414 Nicollet Mall
Minneapolis, MN 55401

April 15, 2016

—Via Electronic Filing—

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

RE: REPLY BRIEF AND FINDINGS OF FACT 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 Reply Brief and Findings of Fact 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. For your convenience we will also email to you Word versions of these documents.

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

CERTIFICATE OF SERVICE

I, SaGonna Thompson, 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 April 2016

/s/

SaGonna Thompson
Regulatory Administrator

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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 REPLY BRIEF REGARDING CRITERIA POLLUTANTS ($PM_{2.5}$, SO_2, AND NO_x)

April 15, 2016

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STATE OF MINNESOTA
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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 BRIEF REGARDING CRITERIA POLLUTANTS ($PM_{2.5}$, SO_2, AND NO_X)

I. INTRODUCTION

Northern States Power Company, doing business as Xcel Energy, respectfully provides this Reply Brief in support of its proposed methodology to estimate the environmental cost of $PM_{2.5}$, SO_2, and NO_x emissions. We recommend that the Commission adopt a range of environmental values for each pollutant for rural, metropolitan-fringe, and urban locations. Our suggested values are based on an extensive damage cost study conducted by Dr. William Desvousges and his research team, including full-chemistry CAMx air quality modeling by Ramboll Environ. A preponderance of the evidence in this proceeding shows that Xcel Energy's proposed environmental values for $PM_{2.5}$, SO_2, and NO_x are reasonable, practicable, and the best available measure of the criteria pollutants' cost.

This case involves complex issues of science, economics, and public policy. The most critical scientific questions are which model to choose, how well that model is able to predict ambient concentration changes, and how to estimate and monetize impacts on human health. CAMx was specifically designed to model criteria pollutant

emissions simultaneously and is recommended by the U.S. Environmental Protection Agency (EPA) for the modeling of ozone and secondary $PM_{2.5}$ formation. A preponderance of the evidence shows that CAMx is the only model in this proceeding that incorporates flue-gas chemistry among pollutants in the point source plume; accurately accounts for chemical reactions in the atmosphere after the pollutants are emitted; and predicts credible ambient air concentration changes that are consistent with what is known about the science of air dispersion. Dr. Desvousges' analysis of mortality risk and the value of a statistical life (VSL) is based on the best and most recent science and reflects the variability of epidemiological and economic studies. His combined Monte Carlo simulation of mortality risk and VSL is a superior way to address the inherent uncertainty involved in estimating and monetizing human health effects from $PM_{2.5}$ exposure.

In addition, there are two significant public policy questions that substantially affect the outcome of this proceeding: the geographic scope of damages evaluated and specificity in source location. As we have explained earlier and will summarize again in this Reply Brief, there are many reasons that speak against adopting a national scope for criteria pollutant damages or modeling a source in each county in Minnesota and within 200 miles from the Minnesota border (nearly 500 counties). When all of these factors are considered together, a preponderance of the evidence shows it is not reasonable or practicable to calculate nationwide damages from emissions generated in Minnesota or to establish county-specific externality values.

The differences among the Parties' air quality modeling results and damage estimates are significant – they are not slight disparities or trivial nuances. We have presented substantial evidence showing that the AP2 and InMAP modeling results are unreliable for this application and clearly outside of any realm of reasonableness. We

agree an update of the current externality values is appropriate at this time, and urge the Commission to consider what amount of change is reasonable for public policy. It is easy to get lost in the scientific details and modeling technicalities, but in the end, the Commission is in charge of establishing public policy that is based on the best available measure, makes common sense, and is reasonable for Minnesota.

II. "PRACTICABLE" GOES BEYOND AVAILABILITY OF DATA

Minn. Stat. § 216B.2422, Subd. 3 requires that the Commission shall, "to the extent practicable," quantify and establish a range of environmental costs. The legislature did not further define the term "practicable," and the meaning was disputed in the original externalities proceeding.

CEO has suggested that practicability should be defined narrowly as "whether there are enough data in the record to establish a value for a particular pollutant on a national scale."[1] Xcel Energy respectfully disagrees, and as explained below, believes that "to the extent practicable" is a much broader concept than just the availability of data. A separate issue is that the data available should be reliable and accurate.

The Commission and ALJ agreed in the initial proceeding that practicable means something that is feasible, achievable, or capable of being accomplished.[2] The Commission further noted that "the quantification of **all** environmental impacts, however slight, difficult to measure, or irrelevant," would be a "bottomless and highly

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[1] CEO Initial Brief at 19.

[2] 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 29 at 10. Hereafter referred as ALJ March 1996 Report. *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. Hereafter referred as Commission January 1997 Order.

speculative task."[3] This implies that there should not be an unreasonable amount of uncertainty or ambiguity involved in the development of the environmental values. Accordingly, the ALJ noted that at some point the degree of uncertainty may become so high that it is no longer practicable to adopt the values.[4]

Xcel Energy believes that practicability also requires that the environmental values can be used for their intended purpose and will provide useful information in their application. It would make no sense at all if at the end of this lengthy process, we are left with environmental values that cannot be used or give irrelevant or inaccurate information when they are used.

III. PUBLIC POLICY ISSUES

A. The Geographic Scope of Damages and Specificity in Source Location Are Public Policy Issues

This proceeding involves complex issues of science, economics, and public policy. The main focus has been on the scientific questions, such as model features, modeling parameters, air dispersion and chemistry of emissions, accuracy of air quality modeling results, and estimating and monetizing the risk of premature mortality. We believe there are three scientific questions that are the most critical – what model to choose, how well that model is able to predict ambient concentration changes, and how to estimate and monetize impacts on human health.

In addition, there are two significant public policy questions that substantially affect the outcome of this proceeding. First, Xcel Energy agrees with the Agencies that the geographic scope of damages estimated is ultimately a policy decision for the

[3] Commission January 1997 Order at 12. [emphasis in the original]
[4] ALJ March 1996 Report, Finding 31 at 11.

Commission.[5] The underlying statute is silent on the geographic scope of damages and does not include any language on how or where the damages should be estimated. Although there is a strong preference in the legislative history to focus on criteria pollutant impacts within Minnesota,[6] the statute does not require, nor deny, Minnesota, national, or global scope. In fact, the statute is currently used to estimate both global (CO_2) and Minnesota (criteria pollutants) damages.[7] CEO claims that since the statute does not have specific language and does not literally state that the geographic scope is within Minnesota, damages must be estimated nationwide, if that is practicable.[8] However, following the same logic, damages should also be estimated in Canada, which of course, no Party has done or suggested.[9]

Another significant, disputed policy issue in this proceeding involves the geographic sensitivity and specificity in emissions sources, in other words, how many sources should be modeled to achieve representative results. In the initial externalities proceeding, 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. There is no question that these two decisions can be characterized as long-standing Commission precedent and interpretation of Minn. Stat. § 216B.2422, Subd. 3. Minnesota courts grant deference to administrative interpretations of statutes, and the level of deference increases when the agency, as here, is construing a statute which it administers and the construction is long-

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[5] Agencies Initial Brief at 56-57.
[6] See Xcel Energy Initial Brief at 8-9.
[7] The focus on global damages in the case of CO_2 is driven by the inherently different nature and impacts of CO_2 as a globally well-mixed pollutant with impacts largely independent of emission source location. Criteria pollutants in contrast have local and regional impacts.
[8] CEO Initial Brief at 28.
[9] For example, CEO states that they did not estimate damage values outside the United States because InMAP "currently estimates concentration changes for the U.S. only." *See* Ex. 451 (CEO Response to MLIG IR No. 328).

standing.[10] Any changes to a long-standing agency interpretation must be supported by substantial evidence in view of the entire record submitted.[11]

B. It Is Not Reasonable or Practicable to Estimate Nationwide Damages

There are many reasons that speak against adopting a national scope for criteria pollutant damages, and when all these factors are considered together, a preponderance of the evidence shows it is not reasonable or practicable to calculate nationwide damages from emissions generated in Minnesota. Our Initial Brief discussed in great detail why it is impracticable to estimate criteria pollutant damages nationwide,[12] and we briefly summarize the reasons here.

