Transcript, Vol. 8 at 122-123 (Muller).
[78] Meteorological data is still from the year 1990. The parameters governing primary particles, emissions of SO_2, and the formation of particulate sulfate were increased. *See* Ex. 605 (Desvousges Rebuttal), Schedule 1 at 7 (DOC Response to Xcel Energy IR No. 9); Ex. 811 (Muller Surrebuttal) at 11.

Dr. Marshall has agreed with the limitations of steady-state Gaussian plume models:

> Gaussian plume models and models that are derived from them (e.g., APEEP, AP2) "analytically estimate the downwind impact of individual sources or source groups. These models are computationally inexpensive and useful for predicting near-source impacts but are not recommended for predictions of pollution over long distances (>50km, US EPA, 2015). Additionally, Gaussian plume models generally cannot robustly represent nonlinear or spatially variable rates of formation and evaporation of secondary $PM_{2.5}$."[79]

Dr. Muller has argued that he used AP2 because the Commission specifically ordered the Agencies to use a reduced-form model.[80] However, the Commission did not order the Agencies to specifically use the AP2 model or to change the geographic scope from Minnesota to estimate nationwide damages.

The fact that AP2 was not an appropriate model to use in this proceeding is evident in Dr. Muller's modeling results. Dr. Desvousges has exhaustively demonstrated in his testimony how Dr. Muller's random and sporadic modeling results due to NO_x emissions are clearly incorrect and how AP2 significantly over-predicts national $PM_{2.5}$ and SO_2 impacts.

3. The InMAP Model

InMAP is a brand new, experimental air quality model that was developed at the University of Minnesota by Dr. Marshall and his research team. InMAP is unlike any other model typically used for air quality modeling and does not fit any of the EPA's air quality model categories.[81] According to Dr. Marshall himself, "[T]o our

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79 Ex. 119 (Marshall Surrebuttal), Schedule 1 (Tessum, Hill, and Marshall 2015) at 9303-9304.
80 Ex. 811 (Muller Surrebuttal) at 6.
81 Ex. 605 (Desvousges Rebuttal) at 8, 23-24; Hearing Transcript, Vol. 6 at 28-29 (Xcel Energy Opening Statement). InMAP is not a steady-state Gaussian plume model nor a non-steady-state Gaussian puff model. *See* Ex. 604 (Desvousges Direct), Schedule 3 at 1-2.

knowledge, the modeling approach developed here is the first of its kind for air pollution."[82]

The current EPA guidelines for air quality modeling (40 CRF Part 51, Appendix W) set criteria for air quality models and indicate that models should be non-proprietary and publicly available; have received a scientific peer-review; and have performed well in past applications.[83] InMAP was originally designated as trade secret in this proceeding; that status was lifted after the filing of Rebuttal Testimony on November 13, 2015. There is no public record or evidence that InMAP has been used by scientists or researchers other than Dr. Marshall's team, and there is only one published article of InMAP application, authored by Dr. Marshall et. al.[84] As far as we understand, this article is a discussion paper that has not gone through the peer-review process.[85] InMAP was also the subject of a paper that was under review for another journal, *Environmental Science and Technology*, but this paper was not accepted for publication.[86] InMAP has not been used in any prior federal rulemakings or state-level regulatory proceedings.

Because InMAP has only been publicly available since November 13, 2015, the academic and scientific community has not had a chance to use InMAP, which is the typical way models are tested, improved, accepted, or rejected by peers. Xcel Energy strongly believes that the Commission should not make significant and long-lasting

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[82] Ex. 119 (Marshall Surrebuttal), Schedule 1 at 9285.
[83] Ex. 606 (Desvousges Rebuttal Non-Public) at 17, 22-24.
[84] The authors are Tessum, Hill, and Marshall. See Ex. 119 (Marshall Surrebuttal), Schedule 1; Hearing Transcript, Vol. 6 at 157 (Marshall).
[85] Ex. 119 (Marshall Surrebuttal), Schedule 1 at 9281. The article was published in the Discussions section of the journal Geoscientific Model Development and the cover page states "This discussion paper is/has been under review for the journal Geoscientific Model Development (GMD). Please refer to the corresponding final paper in GMD if available." No final paper in GMD has been presented to the record in this case.
[86] Ex. 608 (Desvousges Surrebuttal), Schedule 1 at 8 (CEO Response to Xcel Energy IR No. 6).

decisions regarding externality values based on a brand new model that has no proven track-record or acceptance by the scientific community.[87]

Dr. Desvousges has pointed out in his testimony several reasons why InMAP is not a reliable model to use in this proceeding. InMAP uses gridded annual average wind speed, direction, and turbulence data by averaging Weather Research Forecast WRF-Chem data over 12 months. Dr. Marshall fine-tuned the InMAP model with two calibration factors in order for his results to correlate better with the 11 WRF-Chem emission change scenarios (empirical factor F_A was added to advection equation and empirical factor K_{NH} was added to ammonium nitrate chemistry equation). The use of calibration factors demonstrates InMAP's inability to accurately estimate marginal changes in emission concentrations.[88] Furthermore, the WRF-Chem control scenarios were developed for mobile sources looking at alternative light-duty automobile controls (e.g., gasoline, several types of ethanol, and electric vehicles with different electricity sources). Mobile source emissions are modeled as low to ground area sources, while power plant emissions are modeled as atmospheric release point sources – adding calibration factors to InMAP to correlate with a mobile source scenario does not mean that the model was calibrated for modeling emissions from a point source.[89]

InMAP treats emissions as area sources, spreading emissions evenly across the entire county, although power plants are point sources whose transport, dispersion and chemistry of emissions behave very differently from an area source. For example, the high NO_x concentrations in a point source plume will inhibit ozone and secondary $PM_{2.5}$ formation until the plume is sufficiently dispersed. When treated as an area source, the NO_x emissions are instantaneously dispersed, which means that ozone and

87 Hearing Transcript, Vol. 6 at 29 (Xcel Energy Opening Statement).
88 Ex. 606 (Desvousges Rebuttal Non-Public) at 8, 62-63, 75-77.
89 Ex. 606 (Desvousges Rebuttal Non-Public) at 9, 75-77.

secondary $PM_{2.5}$ formation can begin immediately thereby likely overstating the ozone and $PM_{2.5}$ impacts.[90]

Similarly to Dr. Muller, Dr. Marshall also modeled the same amount of each pollutant (in his case, 1,000 tons each of SO_2, NO_x, and $PM_{2.5}$) for the county-by-county values, and did not account for any chemical interaction among the pollutants to resemble a point source plume.[91] Again, not taking into consideration chemical interactions in the plume will lead to an overestimation of the impacts of SO_2 and NO_x on secondary $PM_{2.5}$ formation, because this allows for a set amount of ambient ammonium present in the atmosphere to first bind with SO_2 to form secondary $PM_{2.5}$ and then to bind again with NO_x to form additional secondary $PM_{2.5}$.[92]

The weaknesses of the InMAP modeling are reflected in Dr. Marshall's results. Dr. Desvousges has demonstrated in his testimony how InMAP consistently and grossly over-estimates ambient concentration changes and how its results are biased to the east.

C. Dr. Muller's and Dr. Marshall's Air Quality Modeling Results Are Inaccurate

Throughout Dr. Desvousges' Testimonies and again in this Brief, we have attempted to describe the complex scientific and technical concepts that explain why AP2 and InMAP air quality modeling results are not reliable or accurate enough to form the basis for updating the Minnesota externality values. In this section, we present several maps of the modeling results, which visually confirm our statements.

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[90] Ex. 605 (Desvousges Rebuttal) at 8, 63-64, Schedule 2 at 17 (CEO Response to Xcel Energy IR No. 15).
[91] "So InMAP is a reduced-form model, the pollutants don't interact with each other in the way that we're running it." Hearing Transcript, Vol. 6 at 182 (Marshall). This in fact has the same effect as modeling the three pollutants separately in isolation from one another.
[92] Hearing Transcript, Vol. 7 at 135-137 (Desvousges).

Dr. Desvousges' CAMx air quality modeling results are consistent with what is known about the science of air dispersion and chemistry: The highest changes of $PM_{2.5}$, NO_x, and SO_2 concentrations occur closest to the source with concentrations decreasing as a function of distance from the source. The results show concentration changes for $PM_{2.5}$, NO_x, and SO_2 in every Minnesota county, as is expected, and do not skip any Minnesota counties. In addition, Dr. Desvousges' proposed externality values are consistently lowest for the rural scenario, then higher for the metropolitan fringe scenario, and highest for the urban scenario, as is expected because the values are significantly affected by the size of the population that is exposed to the air quality changes.[93]

In contrast to CAMx, Dr. Muller's AP2 modeling and Dr. Marshall's InMAP modeling show results that are unexpected and inconsistent with what is known about atmospheric dispersion and chemistry.

The following three figures present comparable results for annual average secondary $PM_{2.5}$ concentrations due to Sherco NO_x emissions. Figure 4 shows CAMx modeling results for the Minnesota modeling domain[94] from the hypothetical Sherco facility,[95] Figure 5 shows AP2 modeling results for the Minnesota modeling domain from the actual Sherco plant,[96] and Figure 6 shows InMAP modeling results for the Minnesota modeling domain from the actual Sherco plant.[97]

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[93] E.g., Ex. 605 (Desvousges Rebuttal) at 57-61, Schedule 5; Ex. 608 (Desvousges Surrebuttal) at 17-32.

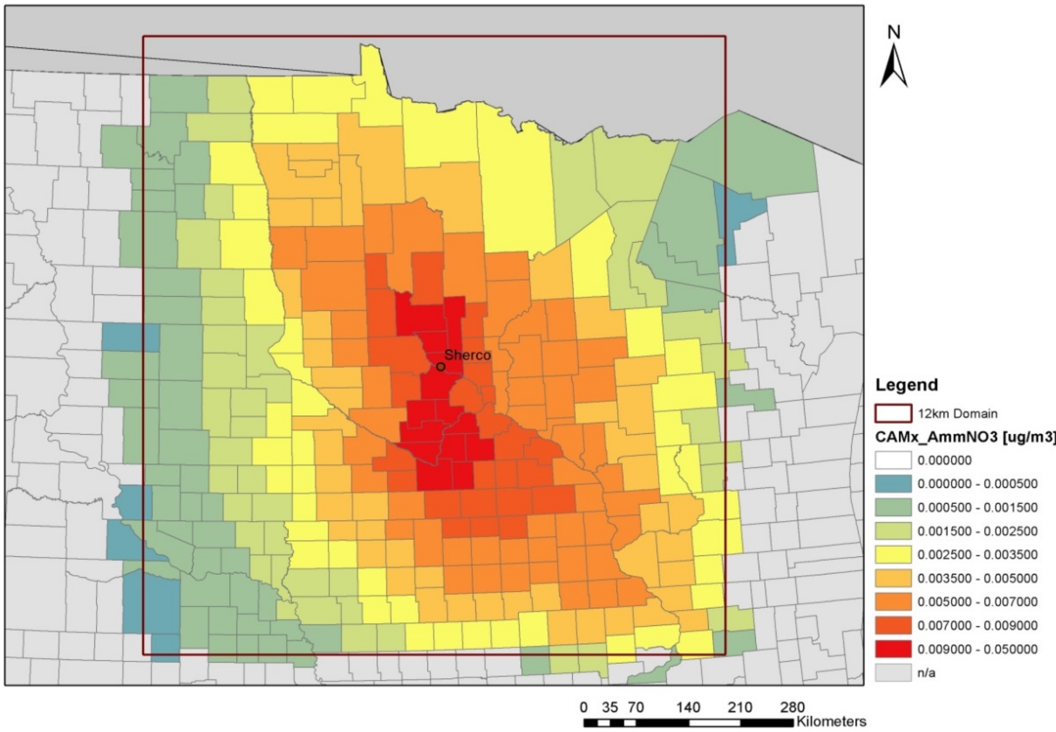
[94] For all three figures, this is the CAMx modeling domain that encompasses Minnesota and 100 miles from the Minnesota border.

[95] A point source was modeled at current Sherco location based on Sherco Unit 1 operational data from 2014, using hourly-calculated plume rise, representative emission rates, representative stack parameters (e.g., height, stack gas exit flow velocity, and temperatures), and hourly-varying meteorological conditions.

[96] Dr. Muller modeled one incremental ton of NO_x separately based on the plant's actual location and stack height. NO_x emissions are scaled to 3,508.2 tons to be equivalent to what was modeled for CAMx.