Long-Standing Commission Precedence. 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 there was a strong preference to focus on protecting Minnesota's economy, environment, and residents. The original Commission interpretation, which estimated criteria pollutant impacts in Minnesota, is consistent with the legislative history.[13] In the initial proceeding, the ALJ and the Commission concluded that unlike CO_2, criteria pollutants are local and regional by nature. The Commission found it reasonable to "focus on the effects of by-products that cause the most significant costs," and for criteria pollutants this meant "quantifying the damage they cause in Minnesota."[14]

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[10] *See McAfee v. Dept. of Revenue*, 514 N.W.2d 301 (Minn. App. 1994).
[11] *Pet. of N. States Power Gas Util.*, 519 N.W.2d 921 (Minn. App. 1994).
[12] See Xcel Energy's Initial Brief at 52-61.
[13] Xcel Energy's Initial Brief at 8-9.
[14] Commission January 1997 Order at 15.

Regional Nature of $PM_{2.5}$, SO_2, and NO_x. Impacts from criteria pollutant emissions are mainly local and regional by nature – the majority of air quality changes from Minnesota sources will occur in Minnesota or in close proximity to the Minnesota border. Changes to ambient concentrations from $PM_{2.5}$, SO_2, and NO_x emissions will generally be highest near the source of emissions and decrease 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, tends to travel further, however, the majority of concentration changes will still take place within 100 miles (160 kilometers) from the source.[15]

Modeling Uncertainty at Further Distances. There is substantial uncertainty in estimating national damages from criteria pollutant emissions. The national scope of damages hinges on the ability of models to accurately predict changes in ambient air concentrations throughout the contiguous United States. Uncertainty is significantly increased and estimates become less reliable the further the modeling distance is from the emission source. This is especially true for models that rely on Gaussian plumes, such as AP2, but also applies to other reduced-form models and photochemical grid models.[16]

Uncertainty of Health Impacts Attributable to Very Small Changes in Concentrations. Estimating the national scope of damages involves additional uncertainty, because the models are predicting very small ambient air concentration changes at further distances (e.g., 0.00000298 μg/m3 or 0.000000643 μg/m3).[17]

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[15] Ex. 608 (Desvousges Surrebuttal) at 35; Ex. 119 (Marshall Surrebuttal), Schedule 2 (Xcel Energy Response to CEO IR No. 11 and No. 12); Xcel Energy Initial Brief at 52-53.
[16] Ex. 608 (Desvousges Surrebuttal) at 46; Xcel Energy Initial Brief at 55.
[17] AP2 and InMAP average change in ambient $PM_{2.5}$ concentrations from the Sherco plant beyond one hundred miles of Minnesota. See Ex. 608 (Desvousges Surrebuttal) at 43.

Contrary to CEO claims,[18] epidemiological research has not addressed adverse health effects at very low ambient concentration levels or examined whether the linear application of concentration-response function is appropriate at very low concentration levels.[19] AP2, InMAP, and CAMx do not have a limit on how small concentration changes can be calculated; 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.[20]

The very small concentration changes, when summed across the contiguous United States, have a significant impact on the externality values. To estimate mortality damages from $PM_{2.5}$, these concentrations are 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. When 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 or 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.[21]

Human Health Protection Through NAAQS and CSAPR. 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

[18] CEO Initial Brief at 47-49. CEO claims that the relationship between premature mortality and $PM_{2.5}$ concentrations is linear with no threshold.
[19] Ex. 608 (Desvousges Surrebuttal) at 42-44; Hearing Transcript, Vol. 7 at 113-117 (Desvousges). CEO only refers to literature that finds linear relationship at *observed* concentrations down to 8 $\mu g/m^3$, but not at very low concentrations levels below that, CEO Initial Brief at 48.
[20] Ex. 608 (Desvousges Surrebuttal) at 44; Hearing Transcript, Vol. 7 at 115 (Desvousges).
[21] Hearing Transcript, Vol. 7 at 113 (Desvousges); Hearing Transcript, Vol. 8 at 33-34 (Muller); Xcel Energy Initial Brief at 55-60.

damages from the interstate transport of emissions. Today, National Ambient Air Quality Standards (NAAQS) are set at levels that are protective of human health and the environment and EPA has determined through Cross State Air Pollution Rule (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.[22] At the time of the original externalities proceeding, EPA had not kept the NAAQS updated; NAAQS did not reflect the latest scientific knowledge; and regulations on the interstate transport of emissions did not exist.[23]

The Agencies and CEO are asking the Commission to change the current geographic scope of criteria pollutant damages, which is based on a long-standing precedent and interpretation of statute. In order to do so, the Commission would have to explain its reasoning and support it by substantial evidence in view of the entire record as submitted.[24] The Agencies and CEO have not presented such substantial evidence in this case.

For example, Dr. Muller and Dr. Marshall reported very different and conflicting proportions of damages within Minnesota and outside of Minnesota, based on their separate modeling.[25] Other evidence presented by the Agencies and CEO in the record, attempting to estimate the geographic scope of damages, is contradictory, incorrect, or unconvincing. For example, Dr. Muller conducted an analysis of EPA's CSAPR modeling data, but his analysis had serious flaws, such as including all types of

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[22] Ex. 607 (Rosvold Rebuttal) at 2-14; Ex. 617 (Rosvold Opening Statement) at 1-2.
[23] ALJ March 1996 Report, Finding 46 at 23.
[24] *Pet. of N. States Power Gas Util.*, 519 N.W.2d 921 (Minn. App. 1994).
[25] Xcel Energy Initial Brief at 54; Ex. 608 (Desvousges Surrebuttal) at 38; Ex. 810 (Muller Rebuttal) at 22; Ex. 116 (Marshall Rebuttal) at 12. For example, Dr. Muller reported that for $PM_{2.5}$, 60 percent of his calculated damages are 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.

emission sources and not correcting for the irregular number of monitoring sites in each state.[26] Dr. Marshall prepared figures that show that the vast majority of $PM_{2.5}$ concentration changes occur within the Minnesota domain, based on his analysis of CAMx hourly results from a lower spatial grid (36 kilometers).[27]

Although a small proportion of concentration changes may occur outside Dr. Desvousges' Minnesota modeling domain,[28] it is not practicable or reasonable to estimate criteria pollutant damages from Minnesota emissions nationwide, considering the mostly local and regional nature of criteria pollutants, the significant uncertainty involved in estimating national damages, and the protection of human health through the NAAQS and CSAPR regulations.

If the Commission does decide to change its prior precedent and applies a national scope for criteria pollutant damages, we oppose using AP2 or InMAP results to estimate those damages. As we have repeatedly stated, neither model can predict nationwide concentration changes reliably or accurately.

C. It Is Not Reasonable or Practicable to Establish County-Specific Externality Values

In the determination of criteria pollutant values, the geographic sensitivity and specificity of emission sources is another significant policy question. The Agencies and CEO modeled a source in each county in Minnesota (87 counties) and within 200 miles from the Minnesota border (nearly 400 counties), a total of nearly 500 sources. The Agencies and CEO have argued that the county-specific values would provide

[26] Xcel Energy Initial Brief at 54-55; Ex. 811 (Muller Surrebuttal) at 24-25; Hearing Transcript, Vol. 8 at 97-110 (Muller).
[27] *See* Xcel Energy Initial Brief at 57-60; 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).
[28] This modeling domain extends approximately 100 miles from the Minnesota border to the east, south, and west, including parts of Iowa, Wisconsin, Michigan, Illinois, Nebraska, South Dakota, and North Dakota.

useful information for the Commission about the variability of damages based on source location.[29]

Xcel Energy modeled one source at three representative locations – Marshall (Lyon County), Sherco (Sherburne County), and Black Dog (Dakota County) – to estimate externality values for a rural, metropolitan-fringe, and urban location. Again, our Initial Brief discussed in detail why it is not reasonable or practicable to develop county-specific externality values.[30] The reasons are briefly summarized here.

Accuracy. It is much more important to model a few representative sources accurately than 500 sources inaccurately. The Commission will not gain any useful information if the county-specific externality values are incorrect because they are based on unreliable air quality modeling. AP2 and InMAP air quality modeling results are not credible, and the disputed need for county-specific values should not be the reason to choose less accurate reduced-form modeling over more accurate photochemical grid modeling.[31]

Three Location Sources Are Representative. We selected the Marshall, Sherco, and Black Dog locations because they are representative of a rural, metropolitan-fringe, and urban area in Minnesota. They are consistent with the geographic groupings adopted in the original proceeding and are realistic potential locations for a new power plant. The three locations also represent a cautious approach. The city of Marshall has a larger population than a typical rural setting and is located in the western part of the state, allowing air dispersion over a greater part of Minnesota. The Sherco site is located upwind from the Twin Cities in the

[29] Ex. 813 (Muller Opening Statement) at 2; Ex. 120 (Marshall Opening Statement) at 2.
[30] Xcel Energy Initial Brief at 62-64.
[31] Xcel Energy Initial Brief at 62-63.

predominant wind pattern, and the Black Dog site is located in the largest urban area in the state.[32]

False Precision. Nearly 500 county-specific values provide an overwhelming amount of information, especially if they are proposed at three different stack heights, as CEO has done. In many cases there is not much variability in the values from county to county.[33] In fact, the county-by-county values falsely imply precision and specificity that does not exist, considering that the values were produced by reduced-form models, which use annual average data and highly simplified atmospheric chemistry algorithms. We believe it is inappropriate to attempt to use the least precise models to develop the most specific values.[34]

County-by-County Values Are Unnecessary. It is not practicable to develop county-specific values, because they cannot be used for their intended purpose in the resource planning process and would not provide useful information in the resource acquisition process. Resource planning determines the size, type, and timing of resource additions or reductions – the location of a new resource is typically unspecified, and therefore resource planning uses a generic resource without a specific location.[35] In resource acquisition, externality values are used in the final stage of the process when specific proposals are weighed against each other by the Commission. However, proposals to build new fossil-fueled resources and the location of those resources are driven by other factors than the externality values: 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

[32] Ex. 608 (Desvousges Surrebuttal) at 61; Ex. 616 (Desvousges Opening Statement) at 2.
[33] Ex. 608 (Desvousges Surrebuttal) at 62.
[34] Ex. 605 (Desvousges Rebuttal) at 26, 65.
[35] Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.

operate a facility in its specific location.[36] Since the Commission does not have jurisdiction over siting new generating sources outside of Minnesota, the nearly 400 out-of-state values proposed by the Agencies and CEO would only be relevant in considering possible long-term power purchases from facilities in other states. It is not practicable to develop and maintain county-specific values for this situation only.[37]

When all of the factors discussed above are considered together, a preponderance of the evidence shows it is not reasonable or practicable to develop and maintain county-specific externality values. The Commission and all regulated utilities in Minnesota have used the rural, metropolitan-fringe, and urban externality values without controversy for the past 20 years. CEO has criticized us for proposing the three values based on location, but not specifying how they would be applied.[38] Since there is a long practice of actually using the externality values based on these three geographic locations, it is unclear why we should have presented evidence how our proposed values would be used.

We recommend that the rural, metropolitan-fringe, and urban values will also be used for out-of-state resource within 200 miles from the Minnesota border, as appropriate based on the location of the source.[39]

The Agencies have not proposed a generic externality value. CEO proposed a generic value for each pollutant based on "separately calculating the impacts of each existing power plant in Minnesota and taking an average of the values weighted by total damages caused by each plant."[40] However, CEO has not supported their proposed generic values with any evidence in the record. For instance, the record

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[36] Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.
[37] Ex. 605 (Desvousges Rebuttal) at 30-31.
[38] CEO Initial Brief at 38.
[39] Ex. 605 (Desvousges Rebuttal) at 31.
[40] Ex. 115 (Marshall Direct) at 28, *see* also CEO Initial Brief at 65.

does not show how many or which existing power plants were modeled, where the plants are located, or if the locations are dominated by urban, metropolitan-fringe, or rural locations. There is no information in the record to evaluate the accuracy or representativeness of the generic values proposed by CEO, and therefore, a preponderance of the evidence does not support adopting CEO's generic values.

IV. SCIENTIFIC ISSUES

A. Xcel Energy's Proposed Externality Values Are Based on a Reliable and Accurate Model that Follows EPA Guidelines

The Agencies and CEO have criticized the CAMx model because, in their opinion, it is complex, costly, and time-consuming.[41] However, in this proceeding, it is critical that the air quality model relied on accurately predicts ambient air concentration changes from power plant emissions. Xcel Energy has already taken responsibility for conducting the CAMx modeling and the results are available now; the time and expense needed for CAMx modeling is therefore a moot point. We used the best air quality model available today and the CAMx modeling produced the most accurate estimates of the dispersion and impacts from $PM_{2.5}$, SO_2, and NO_x emissions.

There are many reasons why AP2 and InMAP are inappropriate models to use in this proceeding. They are both reduced-form models, which do not include flue-gas chemistry and model SO_2, NO_x, and $PM_{2.5}$ emissions in isolation from one another.[42] For the county-specific values, Dr. Muller modeled one incremental ton of each pollutant and Dr. Marshall modeled 1,000 tons of each pollutant. In reality, power plants emit SO_2, NO_x, and $PM_{2.5}$ together in unequal quantities and they interact chemically in the point source plume. Modeling each pollutant independently from

[41] E.g., Ex. 116 (Marshall Rebuttal) at 7; Ex. 810 (Muller Rebuttal) at 35.