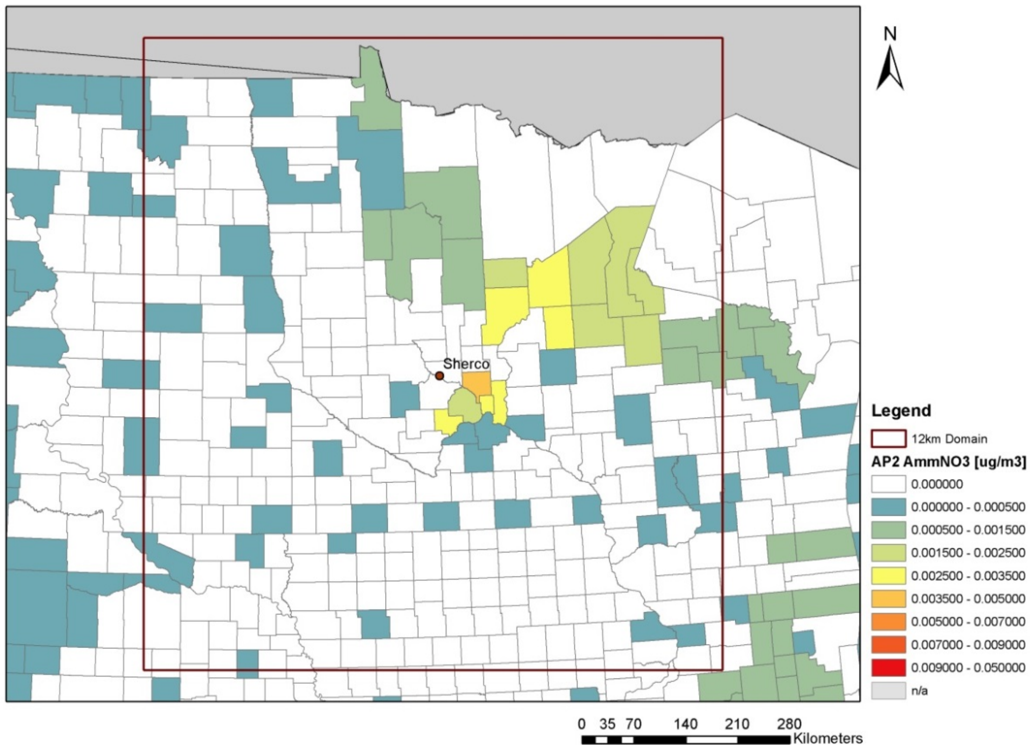
[97] Dr. Marshall's modeling was based on the actual location, stack height, and emissions of the plant; emissions were scaled from three units to one unit to be equivalent to what was modeled for CAMx.

Figure 4. CAMx Secondary $PM_{2.5}$ Concentrations within Minnesota Domain from Sherco NO_x Emissions[98]



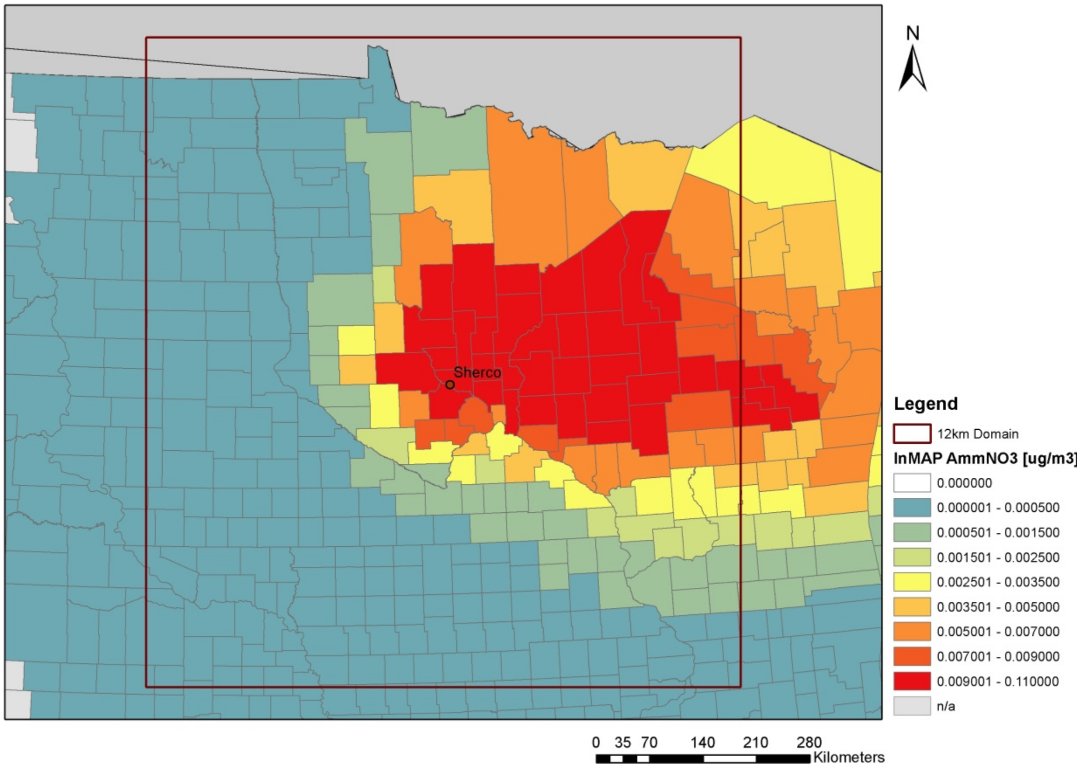
[98] Ex. 608 (Desvousges Surrebuttal) at 23, Figure 3a: CAMx Annual Average Secondary $PM_{2.5}$ Concentrations due to 3,508.2 TPY NO_x Emissions from the Sherco EGU in Sherburne County.

Figure 5. AP2 Secondary $PM_{2.5}$ Concentrations within Minnesota Domain from Actual Sherco NO_x Emissions[99]



[99] Ex. 608 (Desvousges Surrebuttal) at 24, Figure 3b: AP2 Annual Average Secondary $PM_{2.5}$ Concentrations due to 3,508.2 TPY NO_x Emissions from the actual Sherco EGU in Sherburne County.

Figure 6. InMAP Secondary $PM_{2.5}$ Concentrations within Minnesota Domain from Actual Sherco NO_x Emissions[100]



The CAMx results are as expected: the highest secondary $PM_{2.5}$ concentrations are distributed fairly evenly around the Sherco source in all wind directions (north, south, east, and west) and diminish as a function of distance. Concentration changes are predicted in every Minnesota county. The AP2 results contradict everything that is known about atmospheric dispersion and chemistry: the random, sporadic results skip Sherburne County and the majority of all Minnesota counties. Although InMAP's results are more consistent and predict concentration changes in each Minnesota

[100] Ex. 608 (Desvousges Surrebuttal) at 26, Figure 3d: InMAP Annual Average Secondary $PM_{2.5}$ Concentrations due to 3,508.2 TPY NO_x Emissions from the actual Sherco EGU in Sherburne County.

county, they are clearly biased to the east and overestimate concentration changes (showing much larger areas of red and orange than CAMx modeling).[101]

AP2's sporadic, random results and InMAP's bias to the east are also clearly seen in Figures 7 and 8, which present AP2 and InMAP modeling results nationwide from Sherco NO_x emissions.[102] While AP2 predicts no impacts in the majority of the Minnesota counties, it shows secondary $PM_{2.5}$ concentration changes in faraway states to the east, west, and south, including Oregon, California, Florida, Maryland, and the southern tip of Texas. Dr. Marshall's InMAP modeling results for NO_x show the bias to the east; his results for direct $PM_{2.5}$ and SO_2 display a very similar bias to the east.[103]

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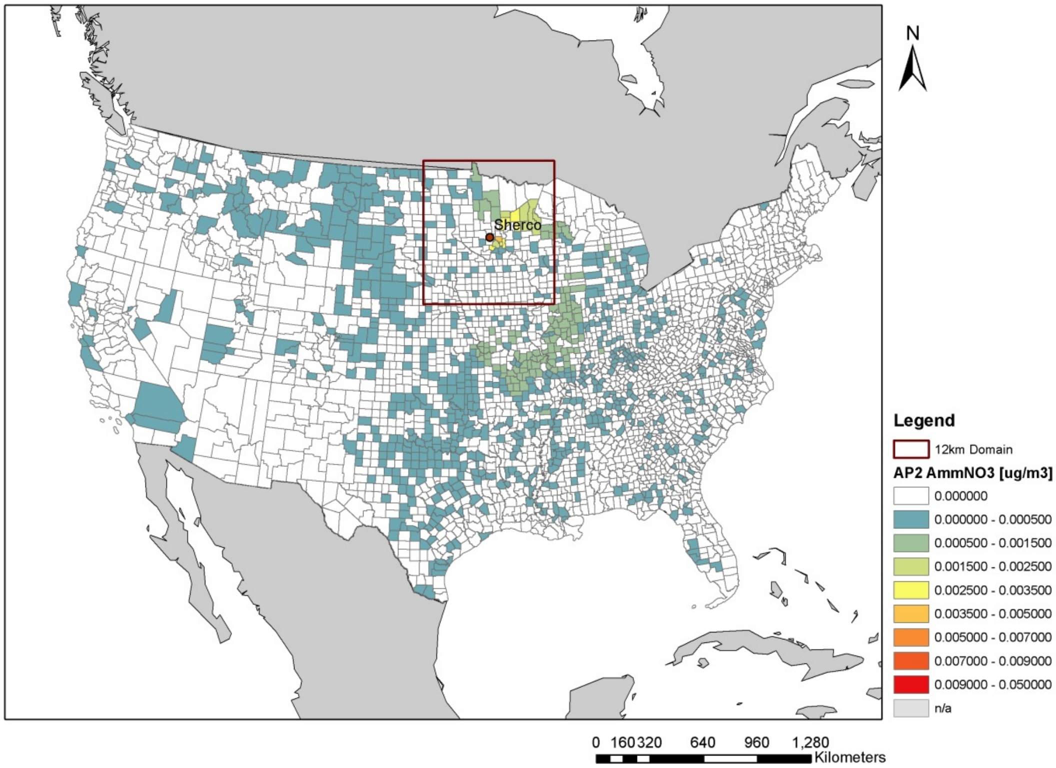
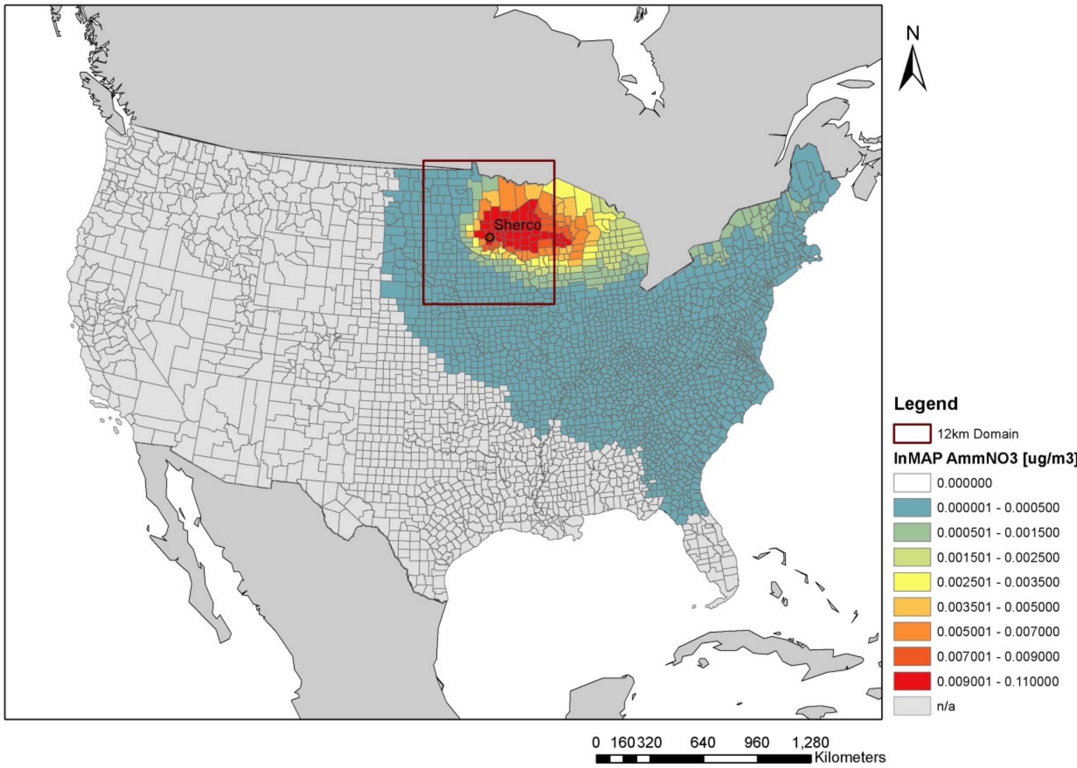
[101] *See* also Ex. 608 (Desvousges Surrebuttal) at 21-32.
[102] Again, NO_x emissions are scaled to 3,508.2 tons to equal what was modeled for CAMx.
[103] *See* also Ex. 608 (Desvousges Surrebuttal) at 21-32.