[42] Although InMap models SO_2, NO_x, and $PM_{2.5}$ at the same time, it in effect treats them separately because there is no chemical interaction among the pollutants and they are all treated linearly.

one another typically overestimates the impacts of SO_2 and NO_x on secondary $PM_{2.5}$ formation, because the model 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 $PM_{2.5}$.[43]

In addition, AP2 and InMAP rely on annual average wind speed and direction data and use simplified chemical transformation algorithms to model ozone and secondary $PM_{2.5}$ formation.[44] Ozone and secondary $PM_{2.5}$ formation have highly variable seasonal and daily differences 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 colder periods.[45] EPA's current (2007)[46] and proposed (2014)[47] guidance for ozone and secondary $PM_{2.5}$ modeling recommends using photochemical grid models, such as CAMx, which incorporate full-science atmospheric chemistry.[48]

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

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[43] Ex. 605 (Desvousges Rebuttal) at 37-38; Hearing Transcript, Vol. 7 at 135-137 (Desvousges).
[44] Dr. Muller acknowledges that AP2 models chemical reactions in the atmosphere "in a very simple way." Hearing Transcript, Vol. 8 at 29 (Muller). Dr. Marshall has stated that "there is no dispute that CAMx is a more realistic representation than InMAP or AP2 of meteorology and atmospheric chemistry. Ex. 119 (Marshall Surrebuttal) at 19.
[45] Ex. 605 (Desvousges Rebuttal) at 34.
[46] 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
[47] 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
[48] Ex. 605 (Desvousges Rebuttal) at 35-37.

temporally and spatially, which impacts the dispersion of emissions and therefore changes in ambient concentrations.[49]

Current EPA air modeling guidelines (40 CFR Part 51, Appendix W)[50] 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.[51] This makes it particularly inappropriate to use AP2 to estimate nationwide damages.

The EPA guidelines (40 CFR Part 51, Appendix W) also set criteria for air quality models and require that the models are non-proprietary and publicly available; have received a scientific peer-review; and have performed well in past applications.[52] The current version of AP2 used in this proceeding was designated trade secret and undergoing peer-review.[53] The trade secret status was lifted on the first day of the evidentiary hearings, on January 12, 2016.[54] InMAP was also initially designated as trade secret until November 13, 2015, after the filing of Rebuttal Testimony.[55]

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[49] Ex. 605 (Desvousges Rebuttal) at 19, 34.
[50] 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
[51] Ex. 604 (Desvousges Direct), Schedule 3 at 2-3; Ex. 605 (Desvousges Rebuttal) at 21-22; Ex. 811 (Muller Surrebuttal) at 6.
[52] Ex. 606 (Desvousges Rebuttal Non-Public) at 17, 22-24.
[53] Ex. 605 (Desvousges Rebuttal) at 17.
[54] Hearing Transcript Vol. 6 at 150-151. The evidentiary hearing transcript Vol. 8 at 123:3 was revised on March 22, 2016 to read that the AP2 "documentation is now entirely public."
[55] See Ex. 608 (Desvousges Surrebuttal), Schedule 1 at 1.

InMAP is a 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.[56] 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.[57] InMAP has not been used in any prior federal or state regulatory proceedings. Simply because InMAP was made available to the other Parties does not mean that it received similar testing and scrutiny, possibly detecting errors in code, as review by the scientific community would provide.

Dr. Marshall's Direct Testimony would have been expected to be much more detailed in order to be transparent, considering that InMAP is a brand new model, different from any other typical air quality models, and not yet commonly used. Dr. Marshall did not include an expert report with his testimony, leaving discovery as the main source to gain more relevant information about InMAP, its features, and the modeling results. This approach had shortcomings.[58]

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 modeling guidelines and guidance and it has been subject to hundreds of peer-reviewed journal articles and used in numerous EPA rulemakings. CAMx and all the supporting

[56] 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.

[57] The authors are Tessum, Hill, and Marshall. See Ex. 119 (Marshall Surrebuttal), Schedule 1; Hearing Transcript, Vol. 6 at 157 (Marshall).

[58] For example, the URL address to the InMAP website and access to instructions how to install and use InMAP were shared for the first time in Dr. Marshall's Surrebuttal Testimony. Ex. 119 (Marshall Surrebuttal) at 26; Hearing Transcript Vol. 6 at 131, 134.

software have been publicly available for free for over ten years and the model was downloaded more than 1,200 times in the last two years alone.[59] Therefore, CAMx has been thoroughly tested and approved by the scientific and academic community. CEO perceives CAMx as a complicated and complex model, and has therefore questioned its transparency.[60] However, CAMx is regularly used by EPA, state agencies, researchers, and others who need reliable air quality modeling, including the Minnesota Pollution Control Agency. EPA guidelines for air quality modeling represent the best scientific practice and highest-level of standards. CAMx is the only model in this proceeding that meets all current EPA guidelines.

B. Xcel Energy's Externality Values Are Based on Reliable and Accurate Air Quality Modeling Results

The Commission limited the Agencies' options in air quality model choice to a reduced-form model because of perceived time and cost concerns;[61] CEO also opted to use a reduced-form model. Xcel Energy's use of a detailed photochemical grid model allowed comparison of results, showing that the AP2 and InMAP modeling conducted by Dr. Muller and Dr. Marshall did not produce reliable or even reasonably accurate results.

The three different modeling approaches used by Dr. Muller, Dr. Marshall, and Dr. Desvousges predicted very different results, regarding both the ambient air concentration changes (air quality modeling component) and the proposed environmental values (estimating and monetizing impacts). There is little agreement

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[59] Ex. 605 (Desvousges Rebuttal) at 18, 21-24, 35-37; Ex. 608 (Desvousges Surrebuttal) at 6; Ex. 616 (Desvousges Opening Statement) at 1.

[60] Ex. 116 (Marshall Rebuttal) at 9.

[61] The Commission acknowledged that photochemical modeling approach may offer the greatest precision, and only the Agencies were directed to use reduced-form modeling. Unlike the Agencies claim, the Commission did not state that a reduced-form model would be preferable in this proceeding for any other reason than possible time and cost concerns. *See* Agencies Initial Brief at 13.

among the AP2, InMAP, and CAMx estimates and the results vary significantly from each other, whether analyzed by pollutant, by individual source, or by geographic scope.[62]

The Agencies and CEO have disputed the geographic scope used for CAMx modeling and the use of three source locations.[63] However, no Party has challenged the accuracy of Dr. Desvousges' CAMx air quality modeling results from the Black Dog, Sherco, and Marshall sources within the Minnesota domain.[64] The record shows that CAMx 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.[65]

In addition, no Party has disputed the accuracy of the comparison of the modeling results presented in Table 1 or the figures included in Dr. Desvousges'

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[62] Xcel Energy's Initial Brief at 18-23.

[63] E.g., Ex. 810 (Muller Rebuttal) at 26, 34; Ex. 116 (Marshall Rebuttal) at 8, 11-12.

[64] Initially, Dr. Muller and Dr. Marshall criticized running the Sherco and Marshall hypothetical facilities together in one CAMx source apportionment simulation (Scenario 1). However, this did not affect the results because CAMx includes source apportionment technology that can isolate the separate contributions from multiple hypothetical facilities. 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). Similarly, we have explained that using the Riverside emission rate for direct $PM_{2.5}$ did not affect our results, because of the linear nature of increased ambient concentrations of $PM_{2.5}$ from direct $PM_{2.5}$ emissions. *See* Ex. 608 (Desvousges Surrebuttal) at 6-12; Xcel Energy Initial Brief at 17-18.