Figure 7. AP2 Secondary $PM_{2.5}$ Concentrations Nationwide from Actual Sherco NO_x Emissions[104]



104 Ex. 608 (Desvousges Surrebuttal) at 25, Figure 3c: AP2 Annual Average Secondary $PM_{2.5}$ Concentrations across the Continental U.S. due to 3,508.2 TPY NO_x Emissions from the actual Sherco EGU in Sherburne County.

Figure 8. InMAP Secondary $PM_{2.5}$ Concentrations Nationwide from Actual Sherco NO_x Emissions[105]



CAMx, AP2, and InMAP display very similar patterns from the Lyon County (Marshall) and Dakota County (Black Dog) sources for secondary $PM_{2.5}$ concentrations from NO_x emissions, and these have been described in several maps included in Dr. Desvousges Rebuttal and Surrebuttal Testimonies.[106]

Dr. Muller has tried to explain away AP2's illogical NO_x modeling results by stating that the counties that show no concentration change did not have enough ambient ammonium to bind with NO_x to form secondary $PM_{2.5}$ (ammonium nitrate,

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[105] Ex. 608 (Desvousges Surrebuttal) at 27, Figure 3e: InMAP Annual Average Secondary $PM_{2.5}$ Concentrations across the Continental U.S. due to 3,508.2 TPY NO_x Emissions from the actual Sherco EGU in Sherburne County.

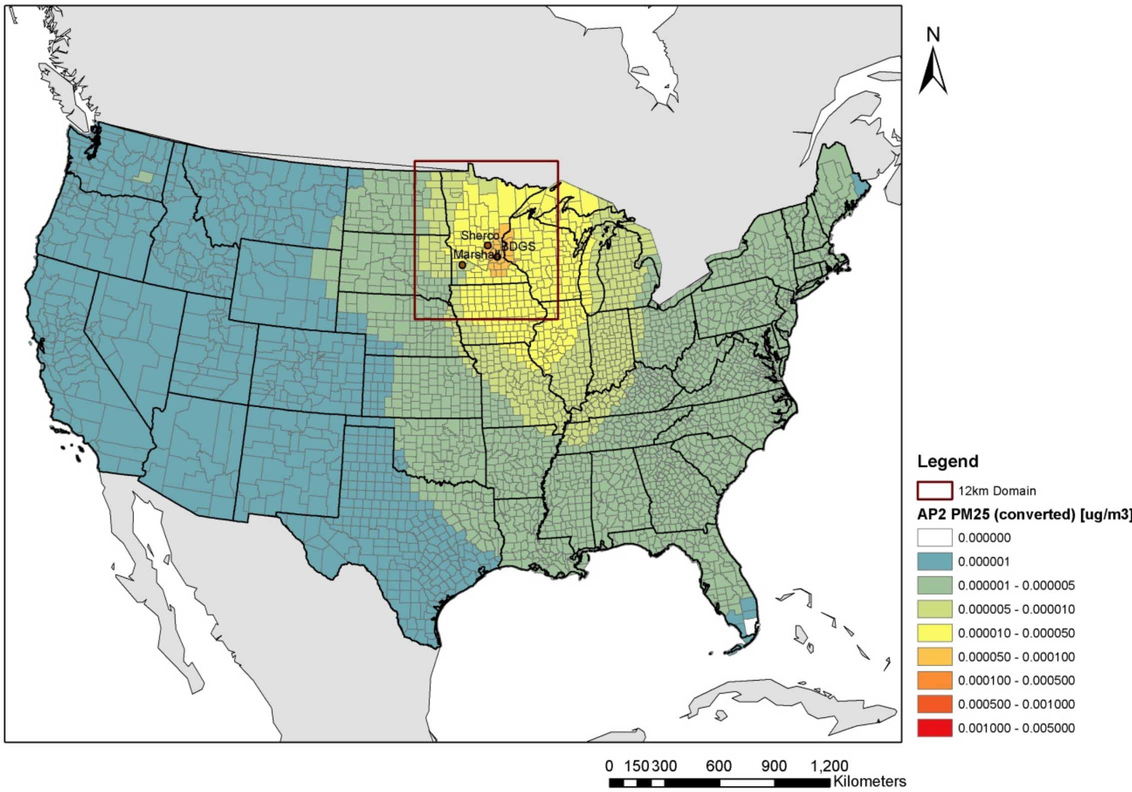
[106] Ex. 605 (Desvousges Rebuttal) at 57-61, Schedule 5; Ex. 608 (Desvousges Surrebuttal) at 21-32.

AmmNO$_3$).[107] However, both Dr. Desvousges' and Dr. Marshall's modeling results do not show this kind of pattern and had a sufficient amount of ammonium in every Minnesota county to bind with NO_x. Figure 7 above also shows that AP2 predicts $PM_{2.5}$ concentration changes from NO_x emissions in every other county from east to west in the southern border of Minnesota, which appears incorrect.

Dr. Muller's AP2 air quality modeling results display some other patterns that raise questions about their accuracy. First, Dr. Muller's predictions for direct $PM_{2.5}$ and secondary $PM_{2.5}$ from SO_2 from the Lyon, Marshall, and Sherburne County sources showed increased ambient concentrations in every county in the contiguous United States. This means that AP2 significantly over-estimates direct $PM_{2.5}$ damages and SO_2 damages because it assumes that basically every person in the United States is affected by $PM_{2.5}$ and SO_2 emissions from Minnesota. Again, these results do not make sense and are different from the CAMx and InMAP results. Figures 9 and 10 below present AP2 modeling results nationwide from Sherco direct $PM_{2.5}$ and SO_2 emissions; AP2 results are similar from Black Dog and Lyon County sources.

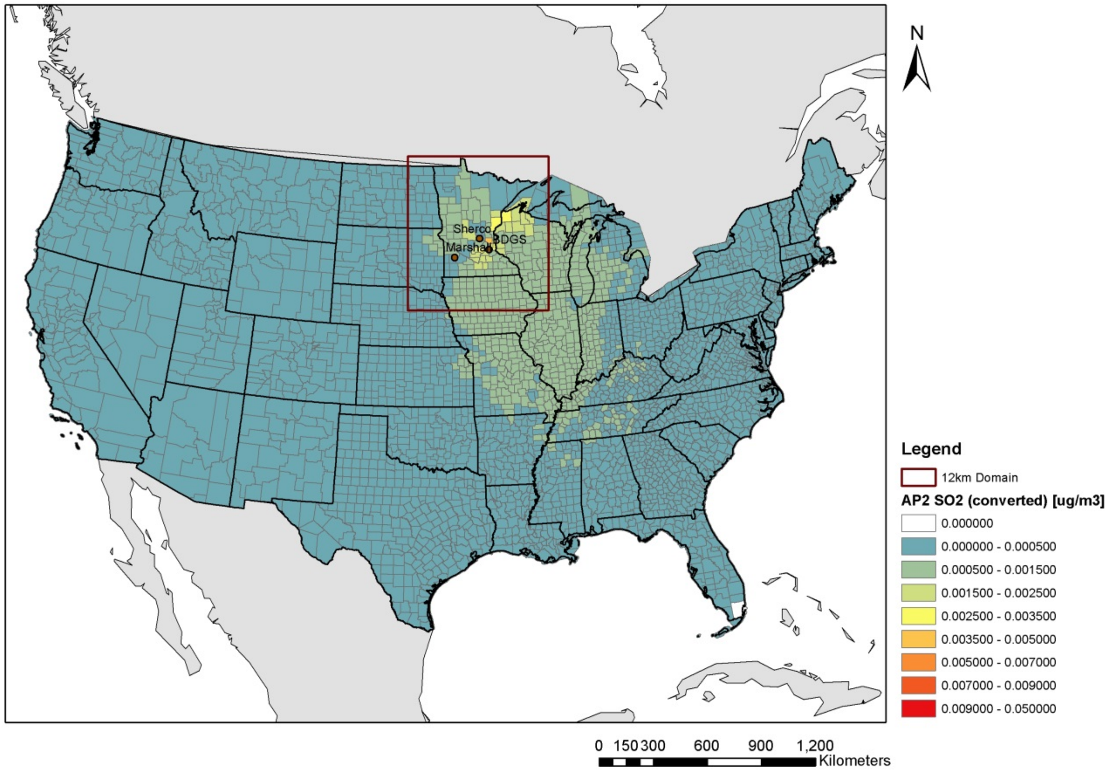
[107] Ex. 811 (Muller Surrebuttal) at 9; Hearing Transcript, Vol. 8 at 87-89, 148-151, 154-155 (Muller).

Figure 9. AP2 Direct $PM_{2.5}$ Concentrations Nationwide from Sherco Emissions[108]



[108] Ex. 605 (Desvousges Rebuttal), Schedule 5 at 5. $PM_{2.5}$ emissions are scaled to 9.4 tons to equal what was modeled for CAMx.

Figure 10. AP2 Secondary $PM_{2.5}$ Concentrations Nationwide from Sherco SO_2 Emissions[109]



Second, although AP2 significantly over-predicted secondary $PM_{2.5}$ concentration changes outside of Minnesota due to SO_2 emissions, it under-predicted changes within Minnesota. Figure 11 compares AP2 (top map) and CAMx (bottom map) modeling results from Sherco SO_2 emissions and shows that CAMx predicts much higher ambient concentration changes in Minnesota, while AP2 shows much lower and more sporadic concentration changes.

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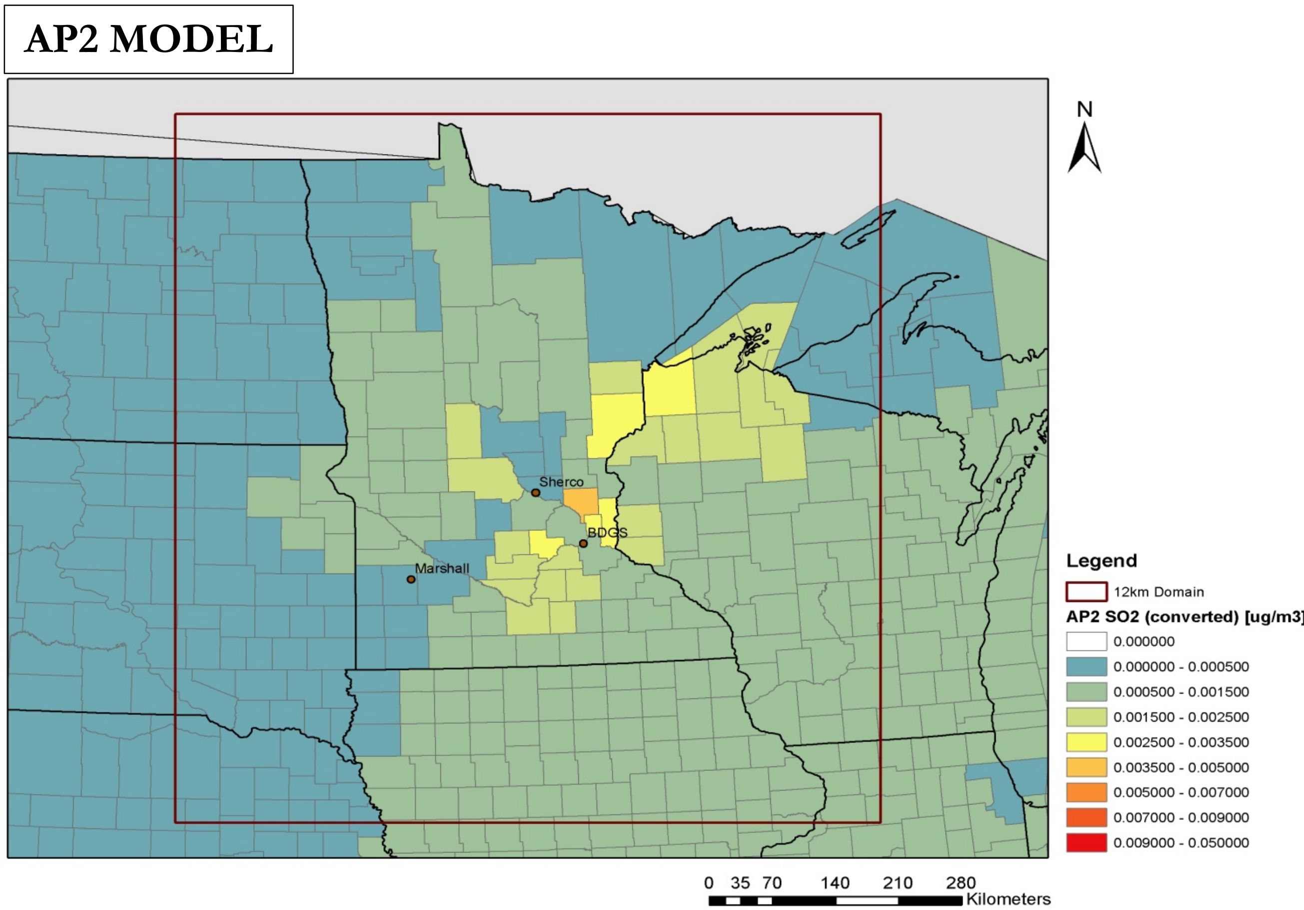
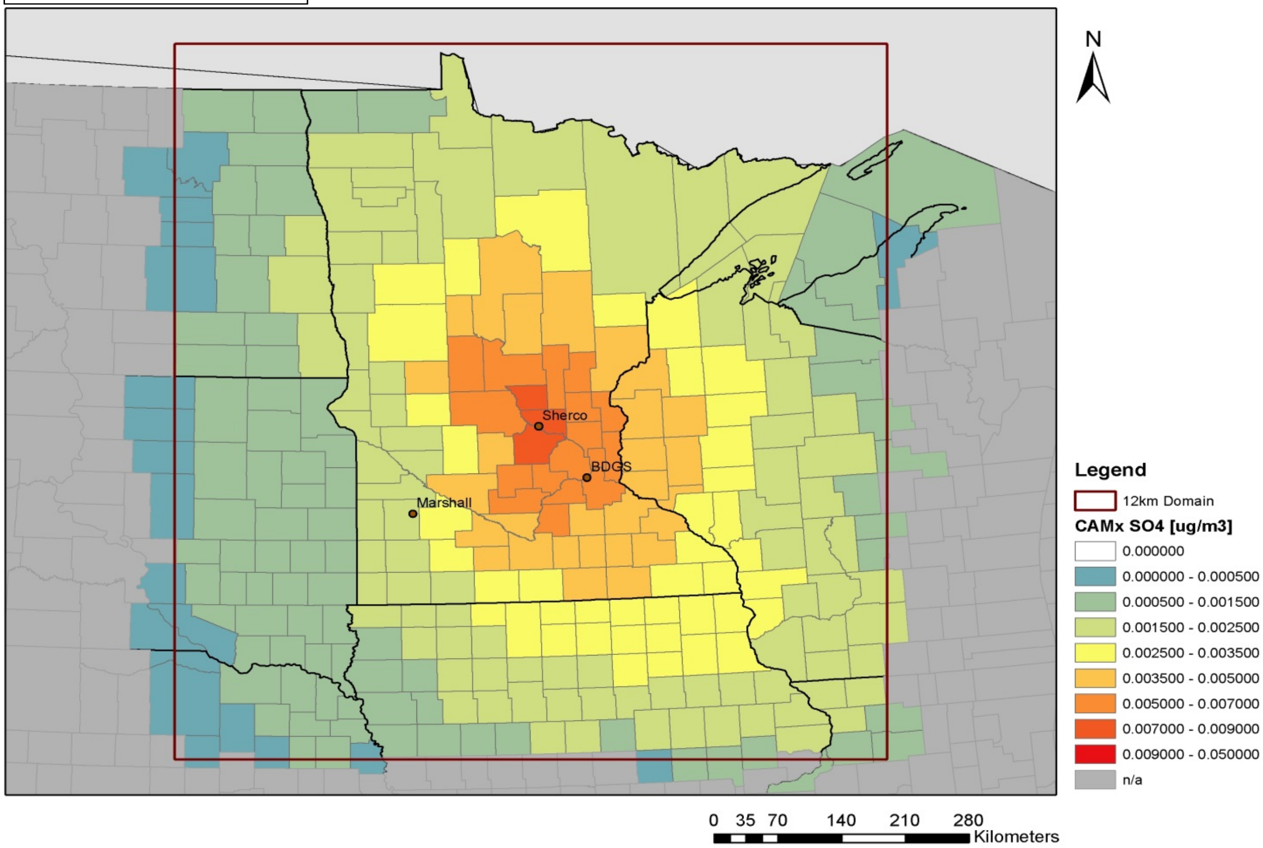
109 Ex. 605 (Desvousges Rebuttal), Schedule 5 at 3. SO_2 emissions are scaled to 1,169.4 tons to equal what was modeled for CAMx.

Figure 11. AP2 and CAMx Secondary $PM_{2.5}$ Concentrations within Minnesota Modeling Domain from Sherco SO_2 Emissions[110]



[110] Ex. 605 (Desvousges Rebuttal), Schedule 5 at 6. SO_2 emissions are scaled to 1,169.4 tons to equal what was modeled for CAMx.

CAMx Model



Dr. Muller compared AP2 and CAMx damage estimates within Minnesota from the Black Dog, Sherco, and Marshall sources, and this comparison presented in Table 4 below confirms what we have stated above.[111] CAMx damage estimates for NO_x are more than six times higher than AP2 damage estimates for all three locations. Similarly, CAMx damage estimates for SO_2 are higher than AP2 damage estimates for each location. For $PM_{2.5}$, AP2 and CAMx damage results are fairly comparable within

[111] See Ex. 810 (Muller Rebuttal) at 23. AP2 estimates were for Minnesota counties, CAMx estimates were for the Minnesota modeling domain.

Minnesota, except AP2 estimates much higher damages for the rural Marshall location (even higher than the urban location).[112]

Table 4. Comparison of AP2 and CAMx Damage Values for $PM_{2.5}$, SO_2, and NO_x from Black Dog, Sherco, and Marshall Sources, Minnesota Damages[113]

Table 14: Comparison of Damage Estimates when AP2 Damages are Limited to Counties in Minnesota. ($/ton)

		$PM_{2.5}$		SO_2		NO_x	
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 I 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.*

Based on all the facts and figures we have presented here and throughout Dr. Desvousges' testimony, it is clear that the AP2 air quality modeling results are not credible or accurate. For NO_x, AP2 predicts no changes in ambient concentrations in the majority of Minnesota counties, but shows sporadic concentration changes in faraway states. For SO_2, AP2 shows low and somewhat sporadic concentration changes in Minnesota, but significantly over-predicts impacts nationwide. For $PM_{2.5}$, AP2 shows fairly reasonable results in Minnesota, but again, substantially over-estimates impacts nationwide.

Dr. Desvousges standardized the AP2, InMAP, and CAMx results for Marshall, Sherco, and Black Dog locations for the differences in geographic scope and valuation assumptions (concentration response function, VSL, Monte Carlo analysis). This

112 AP2's Black Dog and Sherco values are for actual plants (using actual stack height and location); Marshall values are for the hypothetical plant that used a much lower stack height.
113 Reproduced Table 14 from Ex. 810 (Muller Rebuttal) at 23.

allows for the difference in values to be mainly attributed to how the models predict changes in ambient air concentrations in Minnesota and within 100 miles from the Minnesota border.[114] Dr. Desvousges summarized the comparable values in Table 1 of his Surrebuttal Testimony; this table is reproduced as Table 5 below.

Table 5. Comparison of CAMx, AP2, and InMap Damage Values, Standardized for Modeling Domain, Risk Valuation, and VSL[115]

Dollars/Ton of Emissions										
		Rural			**Metro Fringe**			**Urban**		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**	**Low**	**Mean**	**High**
OPM*	InMap[a]	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
NO_x	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
SO_2	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.

Several things, some already discussed above, stand out from Table 5.[116] First, the AP2 values based on modeling a hypothetical plant in each county centroid ("AP2 hypothetical") are consistently and substantially higher than the values based on the

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114 *See* Ex. 608 (Desvousges Surrebuttal) at 17-18.
115 Reproduced Table 1 from Ex. 608 (Desvousges Surrebuttal) at 19.
116 *See* also Ex. 608 (Desvousges Surrebuttal) at 19-20.

modeling of existing power plants ("AP2 actual").[117] For example, the high, mean and low values for $PM_{2.5}$ in the urban scenario are more than six times higher for the hypothetical plant than for the actual plant (Black Dog). In the metropolitan-fringe scenario, the hypothetical plant values are almost four times higher than the actual plant values (Sherco). The same pattern continues for NO_x and SO_2, which calls into question what Dr. Muller modeled as a hypothetical facility.[118]

Second, InMAP consistently and grossly over-estimates potential externality values for $PM_{2.5}$ compared to CAMx and AP2. For example, for the urban scenario, the InMAP values for $PM_{2.5}$ are more than five times higher than the CAMx values and more than seven times higher than the AP2 values (actual). For the metropolitan-fringe scenario, the InMAP values for $PM_{2.5}$ are about twice as high as the AP2 values (actual) and CAMx values. The InMAP damage values for $PM_{2.5}$ are substantially higher although they only include mortality impacts and exclude morbidity.

Third, InMAP consistently and grossly overestimates NO_x values for the urban scenario, which are more than three times higher than the CAMx values. Dr. Marshall's proposed generic values are even higher than any of the values in Table 1: \$125,000 to \$218,000 for $PM_{2.5}$; \$14,000 to \$24,000 for NO_x; and \$16,000 to \$28,000 for SO_2.[119]

Fourth, the InMAP modeling results for SO_2 seem suspect as well, because the values for the rural location are consistently, substantially higher than for the urban or

[117] For actual plants, Dr. Muller modeled one incremental ton of each pollutant separately, using the actual location and stack height.
[118] Ex. 811 (Muller Surrebuttal) at 22.
[119] Ex. 115 (Marshall Direct) at 28; Hearing Transcript, Vol. 6 at 218-221 (Marshall).

metropolitan-fringe location.[120] This unexpected result is evident from Table 5 above, but also shown, for example, in Table 13 in Dr. Muller's Rebuttal Testimony.[121]

D. The Model Performance Evaluations Conducted by Dr. Muller and Dr. Marshall Are Not Meaningful

All Parties conducted a model performance evaluation (MPE) to understand the accuracy and reliability of their air quality modeling. An MPE first compares base case modeling results to actual observations to see how well the model can simulate reality. It is presumed that if the model can predict actual observed concentrations with an accepted level of accuracy, then it is likely to also be able to predict concentration changes reasonably accurately. However, if a model's base case results are not reliable, there is no foundation to suggest it can accurately predict concentration changes. For photochemical grid models, the comparison to actual observed concentrations is the main component of an MPE. For reduced-form models, a well-designed, typical MPE includes a second step, which compares the predicted total concentrations as well as predicted concentration changes associated with an incremental change in emissions to those predicted by a full-science photochemical grid model.

All Parties claim that their MPE shows good model performance, although considering the very different air quality modeling results, and the clearly inaccurate AP2 and InMAP modeling results discussed above, this is not possible. Dr. Muller has attempted multiple times to brush away critiques of his air quality modeling results by stating that because his MPE showed good performance, his results must also be good. However, his MPE was not conducted in accordance with the Boylan and

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[120] Keep in mind that Dr. Marshall only estimated mortality effects, which are highly influenced by the population exposed.

[121] Table 13 presents damage values from Black Dog, Sherco, and Marshall sources as reported by Parties (unadjusted). For all three pollutants, InMAP values are consistently higher for the rural Marshall location than for the Black Dog or Sherco locations. See Ex. 810 (Muller Rebuttal) at 21.

Russell (2006) guidance he relied on, and therefore his MPE is not meaningful. Dr. Muller's MPE changed more than one variable in the analysis, applied performance goals and criteria developed for PM to his ozone evaluation, and converted daily observed data to annual average data. Furthermore, Dr. Muller's MPE only analyzed baseline concentrations, and did not evaluate how well the AP2 modeled concentration changes compared to those from a photochemical grid model.