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

Surrebuttal Testimony.[66] These figures reflect updated information provided by CEO on October 28, 2015, when CEO informed the Parties that the correct amount of each pollutant modeled for InMAP was 1,000 tons, not 1 ton as they had originally stated.[67] Dr. Desvousges' analysis and figures were updated to reflect CEO's corrected information and our conclusions about InMAP air quality modeling results remain the same.[68]

The record shows that AP2's air quality modeling results are unexpected and inconsistent with what is known about the atmospheric dispersion and chemistry of emissions. AP2's random and sporadic modeling results from NO_x emissions skip over most Minnesota counties, but show secondary $PM_{2.5}$ concentration changes in faraway states to the east, west, and south.[69] Similarly, AP2 under-estimates secondary $PM_{2.5}$ concentrations from SO_2 emissions in Minnesota, but significantly over-predicts concentration changes outside of Minnesota.[70] While AP2 shows fairly reasonable results from direct $PM_{2.5}$ emissions in Minnesota, it again significantly over-estimates concentration changes nationwide.[71] In addition, AP2's hypothetical damage values are consistently and substantially higher than the values based on the modeling of existing power plants, which calls into question the validity of what Dr. Muller modeled as a hypothetical facility.[72]

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[66] Surrebuttal Testimony was filed on December 4, 2015.
[67] CEO informed the Parties in a Supplemental Response to Xcel Energy IR No. 11 dated October 28, 2015 that the correct amount of each pollutant modeled for InMAP was 1,000 tons, not 1 ton; see Ex. 608 (Desvousges Surrebuttal), Schedule 1 at 13.
[68] Dr. Marshall's correction about the number of tons modeled was too late to be included in testimony any sooner than Dr. Desvousges' Surrebuttal on November 30, 2015; Dr. Marshall's Surrebuttal criticism (Ex. 119 Marshall Surrebuttal at 17-18) of figures included in Dr. Desvousges' October 30, 2015 Rebuttal is no longer valid.
[69] Ex. 608 (Desvousges Surrebuttal) at 21-22, 24-25, 29-30.
[70] Xcel Energy's Initial Brief at 41-42; Ex. 605 (Desvousges Rebuttal), Schedule 5 at 3, 6.
[71] Ex. 605 (Desvousges Rebuttal), Schedule 5 at 5, 8.
[72] Ex. 605 (Desvousges Rebuttal) at 6, 42-43, Xcel Energy Initial Brief at 45-46.

The record shows that the InMAP results for $PM_{2.5}$, SO_2, and NO_x are clearly biased to the east and overestimate concentration changes and damage values. Several figures presented by Xcel Energy show InMAP's eastern bias.[73] Dr. Desvousges prepared a comparison of CAMx, AP2, and InMAP damage values, included in his Surrebuttal Testimony, Table 1.[74] 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[75] for $PM_{2.5}$ are more than five times higher than the CAMx values and more than seven times higher than the AP2 values,[76] even though InMAP estimates do not include morbidity damages. For Black Dog, InMAP's damage values for NO_x are more than three times higher than the CAMx values.[77] In addition, InMAP damage values for all three pollutants from Black Dog, Sherco, and Marshall sources are consistently highest for the rural Marshall location and lower for the Black Dog and Sherco locations, which is unexpected, contrary to common sense, and unlikely to be correct.[78] A typical pattern is that the highest damages are associated with emissions released in or near large cities, because the damages from human health impacts depend on the size of the population exposed to the emissions.[79] One would especially expect to see this pattern in Dr. Marshall's values, since his analysis only estimated premature mortality effects from direct and secondary $PM_{2.5}$.

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[73] E.g., Ex. 608 (Desvousges Surrebuttal) at 26-27, 31-32.
[74] Ex. 608 (Desvousges Surrebuttal) at 19.
[75] Based on modeling the actual Black Dog plant.
[76] Based on modeling the actual Black Dog plant.
[77] Ex. 608 (Desvousges Surrebuttal) at 17-20.
[78] *See* Ex. 810 (Muller Rebuttal) at 21, Table 13.
[79] *See* Agencies Initial Brief at 59.

The Agencies[80] and CEO[81] have attempted to discredit Dr. Desvousges' CAMx modeling since it used both Sherco Unit 1 and Riverside data. However, we have repeatedly noted that inadvertent use of the Riverside 2014 emission rate for direct $PM_{2.5}$ 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.[82] We modeled representative amounts of NO_x and SO_2 (3,508 and 1,169 tons respectively), which is important because CAMx includes flue-gas chemistry and treats the secondary formation of $PM_{2.5}$ from NO_x and SO_2 in a nonlinear manner. This is much more representative of a real power plant than modeling one ton of each pollutant separately (Dr. Muller) or 1,000 tons of each pollutant simultaneously, but without chemistry among them (Dr. Marshall).[83] As Dr. Marshall has admitted, because InMAP assumes that concentrations change linearly with marginal changes in emissions for *all three pollutants*, the amount of emissions modeled does not ultimately affect his results.[84]

CEO made a claim for the first time in its Initial Brief that the CAMx modeling results may not be representative because we used the Sherco stack height, which is taller than most Minnesota power plants.[85] Dr. Marshall did not suggest in his written testimony or during the evidentiary hearings that the Sherco stack height would influence CAMx results and potentially make them under-estimate damages in

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[80] Ex. 810 (Muller Rebuttal) at 38; Ex. 811 (Muller Surrebuttal) at 23. While we have explained this inadvertent error, Dr. Muller describes it as a "design choice" in his Surrebuttal Testimony.
[81] E.g., CEO Initial Brief at 39.
[82] We filed errata on October 13, 2015, well ahead of Rebuttal Testimony, to explain that the error did not affect our damage values. 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. See Ex. 604A (Errata to Exhibit 604); Ex. 605 (Desvousges Rebuttal) at 5, 39-40, 42; Ex. 608 (Desvousges Surrebuttal) at 3, 11-13.
[83] Ex. 608 (Desvousges Surrebuttal) at 14.
[84] Ex. 119 (Marshall Surrebuttal), Schedule 3 (CEO Supplemental Response to Xcel Energy IR No. 11).
[85] CEO Initial Brief at 38-39.

Minnesota. Since the record is closed, we are not able to present any new evidence to counter this claim. We chose to use the Sherco Unit 1 parameters as a conservative measure because it is a coal unit and emits a substantial amount of each criteria pollutant. For example, a gas facility would emit only a small quantity of SO_2.[86] Furthermore, the actual Sherco stack height (198 meters) is much *shorter* than the high and middle effective stack heights (880 and 310 meters) used in Dr. Marshall's InMAP modeling for county-by-county values.[87]

The record already has evidence that clearly shows that the Sherco stack height is not the reason why the AP2, InMAP, and CAMx modeling results are so different from one another. Our Initial Brief included several figures that present predicted concentration changes by AP2, InMAP, and CAMx. These figures show AP2 and InMAP results based on the actual Sherco plant, *using the actual Sherco stack height*. Dr. Muller used the actual Sherco location and stack height, but modeled one ton of each pollutant separately. Dr. Marshall used the actual Sherco location, stack height, and emissions, but each pollutant was modeled independently from one another. Xcel Energy used the actual Sherco location, stack height, other parameters, and emission rates.[88] All the Figures that presented results from the actual Sherco plant showed the same pattern already discussed:

- ***CAMx:*** The highest changes of $PM_{2.5}$, NO_x, and SO_2 concentrations occur closest to the Sherco location 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.

[86] Ex. 604 (Desvousges Direct), Schedule 2 at 15; Ex. 608 (Desvousges Surrebuttal) at 13-14.
[87] Ex. 115 (Marshall Direct) at 19; Ex. 604 (Desvousges Direct), Schedule 3 at 22.
[88] Except Riverside $PM_{2.5}$ emission rate of 9.4 tons was used for direct $PM_{2.5}$.