For his MPE, Dr. Muller compared AP2 and CAMx modeling results from a run performed by MPCA for annual baseline ozone and $PM_{2.5}$ against observed ambient data. Dr. Muller claims that his AP2 modeling results correlate better with the monitored ambient data than MPCA's CAMx results. However, there are several reasons why Dr. Muller's MPE is not appropriate or reliable.

First, the AP2 modeling uses meteorological data from the 1990's and emissions data from 2011, while the MPCA's CAMx modeling results are based on meteorological and emissions data from 2011. Modeling results are impacted by meteorological conditions and it is not appropriate or accurate to compare data that relies on meteorological data from two different years. In addition, an MPE should only change one variable and hold the others intact. In Dr. Muller's MPE, both the model and the meteorological data were changed.[122]

Second, Dr. Muller relied on the Boylan and Russell performance goals and criteria for both his $PM_{2.5}$ and ozone modeling results. However, the Boylan and Russell guidance is specific to $PM_{2.5}$ evaluation only. Predicting $PM_{2.5}$ concentrations is much more difficult than predicting ozone concentrations, because there are more species, processes, and variance among PM monitors, and therefore the $PM_{2.5}$ performance goals are less stringent (roughly double) than ozone performance

122 Ex. 605 (Desvousges Rebuttal) at 51.

goals.[123] EPA has specific guidance and goals for evaluating ozone performance, which were used in Dr. Desvousges' MPE.[124] Dr. Muller admitted that he was not familiar with this EPA guidance.[125] While Dr. Muller is not a modeler, but an economist, it is surprising that he would apply the $PM_{2.5}$ goals to the ozone MPE.[126]

Third, Dr. Muller neglected to conduct the typical second step for a reduced-form model performance evaluation which is to compare the reduced form modeling results to the modeling results of a photochemical grid model, evaluating both total concentrations and predicted concentration changes associated with incremental emissions.[127]

Fourth, because AP2 cannot predict time intervals shorter than one year, Dr. Muller had to convert the daily observed comparison $PM_{2.5}$ concentrations that had been obtained on a 24-hour time interval to an annual average. Boylan and Russell specifically state that in order for an MPE to provide meaningful results, the modeling results and the actual data need to be from the same time interval: "Performance evaluation should be done on an episode-by-episode basis or on a month-by-month basis for annual modeling."[128] Dr. Muller agreed that his MPE was not done on an episode-by-episode or a month-by-month basis, and argued that the conversion to annual averages was necessary because the modeling literature does not have evaluation criteria that are targeted for evaluating air quality data based on annual concentrations.[129] The lack of evaluation criteria for annual $PM_{2.5}$ concentrations

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123 Ex. 605 (Desvousges Rebuttal) at 52.
124 EPA 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze." April 2007. http://www3.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf EPA 2014. "Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$ and Regional Haze." December 2014. http://www3.epa.gov/ttn/scram/guidance/guide/Draft_O3-PM-RH_Modeling_Guidance-2014.pdf
125 Hearing Transcript, Vol. 8 at 79 (Muller).
126 Hearing Transcript, Vol. 8 at 69 (Muller).
127 Ex. 605 (Desvousges Rebuttal) at 54-55.
128 Ex. 605 (Desvousges Rebuttal) at 52; Hearing Transcript, Vol. 8 at 85-86 (Muller).
129 Hearing Transcript, Vol. 8 at 83, 85-86 (Muller); Ex. 811 at 5.

indicates that $PM_{2.5}$ impacts should be modeled and evaluated on shorter time intervals.

A relevant MPE would compare model results to ambient data based on the collection period of the ambient data, and EPA's guidance recommends that evaluations are conducted using the observational native time.[130] However, neither Dr. Muller nor Dr. Marshall were able to do this, because AP2 and InMAP only predict annual averages. Converting the actual 24-hour observed readings to an annual average diminishes the variation in the data and removes the high and low data points, as was acknowledged by Dr. Muller.[131] It is more difficult to accurately predict the high and low data points throughout the year, as CAMx does, instead of just predicting the annual average as AP2 and InMAP do.

Dr. Marshall's MPE included the typical two steps – a comparison of InMAP's $PM_{2.5}$ modeling results to observed ambient $PM_{2.5}$ concentrations as well as a comparison to the results from a photochemical grid model WRF-Chem. InMAP showed poor performance against observed data: For sulfates (a component of PM), the bias was a negative 137 percent and falls significantly outside the range of acceptable as defined by Boylan and Russell, a bias goal of +/- 30 percent and criteria bias of +/- 50 percent. His modeling results for nitrates were even worse.[132] InMAP's poor performance is a significant issue: If a model cannot predict baseline concentrations accurately, there is no foundation to claim that it can predict concentration changes accurately.

Dr. Marshall's performance comparison to WRF-Chem data has two main weaknesses. First, the WRF-Chem control scenarios were developed for mobile

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[130] Ex. 605 (Desvousges Rebuttal) at 53.

[131] Hearing Transcript, Vol. 8 at 83-84; *see* also Ex. 605 (Desvousges Rebuttal) at 52.

[132] Ex. 606 (Desvousges Rebuttal Non-Public) at 77, Schedule 3 at 8-11 (CEO Response to Xcel Energy IR No. 8); Ex. 119 (Marshall Surrebuttal), Schedule 1 at 9282, 9295-9230; Hearing Transcript, Vol. 6 at 210-212 (Marshall).

sources looking at alternative light-duty automobile controls (e.g., gasoline, several types of ethanol, and electric vehicles with different electricity sources). Mobile source emissions are modeled low to the ground from multiple sources, while power plant emissions are modeled as elevated emissions from a single point source. Second, Dr. Marshall fine-tuned the InMAP model with two calibration factors in order for his results to correlate better with the 11 WRF-Chem emission change scenarios (empirical factor F_A was added to advection equation and empirical factor K_{NH} was added to ammonium nitrate chemistry equation). Adding calibration factors to InMAP to correlate with a mobile source scenario does not mean that the model results would correlate well when emissions are modeled from a power plant, which is a point source.[133]

Dr. Desvousges conducted a performance evaluation on the CAMx modeling results for ozone and $PM_{2.5}$. He compared the CAMx base case ozone modeling results against actual observations from two EPA monitoring networks: the Air Quality System (AQS) and the Clean Air Status and Trends Network (CASTNet) based on EPA's ozone modeling guidance and using EPA's Atmospheric Model Evaluation Tool (AMET). Ozone readings from both networks are collected hourly and then converted to 8-hour averages. When the CAMx ozone modeling results were evaluated against the actual observations over the entire modeling year based on EPA guidance, the CAMx annual ozone error was only 10.1 percent, which is three times lower than EPA's ozone performance goal of 35 percent.[134]

For the PM performance evaluation, Dr. Desvousges obtained actual ambient data from three networks: the Federal Reference Method (FRM), the Chemical Speciation Network (CSN) and the Interagency Monitoring of Protected Visual Environments (IMPROVE). All three networks monitor PM ambient concentrations

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[133] Ex. 606 (Desvousges Rebuttal Non-Public) at 9, 75-77; *see* also Ex. 119 (Marshall Surrebuttal), Schedule 1.
[134] Ex. 604 (Desvousges Direct), Schedule 3 at 4, 29-46, 62-64.

on a 24-hour basis and the CAMx 24-hour model results were compared to the actual observations based on Boylan and Russell guidance, which is specific to particulate evaluations. The results, over the course of the year, indicated a $PM_{2.5}$ bias of 18.3 percent, which is well within the performance goals and criteria set by Boylan and Russell.[135]

The CAMx performance evaluation followed standard evaluation practices, used appropriate performance goals and criteria, included graphical displays of model performance, and showed that the model performed very well. It is the only MPE that was conducted appropriately in this proceeding.[136]

VI. OTHER SIGNIFICANT ISSUES

A. It Is Reasonable and Practicable to Estimate Damages in Minnesota and within 100 Miles from the Minnesota Border

Dr. Desvousges estimated potential damages within Minnesota and an area that extends approximately 100 miles from the Minnesota borders to the south, east, and west. This geographic area is generally consistent with the domain evaluated in the prior case 20 years ago, which is the basis for the current $PM_{2.5}$, NO_x, and SO_2 values. The underlying statute, Minn. Stat. §216B.2422 subd. 3(a), has remained unchanged since then.

We believe it is reasonable and practicable to estimate damages in Minnesota and within 100 miles from the Minnesota border because the majority of air quality changes from Minnesota sources modeled will occur within this area[137] Direct $PM_{2.5}$, SO_2, and NO_x concentrations are generally highest near the source of emissions and

135 Ex. 604 (Desvousges Direct), Schedule 3 at 4, 29-34, 46-63.
136 Ex. 605 (Desvousges Rebuttal) at 53.
137 Ex. 608 (Desvousges Surrebuttal) at 35.

decline with distance – concentrations are typically very small at a distance of 50 kilometers. Secondary $PM_{2.5}$, formed from SO_2 and NO_x emissions, tend to travel further, however, the majority of concentration changes will still take place within 100 miles (160 kilometers) from the source.[138]

The Commission in the original proceeding noted that "the quantification of all environmental impacts, however slight, difficult to measure, or irrelevant," would be a "bottomless and highly speculative task."[139] The ALJ also stated that "[At] some point, the degree of uncertainty associated with a proposed value becomes so great that there is insufficient evidence to meet the preponderance standard, and the value cannot be adopted."[140] We believe the uncertainties in model predictions are so great at distances further from the source and at extremely small concentration-change levels that it is not practicable to estimate nationwide damages.

1. Other Parties' Estimates on the Proportion of Damages from Minnesota Emissions Nationwide and Within Minnesota Are Not Credible

When considering the geographic scope, it is critical to make a distinction between the *air concentration changes* and the *monetized damages* that are estimated from those changes. We believe it is reasonable to focus on impacts in Minnesota and within 100 miles from the Minnesota borders, because this is the geographic area where the majority of the *concentration changes* occur. Dr. Muller and Dr. Marshall have used their own modeling results to support a national scope, however, these estimates are based on damage values, which are substantially affected by the populations exposed. When the minority of concentration changes outside of Minnesota are

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138 Ex. 119 (Marshall Surrebuttal), Schedule 2 (Xcel Energy Response to CEO IR No. 11 and No. 12).
139 Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* ORDER ESTABLISHING ENVIRONMENTAL COST VALUES. January 3, 1997 at 12.
140 Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* FINDINGS OF FACT, CONCLUSIONS, RECOMMENDATION, AND MEMORANDUM. March 22, 1996, Order Point 31 at 11.

multiplied by the majority of the U.S. population, the analysis will inevitably show a large proportion of damages outside of Minnesota.

As stated before, we believe that Dr. Muller's and Dr. Marshall's modeling results are so inconsistent and unreliable that they should not be used to draw any conclusions regarding the geographic scope. For example, Dr. Muller reported that for $PM_{2.5}$, 60 percent of his calculated damages occur outside Minnesota, while Dr. Marshall noted that 26 percent of his calculated damages from $PM_{2.5}$ are beyond 100 miles from Minnesota. Similarly, Dr. Muller reported that for NO_x, 65 percent of his calculated damages are outside Minnesota, while Dr. Marshall noted that 27 percent of his calculated damages from NO_x are beyond 100 miles from Minnesota.[141]

In his Surrebuttal Testimony, Dr. Muller used EPA's recent analysis of the Cross State Air Pollution Rule (CSAPR) to claim that as much as two-thirds of the increased ambient concentrations of secondary $PM_{2.5}$ from NO_x and SO_2 emissions occur outside of Minnesota. He summed the secondary $PM_{2.5}$ concentration changes due NO_x emissions from all monitoring sites in the United States (31.96 $\mu g/m^3$), subtracted from this number all of the Minnesota monitoring site readings, and ended up with a number of 21.01 $\mu g/m^3$. He repeated the same exercise for SO_2.[142] However, his analysis has serious flaws and should not be given any consideration.

First, the CSAPR analysis, as admitted by Dr. Muller at the evidentiary hearings, included all emission sources, not just power plants. However, a large proportion of Minnesota air emissions come from other than electric utility sources, including other point sources, mobile vehicles, and fires.[143] Second, Dr. Muller summed all annual readings available for the monitoring sites within each state, yet the

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141 Ex. 605 (Desvousges Rebuttal), Schedule 1 at 29 (DOC Response to Xcel Energy IR No. 28); Ex. 116 (Marshall Rebuttal) at 12.
142 Ex. 811 (Muller Surrebuttal) at 24-25.
143 Hearing Transcript, Vol. 8 at 99-100 (Muller); Ex. 607 (Rosvold Rebuttal) at 19.

numbers of monitoring sites vary by state. This means that the sum of observed concentrations is highly dependent on the number of monitoring sites located in each state: the larger the number of monitoring sites located outside of Minnesota, the higher the "proportion" of concentrations outside Minnesota. Finally, the number of monitoring sites in each state is random and varies by funding availability and other factors, and the monitoring sites are typically located in problem areas that are expected to have higher than average concentrations unlike Minnesota.[144] Dr. Muller acknowledged that his analysis based on the CSAPR data was weighted by the number of monitors located outside of Minnesota and admitted that the analysis was a suboptimal way to try to estimate the proportion of concentration changes in Minnesota and outside of Minnesota.[145] He also recognized that the CSAPR results show the largest concentration changes from Minnesota emissions in Minnesota.[146]

2. There is Significant Uncertainty in Estimating National Damages

There is substantial uncertainty in model predictions, including CAMx predictions, when the modeling distance increases and the estimates become less reliable the further one travels from the source. The determination of the national scope of damages hinges on the ability of models to accurately predict changes in ambient air concentrations throughout the contiguous United States, and as we have repeatedly stated, we do not believe that AP2 and InMAP are capable of doing this. EPA specifically recommends that an air quality model that uses steady-state Gaussian plume model formation, such as AP2, should not be used beyond 50 kilometers.

There is additional uncertainty because the models are predicting very small ambient air concentration changes at further distances. All of the air quality models used in this proceeding are computer software programs that model ambient air

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[144] See Ex. 811 (Muller Surrebuttal) at 24-25; Hearing Transcript, Vol. 8 at 97-110 (Muller).
[145] Hearing Transcript, Vol. 8 at 110 (Muller).
[146] Hearing Transcript, Vol. 8 at 101 (Muller).

concentration changes based on mathematical algorithms and calculations. In theory, the model algorithms can calculate concentration changes out to many significant digits at faraway distances from the source. In reality, these small concentration changes are not measurable or observable – it is uncertain if the extremely small numbers should be treated any differently than a concentration change of zero.[147] For example, Dr. Muller's AP2 results showed an average change in ambient $PM_{2.5}$ concentrations of 0.00000298 $\mu g/m^3$ from the Sherco facility beyond one hundred miles from Minnesota; for Dr. Marshall's InMAP results, the corresponding $PM_{2.5}$ change in ambient concentration was 0.000000643 $\mu g/m^3$.[148]

AP2, InMAP, and CAMx do not have a limit on how many digits can be calculated for a number, neither do they incorporate any estimate of the variance or uncertainty around the predicted results. What this means is that the models do not report any measures of significance or confidence that could help estimate the validity of the predicted concentration changes.[149] Basically, these small, near-zero numbers only exist because of the current computational and mathematical ability to calculate them.[150]

However, these very small concentration changes have a significant impact on the externality values that have been proposed by Parties. For example, to estimate mortality damages from $PM_{2.5}$, these concentrations are first multiplied by the concentration-response function, then by the value of a statistical life, and finally by the number of people who are potentially exposed to the concentration change. Dr. Muller's $PM_{2.5}$ damage values basically assume that every person in the United States is exposed to $PM_{2.5}$ emissions from Minnesota.

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147 Ex. 608 (Desvousges Surrebuttal) at 42-44; Hearing Transcript, Vol. 7 at 134 (Desvousges).
148 Ex. 608 (Desvousges Surrebuttal) at 43.
149 Ex. 608 (Desvousges Surrebuttal) at 44; Hearing Transcript, Vol. 7 at 115 (Desvousges).
150 As Dr. Marshall expressed: "The numbers come from a computer model. When you start multiplying and dividing numbers, the computer will report back to you a large number of significant digits." Hearing Transcript, Vol. 6 at 198 (Marshall).

If the damages from $PM_{2.5}$, SO_2, and NO_x are estimated nationwide, the externality values increase substantially, simply because the very small concentration changes that cannot be measured and observed, may or may not cause human health effects, and may or may not cause health effects in a linear manner, can be calculated by computer programs.[151]

The consequences of combining the very small concentration changes with large populations, high mortality risk value, and high VSL are clear from Dr. Marshall's analysis of CAMx results, based on predictions in the continental U.S.[152] Dr. Marshall processed the CAMx hourly results from a lower spatial (36 kilometer) grid to obtain national annual average concentration predictions; applied his methodology to the results (e.g., mortality risk value and VSL); and estimated the proportion of damages within and outside of the Minnesota domain (Minnesota plus 100 miles). Dr. Marshall reported the following damage cost estimates for primary $PM_{2.5}$:

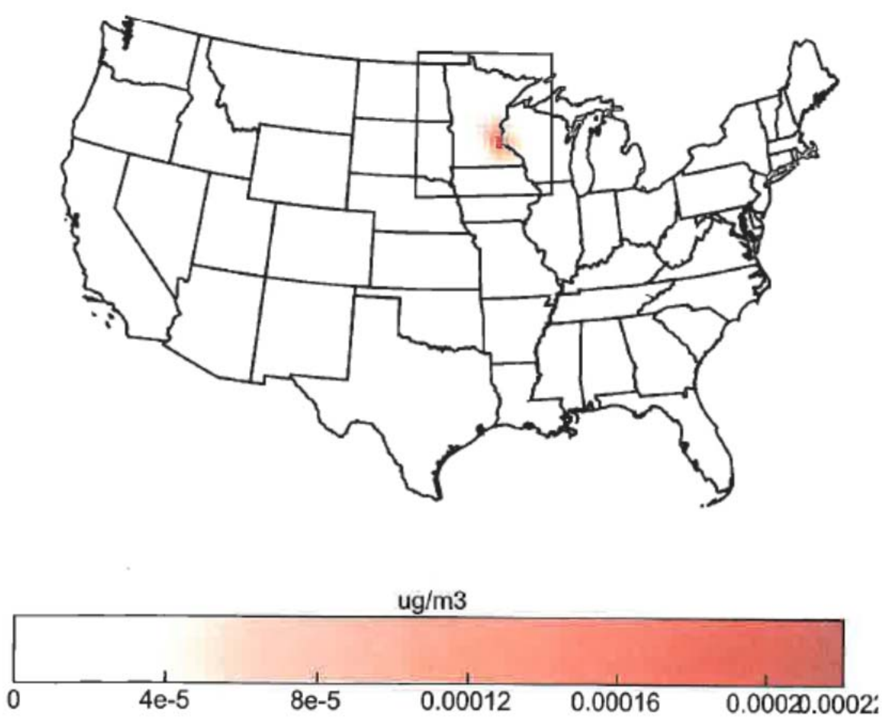
Table 6. CAMx 36 Kilometer Grid $PM_{2.5}$ Damage Cost Per Ton Estimates, Prepared by Applying Dr. Marshall's Methodology to CAMx Concentration Changes[153]

CAMx Domain	Black Dog $PM_{2.5}$	Sherco $PM_{2.5}$	Marshall $PM_{2.5}$
Minnesota	\$38,000	\$24,000	\$13,000
United States	\$78,000	\$60,000	\$49,000

151 Hearing Transcript, Vol. 7 at 113 (Desvousges); Hearing Transcript, Vol. 8 at 33-34 (Muller).
152 These nationwide hourly results were not post-processed or used in Dr. Desvousges' analysis, but were a by-product of his modeling. CEO requested the data from Xcel Energy in IR No. 10. Since the spatial resolution for the U.S. domain was much more coarse than recommended by EPA (36 kilometers instead of 12 kilometers), we do not believe these results are as such very accurate or reliable. Ex. 119 (Marshall Surrebuttal) at 11, Schedule 2 (Xcel Energy Response to CEO IR No. 10); Ex. 450 (CEO Response to MLIG IR No. 327).
153 Table 6 is compiled from Tables 1, 2, and 3 from Ex. 119 (Marshall Surrebuttal) at 14.

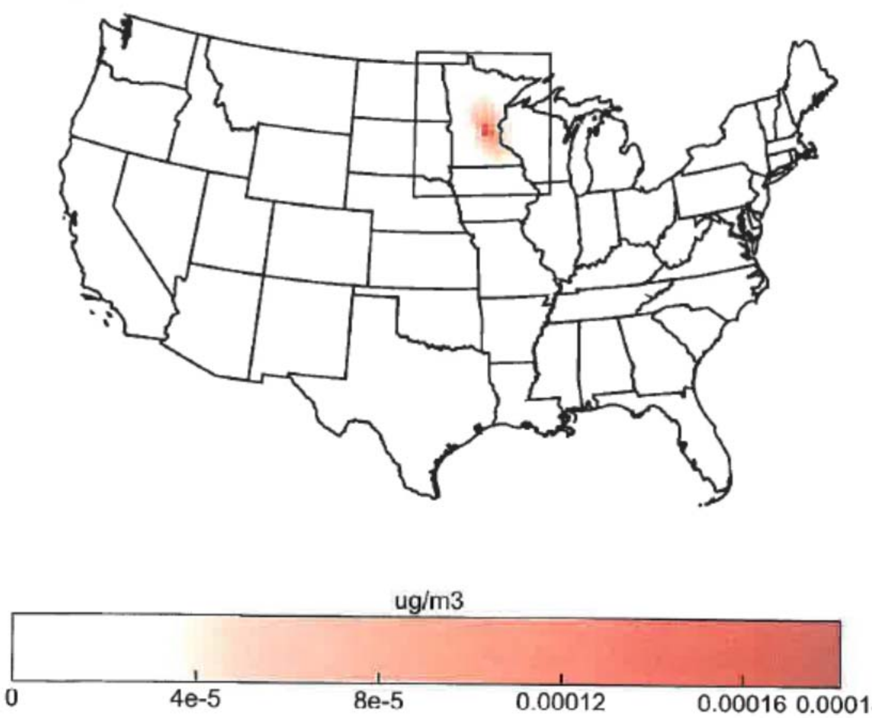
Table 6 indicates that Dr. Desvousges' $PM_{2.5}$ externality values would be more than two times higher if he had estimated national damages. However, based on the following Figures 12, 13, and 14, prepared by Dr. Marshall and presenting the same CAM_x air quality modeling results,[154] one would draw an entirely opposite conclusion. These maps show that the vast majority of the $PM_{2.5}$ concentration changes predicted by CAMx occur within the Minnesota domain, and it is hard to understand how more than half of the damages could possibly be outside the Minnesota domain.

Figure 12. CAMx 36 Kilometer Grid $PM_{2.5}$ Concentration Changes from Black Dog, Prepared by Dr. Marshall[155]



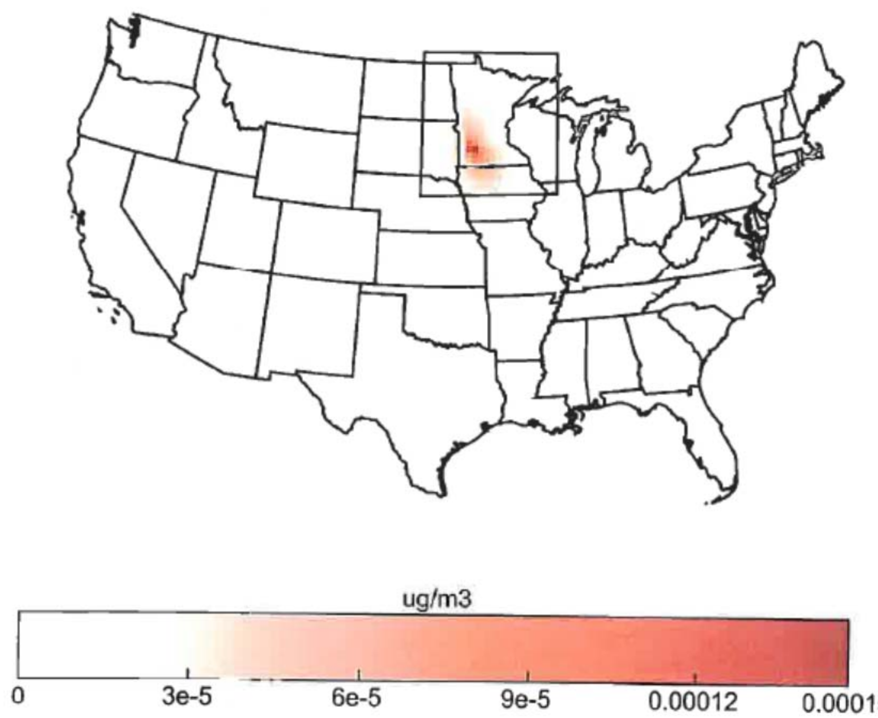
[154] Maps were prepared by Dr. Marshall and included in Ex. 450 (CEO Response to MLIG IR No. 327).
[155] Ex. 450 (CEO Response to MLIG IR No. 327), Map No. 2.