- ***AP2:*** The random and sporadic modeling results from Sherco NO_x emissions skip most Minnesota counties, but show secondary $PM_{2.5}$ concentration changes in faraway states to the east, west, and south. AP2 under-estimates secondary $PM_{2.5}$ concentrations from Sherco SO_2 emissions in Minnesota, but significantly over-predicts concentration changes outside of Minnesota. While AP2 shows fairly reasonable results from Sherco direct $PM_{2.5}$ emissions in Minnesota, it again significantly over-estimates concentration changes nationwide.
- ***InMAP:*** Sherco results for NO_x, $PM_{2.5}$ and SO_2 are clearly biased to the east and overestimate concentration changes and damage values.

While we have repeatedly disputed the accuracy of AP2 and InMAP air quality modeling results, Dr. Muller and Dr. Marshall have not addressed our specific concerns. Their main response has been that because the model performance evaluations showed that AP2 and InMAP were performing well, the modeling results must be accurate.[89] However, the CAMx performance evaluation also showed it was performing excellently. It is not possible that the performance evaluations for all three models are reliable and that the modeling results are accurate, when at the same time the AP2, InMAP, and CAMx results are significantly different and far from being alike or in agreement with one another.

While Xcel Energy has pointed out several weaknesses in the AP2 and InMAP performance evaluations and challenged their meaningfulness, Dr. Muller and Dr. Marshall have not disputed the reliability of the CAMx performance evaluation.

[89] E.g., Ex. 810 (Muller Rebuttal) at 44-46; Ex. 811 (Muller Surrebuttal) at 8-9; Ex. 119 (Marshall Surrebuttal) at 23-24.

Dr. Muller compared AP2 and CAMx modeling results for annual baseline ozone and $PM_{2.5}$ against observed ambient data. The CAMx modeling run was performed by the Minnesota Pollution Control Agency outside of this docket for another purpose. Dr. Muller's performance evaluation inappropriately compared results that relied on meteorological data from two different years; changed more than one variable in the analysis; applied performance goals and criteria developed for PM to his ozone evaluation; converted observed daily $PM_{2.5}$ concentrations and 8-hour ozone concentrations to annual average data against the Boylan and Russell (2006) guidance; and did not evaluate how well AP2 is capable of predicting concentration changes.[90] Dr. Muller 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.[91] The lack of evaluation criteria for annual $PM_{2.5}$ concentrations does not mean that it is appropriate or meaningful to convert the existing criteria to an annual average. Instead, the lack of evaluation criteria indicates that $PM_{2.5}$ impacts should be modeled and evaluated on shorter time intervals than 12 months.

When InMAP was evaluated against observed ambient data, it showed very poor performance. For sulfates, the bias was a negative 137 percent, which 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. InMAP's performance for nitrates was even worse.[92] If a model cannot predict baseline concentrations accurately, there is no foundation to claim that it can predict concentration changes

[90] Ex. 605 (Desvousges Rebuttal) at 51-55; Xcel Energy Initial Brief at 47-50.
[91] Hearing Transcript, Vol. 8 at 83, 85-86 (Muller); Ex. 811 (Muller Surrebuttal) at 5.
[92] 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).

accurately. InMAP's performance was also compared against a photochemical grid model WRF-Chem, however, the 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 low to the ground from multiple sources, while power plant emissions are modeled as elevated emissions from a single point source. InMAP was calibrated to correlate with mobile source scenarios, which does not mean that the model results would correlate equally well when emissions are modeled from a power plant.[93]

A relevant model performance evaluation should compare model results to ambient data based on the collection period of the ambient data, and EPA's guidance recommends this as well.[94] However, neither Dr. Muller nor Dr. Marshall were able to do this, because AP2 and InMAP only predict annual averages, but $PM_{2.5}$ data is collected over a 24-hour time period. 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.[95] It is more difficult for a model to accurately predict the high and low data points throughout the year as CAMx does, instead of just predicting the annual average as is done by AP2 and InMAP.

Dr. Muller's and Dr. Marshall's model performance evaluations did not follow conventional practices for well-designed evaluations or use appropriate performance goals and criteria. These evaluations are therefore not meaningful and do not reveal relevant information about the capability of AP2 and InMAP to predict ambient concentration changes from power plant emissions. Certainly the questionable

[93] Ex. 606 (Desvousges Rebuttal Non-Public) at 9, 75-77; *see* also Ex. 119 (Marshall Surrebuttal), Schedule 1.
[94] Ex. 605 (Desvousges Rebuttal) at 53. EPA recommends that evaluations are conducted using the observational native time for each pollutant.
[95] Ex. 605 (Desvousges Rebuttal) at 52.

evaluations do not support the adoption of the AP2 and InMAP air quality modeling results in this proceeding and should not be used as the main basis to claim the results are accurate, as Dr. Muller and Dr. Marshall have done.[96]

C. Xcel Energy's Mortality Risk and VSL Estimates Are Based on the Best and Most Recent Science

Dr. Desvousges' Monte Carlo analysis of concentration-response function and VSL is based on the best and most recent science. His approach relies on four recent meta-analyses and three recent individual studies, hence taking into account the diversity in existing research and variability in study results. Since Monte Carlo simulations create a distribution using the mean and standard error values of the selected studies, they are the best way to address the inherent uncertainty involved in estimating human health effects from $PM_{2.5}$ exposure.

There is a vast body of epidemiological literature that estimates the risk of premature mortality from $PM_{2.5}$ exposure, including both cross-sectional and cohort studies as well as meta-analyses and single studies. Since the original externalities proceeding, literally thousands of papers have been published on the impacts of ambient $PM_{2.5}$ concentrations on human health. The studies have followed different cohorts (varying by size, location, age, gender, occupation, etc.) and estimated different health effects.[97] There is no consensus in the epidemiological literature on the appropriate value or range of concentration-response function from $PM_{2.5}$ exposure, and it is a disputed issue in this proceeding as well. Similarly, a substantial number of economic studies focus on estimating VSL, but there is no agreement in the economic literature or in this case on the correct value or range of VSL.

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[96] E.g., Ex. 810 (Muller Rebuttal) at 44-46; Ex. 811 (Muller Surrebuttal) at 6, 8-9; Ex. 119 (Marshall Surrebuttal) at 23-24.

[97] Ex. 604 (Desvousges Direct), Schedule 2 at 29-35, Appendix A.

Dr. Muller agreed with the concentration-response function and VSL values developed by Dr. Desvousges and stated that these two areas of solid agreement regarding VSL and mortality risk are very important.[98] CEO and its witnesses, on the other hand, have challenged Dr. Desvousges' use of the Monte Carlo approach as well as his selection of epidemiological and economic studies and weighting of those studies.

Dr. Desvousges used Monte Carlo analysis 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. Monte Carlo simulation incorporates both the mean and standard error values from the selected studies, and therefore takes into account the variability in the underlying studies.[99]

Unlike Dr. Marshall, Dr. Desvousges identified several criteria he used in determining which studies were appropriate to include in his mortality risk and VSL analysis. Dr. Desvousges preferred meta-analyses over single studies and more recent studies over older studies, and evaluated each study based on its scientific soundness, statistical techniques used, variability in results, and sample size. He conducted a thorough literature review of available epidemiological and economic studies, and included summaries of key studies with his Direct Testimony.[100]

1. Dr. Desvousges' Mortality Risk Analysis Reflects the Variability of Existing Studies and Takes into Account the Uncertainty Involved in Estimating Health Impacts from $PM_{2.5}$

[98] See Ex. 810 (Muller Rebuttal) at 18-19, 46; Ex. 811 (Muller Surrebuttal) at 16; Agencies Initial Brief at 46.
[99] Ex. 608 (Desvousges Surrebuttal) at 48-49.
[100] Ex. 604 (Desvousges Direct) at 7, 21-23, Schedule 2 at 12-13, 54, Appendix A and B.