Figure 13. CAMx 36 Kilometer Grid $PM_{2.5}$ Concentration Changes from Sherco, Prepared by Dr. Marshall[156]



[156] Ex. 450 (CEO Response to MLIG IR No. 327), Map No. 8.

Figure 14: CAMx 36 Kilometer Grid PM2.5 Concentration Changes from Marshall, Prepared by Dr. Marshall[157]



Xcel Energy focused on estimating damages in Minnesota and within 100 miles from the Minnesota border, because the majority of air quality changes from Minnesota emissions takes place within this geographic scope. In addition, there is more certainty that the air quality modeling predictions within this area are reliable and that the predicted concentration changes, although still quite small, are greater than zero.

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[157] Ex. 450 (CEO Response to MLIG IR No. 327), Map No. 5.

3. Interstate Transport of Pollution Is Regulated at the National Level

Since the last externalities proceeding in the mid-1990s, there has been considerable change in the regulation of the interstate transport of emissions through the National Ambient Air Quality Standards (NAAQS) and the Cross State Air Pollution Rule (CSAPR), which have limited the potential impacts of emissions across state lines. First, EPA has been timely in reviewing and updating the NAAQS; they now reflect the most recent scientific knowledge; and they are now set at lower and more protective levels than they were 20 years ago.[158] At the time of the original externalities proceeding, EPA had not kept the NAAQS updated and they did not reflect the latest scientific knowledge.[159] Second, EPA has specifically addressed the interstate transport of SO_2 and NO_x emissions through CSAPR, which requires strict emission reductions to eliminate any significant impacts of upwind state contributions to ambient air quality in downwind states.[160]

As Mr. Rosvold explained in his Rebuttal Testimony, NAAQS are set at levels that are protective of human health and the environment and EPA has determined through CSAPR modeling and required reductions that Minnesota is not significantly contributing to ambient air concentrations of $PM_{2.5}$, SO_2 or NO_x in any other state. From a public policy perspective, there is no need in this proceeding to estimate impacts from criteria pollutants on a national basis, because federal rules and regulations are already in place to minimize damages due to the interstate transport of emissions.[161]

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158 Ex. 607 (Rosvold Rebuttal) at 6-7; Ex. 617 (Rosvold Opening Statement) at 1-2.
159 Docket No. E-999/CI-93-583. *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* FINDINGS OF FACT, CONCLUSIONS, RECOMMENDATION, AND MEMORANDUM. March 22, 1996, Finding 46 at 23.
160 Ex. 607 (Rosvold Rebuttal) at 10-14; Ex. 617 (Rosvold Opening Statement) at 1-2.
161 Ex. 607 (Rosvold Rebuttal) at 2-14.

B. County-by-County Values Are Not Used in Resource Planning and Do Not Provide Useful Information for Resource Acquisition

Dr. Desvousges modeled one hypothetical, substantially-sized coal plant at three locations – Marshall (Lyon County), Sherco (Sherburne County), and Black Dog (Dakota County) – to estimate externality values representative of a rural, metro-fringe, and urban location. These three locations were chosen because they are consistent with the geographic groupings adopted in the original proceeding, are realistic potential locations for a power plant, and represent a cautious, conservative approach.[162]

Dr. Muller and Dr. Marshall proposed county-specific values for each Minnesota county (87 counties) and all counties within 200 miles from the Minnesota border (nearly 400 counties). In order to do this, Dr. Muller's and Dr. Marshall's analyses required several thousand modeling runs. In addition, Dr. Muller and Dr. Marshall both modeled all existing power plants in Minnesota, and Dr. Muller also modeled 26 existing power plants within 200 miles from the Minnesota border.[163]

Dr. Muller and Dr. Marshall both argue that it is important to model a source in each county, because this would provide useful information for the Commission about the variability of damages based on source location.[164] They have also concluded that in order to develop county-specific values, it is better to use a reduced-form model, which requires less time and computational power than a photochemical grid model.[165] We respectfully disagree for two main reasons.

First, it is more important to model a few representative sources accurately than 500 sources inaccurately. The Commission will gain no useful information if the

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162 Ex. 608 (Desvousges Surrebuttal) at 61-62; Ex. 616 (Desvousges Opening Statement) at 2.
163 Ex. 605 (Desvousges Rebuttal) at 24-25.
164 Ex. 810 (Mullr Rebuttal) at 5; Ex. 120 (Marshall Opening Statement) at 2.
165 Ex. 810 (Muller Rebuttal) at 35.

county-specific values are based on unreliable air quality modeling results and are plainly wrong. As we have repeatedly demonstrated, AP2 and InMAP air quality modeling results are not credible or even reasonably accurate.

Second, we do not believe that the county-specific values will provide valuable information, considering the nature of resource planning and resource acquisition. Dr. Marshall insists that county-by-county values are needed, yet at the same time states that he does not know how resource planning decisions are made or how the Commission would use the values.[166]

Long-term resource planning tests various generation and demand side management (DSM) resource combinations ("scenarios") under various assumptions ("sensitivities") to determine which combination of resources meets future demand in a reasonably cost-effective manner. Other factors, such as environmental policy, flexibility of the plan, and other goals are also taken into consideration. Resource planning determines the size, type, and timing of resource additions or reductions – what amount and type of resources will be added or retired during the planning period. The location of a new resource is open and unspecified, and therefore resource planning uses a generic resource without a specific location. The county-specific values are unnecessary and could not be used in resource planning.[167]

Since the Commission does not have jurisdiction over siting new generating sources outside of Minnesota, the nearly 400 out-of-state values proposed by Dr. Muller and Dr. Marshall would only be relevant in considering possible long-term power purchases from facilities in other states. We do not believe it is practical to develop county-specific values for this one situation, which is not that common. In the original externalities proceeding, Minnesota rural values were adopted as such to

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166 Hearing Transcript, Vol. 6 at 217 (Marshall).
167 Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.

be used for out-of-state resources (within 200 miles from the Minnesota border), and separate sources outside of Minnesota were not modeled. Dr. Desvousges followed this precedent in his damage cost study.[168]

Finally, in the resource acquisition process, the externality values are used in the final stage of the process when specific proposals are weighed against each other by the Commission. However, the externality values are by no means the only consideration driving the process. Specific proposals to build new fossil-fueled resources and the location of those resources are also driven by transmission capacity, proximity to existing gas pipelines, distance from population and industrial centers, access to water, land ownership, soil conditions, wild life, and costs to build and operate a facility in its specific location.[169] In fact, we doubt there are very many counties in Minnesota that would be seriously considered as a suitable, potential location for a new thermal power plant by any Minnesota utility. Therefore, it is not necessary or practical to develop county-specific values for the resource acquisition process either.

C. Dr. Desvousges' Analysis of Concentration-Response Function and VSL Is the Most Comprehensive and Statistically Robust

There is no doubt that Dr. Desvousges' analysis of concentration-response functions[170] and VSL was far more thorough and statistically advanced than Dr. Muller's or Dr. Marshall's approach. His testimony included a detailed literature review on the epidemiological and economic studies that were considered and explained at great length why certain studies were rejected or selected. Dr. Desvousges' Report, which was attached as Schedule 2 to his Direct Testimony, spent more than 20 pages for reviewing and discussing epidemiological studies regarding

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[168] Ex. 605 (Desvousges Rebuttal) at 30-31.
[169] Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.
[170] We also use terms "relative risk" or "mortality risk" for concentration-response function.

premature mortality and morbidity risks and in an Appendix included summaries of the cohort studies reviewed.[171] Another 10 pages of the Report discussed VSL.[172] Dr. Marshall's Direct Testimony devoted less than two pages to explain his approach to select values for a concentration-response function and VSL,[173] while Dr. Muller's Direct Testimony included a slightly longer analysis in a Technical Appendix.[174]

Dr. Desvousges used statistically superior Monte Carlo simulations to address the uncertainty in estimating premature mortality damages, which are jointly determined by the relative risk of premature mortality and VSL. His Monte Carlo simulation first took a draw from the mortality risk distribution and then another draw from the VSL distribution, and multiplied them together to obtain the value of the risk. This process was repeated tens of thousands of times to form a combined distribution. The Monte Carlo simulation is an advanced approach that incorporates both the mean and standard error values, and therefore takes into account the variability in the underlying studies.[175]

Dr. Desvousges' analysis of the concentration-response function used data from three different studies: a meta-analysis by Hoek et. al. (2013),[176]the most recent paper on the Harvard Six Cities cohort (LePeule et. al. 2012),[177] and a recent paper on the American Cancer Society cohort (Jerret et. al. 2013).[178] The Hoek et. al. (2013)

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171 Ex. 604 (Desvousges Direct), Schedule 2 at 25-46, Appendix 1.
172 Ex. 604 (Desvousges Direct), Schedule 2 at 48-59.
173 Ex. 115 (Marshall Direct) at 22, 25.
174 Ex. 808 (Muller Direct), Schedule 2.
175 Ex. 608 (Desvousges Surrebuttal) at 48-49.
176 Gerard Hoek, Ranjini Krishnan, Rob Beelen, Annette Peters, Bart Ostro, Bert Brunekreef, and Joel Kaufman. 2013. "Long-Term Air Pollution Exposure and Cardio-Respiratory Mortality: A Review." *Environmental Health* 12:43.
177 LePeule, Johanna, Francine Laden, Douglas Dockery, and Joel Schwartz. 2012. "Chronic Exposure to Fine Particles and Mortality: An Extended Follow-Up of the Harvard Six Cities Study from 1974 to 2009. *Environmental Health Perspectives* 120(7):965-970.
178 Jerrett, Michael, Richard T. Burnett, Bernardo S. Beckerman, Michele C. Turner, Daniel Krewski, George Thurston, Randall V. Martin, Aaron van Donkelaar, Edward Hughes, Yuanli Ski, Susan M. Gapstur, Michael J. Thun, and C. Arden Pope III. 2013. "Spatial Analysis of Air Pollution and Mortality in California." *American Journal of Respiratory and Critical Care Medicine*. 188(5):593-599.

meta-analysis incorporates results from 11 individual studies and includes the most significant U.S. and Canadian $PM_{2.5}$ long-term mortality cohort studies. Dr. Desvousges assigned weights to each of the three studies (75 percent, 12.5 percent, and 12.5 percent respectively) based on his professional expertise and judgment. The resulting distribution for the concentration-response function has an average relative risk of 6.8 percent for a 10μg/m^3 change in $PM_{2.5}$, a low relative risk value of 5.3 percent (the 25th percentile value), and a high relative risk value of 7.3 percent (the 75th percentile value).[179]

We believe Dr. Desvousges' Monte Carlo simulation is preferable and superior to Dr. Muller's and Dr. Marshall's approaches. They both selected one point estimate from the Krewski et. al. (2009)[180] single study to represent the low risk and one point estimate from the LePeule et.al. (2012) single study to represent the high risk.[181] Their risk value is based on two point estimates from two individual studies, while Dr. Desvousges' analysis is based on a distribution of values drawn from 12 different studies.

The $PM_{2.5}$ air concentration changes analyzed in this proceeding are extremely small compared to those that are reported in the epidemiology literature or used by EPA to set standards for protecting human health. For example, the primary NAAQS standard for $PM_{2.5}$ is set at 12 μg/m^3, and the range of $PM_{2.5}$ concentration changes in the 13 key long-term cohort studies published since 2000 and reviewed by Dr. Desvousges ranged from 8 to 23 μg/m^3. The risk of premature mortality is typically presented as a percentage change per $PM_{2.5}$ concentration change of 10 μg/m^3. For

[179] Ex. 604 (Desvousges Direct), Schedule 2 at 36-38; Ex. 117 (Jacobs Rebuttal), Schedule 4 (Xcel Energy Response to CEO IR No. 4).

[180] Krewski, Daniel, Michael Jerrett, Richard T. Burnett, Renjun Ma, Edward Hughes, Yuanli Shi, Michelle C. Turner, C. Arden Pope, George Thurston, Eugenia E. Calle, and Michael J. Thun. 2009. "Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality." Health Effects Institute. Presentation 140:5-114. Discussion 115-36.