Dr. Desvousges' analysis of the concentration-response function used data from three different studies: a meta-analysis by Hoek et. al. (2013),[101] the most recent paper on the Harvard Six Cities cohort (LePeule et. al. 2012),[102] and a recent paper on the American Cancer Society cohort (Jerrett et. al. 2013).[103] The Hoek et. al. (2013) 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.

We take exception to CEO's claim that "Dr. Desvousges did not provide a justification for using the particular studies he relied upon in his Monte Carlo analysis: Hoek et. al. (2013), Lepeule et.al. (2012), and Jerrett et. al. (2013). It is unclear why Dr. Desvousges chose these three studies to use to create his new values."[104] Dr. Desvousges' expert report included the following explanations for choosing the Hoek et. al. (2013) meta-analysis:

> "A meta-analysis by Hoek et. al. (2013) incorporates a number of the most recent significant cohort studies into one estimate. Rather than repeating their work, we use this study as the basis for our estimate of the increased risk of premature mortality of $PM_{2.5}$. The Hoek et. al. (2013) meta-analysis includes

[101] 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.
[102] 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.
[103] 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.
[104] CEO Initial Brief at 44.

most of the significant US and Canadian $PM_{2.5}$ long-term mortality cohort studies."[105]

"Choosing the results from one cohort study to represent the risks of premature mortality from $PM_{2.5}$ in our externality cost study is problematic because of the variability in the study designs, samples selection, and the wide range of results. Moreover, the reliance on a single study would require a significant amount of judgment to assess the overall quality relative to the individual design effects."[106]

Dr. Desvousges also explained that "[a] meta-analysis uses information from each study about the statistical significance and variability of the estimates to weight the value of the estimate in an overall analysis," "uses weights, chosen by the study author, that reflect the standard error of the estimates", and "assigns studies with smaller standard errors higher weights because these risk results have more statistical certainty associated with them."[107]

This clearly explains why we have criticized both Dr. Muller and Dr. Marshall for relying on only two single studies to estimate mortality risk, Lepeule et. al. (2012) and Krewski et. al. (2009). There is no doubt that a well-executed, recent meta-analysis should be selected over a single study, because meta-analyses systematically use information from a number of individual studies and prioritize the studies based on the statistical certainty associated with the results (studies with smaller standard errors are assigned higher weights). Dr. Muller and Dr. Marshall should have used the Hoek et. al. (2013) meta-analysis for estimating mortality risk.

Dr. Desvouges, Dr. Marshall and Dr. Muller all relied on the Lepeule et. al. (2012) study of the Harvard Six Cities cohort. Dr. Desvousges explained that he chose the Lepeule et. al. (2012) and Jerrett et. al. (2013) studies to supplement the Hoek et. al. (2013) meta-analysis in order to "reflect the variability in the range of

[105] Ex. 604 (Desvousges Direct), Schedule 2 at 34-35.
[106] Ex. 604 (Desvousges Direct), Schedule 2 at 35.
[107] Ex. 604 (Desvousges Direct), Schedule 2 at 36-37.

values and to include the most recent work with two of the most studied cohorts, Harvard Six Cities and American Cancer Society."[108]

CEO criticized Dr. Desvousges because he chose the Jerrett et. al. (2013) study to represent the American Cancer Society cohort, and not a study focusing on a larger subset, such as Pope et. al. (2002), Pope et. al. (2015), or Krewski et. al. (2009).[109] However, the Hoek et. al. (2013) meta-analysis in fact includes the Pope et. al. (2002) study focusing on a large subset of 552,138 participants. Dr. Desvousges' mortality risk analysis therefore used *two* studies of the American Cancer Society cohort: Pope et. al. (2002) *and* Jerrett et. al. (2013).[110] In addition, as Dr. Desvousges has explained, the results from the four different American Cancer Society studies mentioned above are very similar, with an average concentration-response function of 6 to 7 percent for a 10 $\mu g/m^3$ change in $PM_{2.5}$.[111]

All Parties used studies involving the American Cancer Society and Harvard Six Cities cohorts to estimate mortality risk, however, Dr. Desvousges' analysis was the only one that also used nine other studies from Hoek et. al. (2013) that had researched other cohorts (e.g., persons enrolled in the U.S. Medicare system, registered nurses in 11 states, California public health professionals, and Canadian adults mandated to provide detailed census data).[112] Therefore, his analysis was much more inclusive and comprehensive than Dr. Muller's or Dr. Marshall's approaches, which used only one point estimate from one individual study of the American Cancer Society cohort and one point estimate from one individual study of the Harvard Six Cities cohort.

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[108] Ex. 604 (Desvousges Direct), Schedule 2 at 37.
[109] CEO Initial Brief at 44.
[110] Ex. 604 (Desvousges Direct), Schedule 2 at 36.
[111] Ex. 604 (Desvousges Direct), Schedule 2 at 96 (Appendix A).
[112] Ex. 604 (Desvousges Direct), Schedule 2 at 36, 98-102 (Appendix A).

CEO also claims that Dr. Desvousges assigned arbitrary and skewed weights to each of the three mortality risk studies included in his Monte Carlo approach,[113] but does not suggest what kind of weights would have been more appropriate or less skewed. The nature of Monte Carlo analysis *requires* the assignment of weights to the studies that are used to create the distribution. Dr. Desvousges exercised his professional expertise and best knowledge to assign the weights, and it is appropriate that the two individual studies have lower weights (12.5 percent each) than the meta-analysis (75 percent), which is the best synthesis of the available studies and data.[114]

We acknowledge that the assignment of weights to mortality risk studies and VSL studies involves professional judgment, but so also does Dr. Marshall's decision on how many and what studies to use to estimate the concentration-response function and VSL. Dr. Marshall's judgment was to give a 100 percent weight to an outdated EPA meta-analysis, and to rely on only one point estimate for his VSL value, which decision has been criticized by both Dr. Muller[115] and Dr. Desvousges.[116] For his concentration-response function, Dr. Marshall gave a 50 percent weight each to two individual studies, but ignored a recent, credible meta-analysis (Hoek et. al. 2013). We do not believe that Dr. Marshall's selection of studies for mortality risk and VSL reflect either the best science or reasoned professional judgment.