[181] Ex. 808 (Muller Direct) at 39-40; Ex. 115 (Marshall Direct) at 21-22.

example, a 7.3 percent risk would mean that there is a 7.3 percent increase in premature mortality for every 10 μg/m^3 increase in $PM_{2.5}$.[182]

Every Party that conducted modeling, treated the results of health studies linearly, meaning that the relationship between mortality risk and $PM_{2.5}$ concentration change are considered the same whether the concentration change is 10 μg/m^3 or 0.00001 μg/m^3. However, this linear relationship has been established based on correlations seen at the 8-23 μg/m^3 range and has not been evaluated at very low concentration levels. Similarly, there is no existing health research that supports an association between very small $PM_{2.5}$ concentration levels and premature mortality; all epidemiological studies have focused on much higher levels of concentrations that can be observed and measured. Again, every Party that conducted modeling assumed that the very small changes in $PM_{2.5}$ ambient concentrations are statistically different than zero, although there is no existing research to support that conclusion.[183]

Dr. Muller has argued that because the majority of criteria pollutant damages are from premature mortality effects, and because long-term mortality effects are reported as annual averages, there is no need for the daily and hourly detail that a photochemical grid model can provide.[184] We do not believe these two things have anything to do with each other. The daily and hourly detail is needed to model the dispersion and chemistry of emissions accurately so that the resulting concentration changes and mortality effects can be estimated accurately.

Dr. Desvousges' Monte Carlo simulation for VSL incorporated data from three different meta-analyses (Kochi et. al. 2006;[185] Mrozek and Taylor 2002;[186] and Viscusi

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[182] Ex. 608 (Desvousges Surrebuttal) at 42-44.
[183] Ex. 608 (Desvousges Surrebuttal) at 42-44; Hearing Transcript, Vol. 8 at 113-117.
[184] Hearing Transcript, Vol. 8 at 19 (Muller); Ex. 811 (Muller Surrebuttal) at 3, 28.
[185] Kochi, I., B. Hubbell, and R. Kramer. 2006. "An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for environmental Policy Analysis." *Environmental and Resource Economics* 34:385-406.

and Aldy 2003)[187] and data from a recent individual study by Kniesner et. al. (2012).[188] He again assigned appropriate weights based on his expertise for each study (55 percent, 15 percent, 15 percent, and 15 percent respectively) and used both the mean and standard error values from the four studies. The Monte Carlo simulation drew an overall distribution with an average VSL value of $5.9 million, a low VSL value of $4.1 million (the 25th percentile value), and a high value of $7.9 million (the 75th percentile value).[189]

Again, Dr. Desvousges' Monte Carlo analysis is a more comprehensive and statistically sound way to develop a VSL range than Dr. Muller's and Dr. Marshall's approaches. Both Dr. Muller (for his high VSL value) and Dr. Marshall (for his only VSL value) relied on an outdated EPA meta-analysis from 1999, which included 26 individual studies published during 1974-1991.[190] In fact, Dr. Desvousges used the majority of these studies for his damage cost study in the original externalities proceeding. Besides being dated, this EPA meta-analysis has one of the highest VSL values of any of the studies Dr. Desvousges reviewed. There are many newer VSL studies that have larger sample sizes, rely on better statistical techniques, and use improved study methods, such as panel data.[191] The intent of this proceeding is to update the existing externality values based on current scientific data, which is not

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186 Mrozek, J.R. and L.O. Taylor. 2002. "What Determines the Value of Life? A Meta-Analysis." *Journal of Policy Analysis and Management* 21:253-70.
187 Viscusi, W.K., and J.E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." *Journal of Risk and Uncertainty* 27:5-76.
188 Kniesner, Thomas J., W. Kip Viscusi, Christopher Woock, and James P. Ziliak. 2012. "The Value of a Statistical Life: Evidence from Panel Data." *Review of Economics and Statistics* 94(1):74-87.
189 Ex. 604 (Desvousges Direct), Schedule 2 at 54-56; Ex. 117 (Jacobs Rebuttal), Schedule 4 (Xcel Energy Response to CEO IR No. 4).
190 Ex. 808 (Muller Direct) at 41-42; Ex. 115 (Marshall Direct) at 25.
191 Ex. 604 (Desvousges Direct), Schedule 2 at 56; Ex. 608 (Desvousges Surrebuttal) at 55-56.

achieved by relying on VSL studies from 1974-1991. EPA is currently in the process of revising its VSL guidance and considering more recent studies.[192]

Dr. Muller in his Rebuttal Testimony agreed on Dr. Desvousges' VSL and concentration-response functions, and stated that these two areas of solid agreement are very important.[193] Dr. Muller himself used an approach that inflates the range of his proposed externality values, because he chose a very low value and a very high value for both the mortality risk (6 percent and 14 percent for a $10\mu g/m^3$ change in $PM_{2.5}$) and VSL ($3.7 million and $9.5 million). Dr. Muller stated that he chose this approach as a sensitivity analysis to show the Commission the wide range of possible damage values and noted that for the concentration response function alone, his damage values more than double if the high mortality risk value is used instead of the low mortality risk value.[194] Dr. Muller went even further in his sensitivity analysis by multiplying the low mortality risk value with the low VSL, and the high mortality risk value with high VSL, which makes the range of his damage estimates even wider. These damage estimates have a very low chance of ever occurring because Dr. Muller took the least probable values for mortality risk and VSL and multiplied them together.

VII. CONCLUSION

Xcel Energy believes that the Commission should update the externality values based on the best and most accurate method that accounts for the majority of air quality changes and impacts from $PM_{2.5}$, SO_2, and NO_x emissions generated in

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192 Hearing Transcript, Vol. 6 at 163-165 (Marshall). Dr. Marshall referenced EPA 2000, *Guidelines for Preparing Economic Analyses*, as the source of his VSL, *see* Ex. 115 (Marshall Direct) at 25. Xcel Energy offered Appendix B of the most recent version of that publication to the record as Exhibit 614, but it was not admitted (*EPA Guidelines for Preparing Economic Analyses*, December 17, 2010, Updated May 2014). As quoted at the hearing, the EPA stated in the current guidelines that the studies used in the original EPA meta-analysis "were the best available data at the time, they are sufficiently dated and may rely on obsolete preferences for risk and income," Hearing Transcript, Vol. 6 at 165.
193 Ex. 810 (Muller Rebuttal) at 17-19, 46.
194 Ex. 808 (Muller Direct) at 39-45; Hearing Transcript, Vol. 8 at 46 (Muller).

Minnesota. There is no question that out of all Parties in this proceeding, we have used the best model and science available today to estimate externality values: We used the most accurate air quality model CAMx, the most recent and comprehensive epidemiological and economic studies, and the most advanced statistical methods. We used Monte Carlo simulations to create a combined distribution of concentration-response functions and VSL, which takes into account the uncertainty and variability in the underlying studies.

There are many reasons why it is not practicable or reasonable to determine separate externality values for each county in Minnesota and within 200 miles from the Minnesota border, as the Agencies and CEO have proposed. Neither is it practicable or reasonable to estimate nationwide damages from $PM_{2.5}$, SO_2, and NO_x emissions generated in Minnesota, as the Agencies and CEO have recommended.

In the original externalities proceeding in the mid-1990s, the criteria pollutant values were established for three locations: urban, metropolitan-fringe, and rural areas. Damages from criteria pollutants were estimated in Minnesota, not nationwide. The geographic scope of damages and specificity in emission source locations are significant policy questions. Our understanding is that this proceeding was re-opened to update the externality values to reflect the current state of science, but the Agencies and CEO now propose to change significant policy principles, which are not questions of science.

Dr. Muller and Dr. Marshall have argued that it is important to model a source in each county, because this would provide useful information for the Commission about the variability of damages based on source location. However, the Commission will not gain any useful information if the county-specific values are based on unreliable air quality modeling and are plainly wrong. It is more important to model a few representative sources accurately than nearly 500 sources inaccurately. In addition, it is not practical to develop county-specific values, because they cannot be used in integrated resource planning; the values for nearly 400 out-of-state sources would only be relevant in considering power purchases from other states; and in the resource acquisition process, proposals to build new fossil-fueled resources and the location of those resources depend on several other more significant factors than the externality values. It is not practicable or necessary to develop county-specific values, and this should not be the reason why unreliable and inaccurate AP2 or InMAP modeling would be chosen over CAMx modeling.

There are many reasons that speak against adopting a national scope for criteria pollutant damages, and when all these factors are considered together, Xcel Energy believes it is not practicable to calculate nationwide damages from emissions generated in Minnesota. We estimated ambient air concentration changes in Minnesota and within 100 miles from the Minnesota border, because the majority of air quality changes from Minnesota emissions occur within this geographic scope. From a scientific perspective, there is more uncertainty when air quality changes are modeled far away from the source and when the predicted concentration changes are very small (e.g., 0.000000643 $\mu g/m^3$). Epidemiological research has not addressed adverse health effects at very small ambient concentration levels or examined whether the linear application of concentration-response function is appropriate at very small concentration levels. From a public policy perspective, there is no need to estimate impacts from criteria pollutants on a national basis, because federal rules and regulations are already in place to minimize damages from the interstate transport of emissions. Today NAAQS are set at levels that are protective of human health and the environment and EPA has determined through CSAPR modeling and required reductions that Minnesota is not significantly contributing to ambient air concentrations of $PM_{2.5}$, SO_2 or NO_x in any other state.

Xcel Energy believes that AP2 and InMAP are inappropriate models to use in this proceeding and disputes the accuracy of AP2 and InMAP modeling results. Accordingly, we oppose adopting any externality values based on AP2 or InMAP modeling. Both models were applied against EPA's current and proposed air quality modeling guidelines and guidance; InMAP is also a brand new model unlike any other model typically used for air quality modeling. Since AP2 and InMAP are reduced-form models, they use simplified air dispersion and chemistry algorithms; rely on annual average meteorological data; model an equal amount of each pollutant; and do not account for any chemical interaction among the emitted pollutants to resemble a point source plume. We believe that all these factors together contributed to the inaccurate AP2 and InMAP air quality modeling results.

AP2's random and sporadic modeling results from NO_x emissions skip most Minnesota counties, but show secondary $PM_{2.5}$ concentration changes in faraway states to the east, west, and south. Similarly, AP2 significantly over-predicts secondary $PM_{2.5}$ concentrations from SO_2 emissions outside of Minnesota, but under-estimates concentration changes within Minnesota. AP2 shows fairly reasonable results from direct $PM_{2.5}$ emissions in Minnesota, but again significantly over-estimates concentration changes nationwide. AP2's hypothetical damage values are also consistently and substantially higher than the values based on the modeling of existing power plants.

The InMAP results for NO_x, $PM_{2.5}$ and SO_2 are clearly biased to the east and overestimate concentration changes and damage values. When the emission source, geographic scope, concentration response-function, and VSL are held equal, InMAP's damage values are significantly higher than the CAMx or AP2 values. For example, for Black Dog (urban location), InMAP's damage values for $PM_{2.5}$ are more than five times higher than the CAMx values and InMAP's damage values for NO_x are more than three times higher than the CAMx values.

Dr. Desvousges' CAMx modeling incorporates hourly, varying, three-dimensional wind speeds and directions as well as full-science chemistry algorithms. Clearly CAMx is the only model in this proceeding that can accurately determine the dispersion of emissions throughout the year; incorporates chemistry among pollutants in the point source plume; and accurately accounts for the chemical reactions in the atmosphere after the pollutants are emitted. CAMx was specifically designed to simultaneously model criteria pollutant emissions and is recommended by EPA for the modeling of ozone and secondary $PM_{2.5}$ formation. Since CAMx has been subject to hundreds of peer-reviewed journal articles and used in numerous EPA rulemakings, it has been thoroughly tested and approved by the scientific and academic community.

The Commission's existing externality values do need to be updated with the current state of science and knowledge. With the assistance and expertise of Dr. Desvousges, Xcel Energy has presented updated modeling that is accurate, reliable and credible. We respectfully request that the Commission establish externality values based on our CAMx modeling and adopt our proposed methodology and values as reasonable, practicable, and the best available measure to estimate environmental values for $PM_{2.5}$, SO_2, and NO_x.

Respectfully submitted by:

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CERTIFICATE OF SERVICE

I, Carl Cronin, hereby certify that I have this day served copies of the foregoing document on the attached list of persons.

xx by depositing a true and correct copy thereof, properly enveloped with postage paid in the United States mail at Minneapolis, Minnesota; or

xx by electronic filing.

MPUC Docket No: E999/CI-14-643

Dated this 15th day of March 2016

/s/

____

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