Dr. Muller also made a judgment call to combine a very low mortality risk value with a very low VSL and a very high mortality risk value with a very high VSL. We have disputed this decision, because it creates an extremely wide range, where the low and high values are highly uncertain and unlikely to be the "true" values. Dr. Muller's average high values for each criteria pollutant are about five times higher than his

[113] CEO Initial Brief at 45.
[114] Ex. 604 (Desvousges Direct), Schedule 2 at 37.
[115] Ex. 810 (Muller Rebuttal) at 16.
[116] Ex. 605 (Desvousges Rebuttal) at 75.

average low values (based on results from 93 Minnesota sources), whereas Dr. Desvousges' high values for each pollutant for each location (rural, metropolitan-fringe, and urban) are only about 2.5 times higher than his low estimates.[117] Dr. Desvousges used the 25th and 75th percentile values from the combined mortality risk and VSL distribution, hence accounting for the uncertainty and excluding the most unlikely values.[118]

2. Dr. Desvousges' VSL Analysis Reflects the Variability of Existing Studies and Takes into Account the Uncertainty Involved in Estimating Health Impacts from $PM_{2.5}$

Dr. Desvousges' Monte Carlo simulation for VSL incorporated data from three different meta-analyses (Kochi et. al. 2006;[119] Mrozek and Taylor 2002;[120] and Viscusi and Aldy 2003),[121] and data from a recent individual study by Kniesner et. al. (2012).[122] 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.[123]

In its Initial Brief, CEO criticized at length the way Dr. Desvousges treated the Kochi et. al. (2006) study for his VSL analysis. First, we note that Dr. Marshall did not use this meta-analysis for his VSL determination, nor any of the other more recent meta-analyses available. Instead, he uncritically took one point estimate from an

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[117] Ex. 808 (Muller Direct) at 49-51; Ex. 604 (Desvousges Direct) at 6.
[118] Ex. 608 (Desvousges Surrebuttal) at 48-49.
[119] 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.
[120] 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.
[121] 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.
[122] 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.
[123] Ex. 604 (Desvousges Direct), Schedule 2 at 55.

outdated EPA meta-analysis from 1999 (discussed in *Guidelines for Preparing Economic Analyses 2000*),[124] which included studies published between 1974 and 1991.[125] EPA is currently in the process of revising its VSL guidance and considering more recent studies. In the current version of *Guidelines for Preparing Economic Analyses*, EPA states that although the studies used in the original 1999 meta-analysis "were the best available data at that time, they are sufficiently dated and may rely on obsolete preferences for risk and income."[126] There was no attempt on Dr. Marshall's part to use the best knowledge or most recent science to update the VSL value. Second, we note that Dr. Muller also used the Kochi et. al. (2006) study for his low VSL value, and CEO's own witness Dr. Polasky supported using as an alternative VSL value a combined estimate of $7.7 million from the Kochi et. al. (2006) study.[127]

Dr. Desvousges decided to use Kochi et. al. (2006) because it is the most recent and up-to-date meta-analysis on VSL; includes results from both stated preference studies and revealed preference (hedonic wage) studies; uses the most advanced statistical methods; and provides several estimates of VSL under different modeling assumptions. Therefore, it is possible and also preferable to select several estimates from the Kochi et. al. (2006) study to reflect the uncertainty and sensitivity in modeling parameters.[128] Dr. Desvousges decided to use as a key measure an estimate from Kochi et. al. (2006) that is based on the complete data from all the individual studies (this central value was assigned a 35 percent weight). This estimate includes

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[124] As his VSL source, Dr. Marshall cites U.S. Environmental Protection Agency, 2000. *Guidelines for Preparing Economic Analyses*, Ex. 115 (Marshall Direct) at 25.
[125] Ex. 115 (Marshall Direct) at 25. *See* also Ex. 604 (Desvousges Direct), Schedule 2 at 56 explaining that this EPA meta-analysis uses only older studies and has been superseded by the three more recent meta-analyses.
[126] Quoted in Hearing Transcript, Vol. 6 at 165. Xcel Energy offered Appendix B of the most recent version of the EPA Guidelines to the record as Exhibit 614, but it was not admitted (*EPA Guidelines for Preparing Economic Analyses*, December 17, 2010, Updated May 2014).
[127] Ex. 808 (Muller Direct) at 42; Ex. 118 (Polasky Rebuttal) at 8.
[128] Ex. 604 (Desvousges Direct), Schedule 2 at 54.

negative values in the raw data, which is appropriate, because both the high and low values of the original studies are treated symmetrically without discarding only the low-end of the values.[129] Dr. Desvousges used two other estimates from Kochi et. al. (2006) and adjusted these two estimates as if the negative values had been included in the raw data and each estimate was assigned a 10 percent weight.[130]

We believe it is appropriate to retain the negative values that were included in the original studies and raw data used by Kochi et. al. (2006) – the negative values were part of the original statistical distribution, affect the mean value, and impact where the median and other percentiles land in the distribution. It would be extraordinary and atypical to remove only low-end values of valid study results.[131] CEO and Dr. Polasky cite an EPA Science Advisory Board (SAB) paper as support for removing the negative values from the Kochi et. al. (2006) results. However, this is not at all what the SAB recommends:

> "In general, the preferred approach for selecting studies is based on study design criteria, not study results, but there may be limited circumstances when it is appropriate to exclude *studies* based on results. One of these is a finding of statistically significant negative values for mortality risk reduction… Obtaining statistically insignificant results, implying zero value for an incremental risk reduction, is on the other hand, a theoretically plausible result and is not sufficient reason for exclusion of a *study*."[132] [emphasis added]

The SAB is clearly stating that if an individual VSL study estimates any negative results, then that particular study could be excluded from a VSL meta-analysis, not

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[129] Ex. 604 (Desvousges Direct), Schedule 2 at 51-52.
[130] Ex. 604 (Desvousges Direct), Schedule 2 at 52, 54-55. One of the estimates included additional studies without a sampling error measure and another was based on an alternative analysis of U.S. only hedonic wage studies.
[131] Ex. 608 (Desvousges Surrebuttal) at 51-53.
[132] Ex. 118 (Polasky Rebuttal) at 11 citing EPA Science Advisory Board. "Advisory on EPA's Issues in Valuing Mortality Risk Reduction." October 12, 2007, at D-8. *See* also CEO Initial Brief at 55-56.

just the negative results. The SAB is by no means advocating that it would be appropriate to manipulate the original distribution of a particular study asymmetrically by removing only the negative values and retaining only the positive values, including any implausibly high valuations. In fact, the SAB stated that "A preferable approach would be to include an analysis of the effects of outliers on the estimates of mean values and some eventual judgment about how much weight may be appropriate to give the outliers."[133]

In the Interagency Working Group (IWG) analysis for Social Cost of Carbon (SCC), one of the three Integrated Assessment Models, the FUND model, predicted negative values at all three discount rates for all five Stanford Energy Modeling Forum (EMF-22) scenarios.[134] However, the IWG did not remove these negative values from the distribution or ignore them when the summary SCC statistics were calculated. Neither did the CEO request that the negative values be removed from the SCC analysis for the CO_2 portion of this proceeding.

In his VSL analysis, Dr. Desvousges assigned an equal weight, 15 percent each, to two additional meta-analyses (Mrozek and Taylor 2002 and Viscusi and Aldy 2003) and a recent individual study by Kniesner et. al. (2012).[135] CEO has suggested that a Monte Carlo simulation should not combine meta-analyses and individual studies. However, based on Dr. Desvousges' expertise, it is reasonable to supplement the selected meta-analyses with an individual study if that study represents more recent research, new data, or better scientific methods. The Kniesner et. al. (2012) study was published six to ten years later than any of the three meta-analyses and collected panel data, which means that it allows for multiple observations per person. There is no

[133] Ex. 608 (Desvousges Surrebuttal) at 52 citing EPA Science Advisory Board. "Advisory on EPA's Issues in Valuing Mortality Risk Reduction." October 12, 2007, at D-8.
[134] Ex. 602 (Martin Surrebuttal), Schedule 1 (July 2015 TSD) at 18-19.
[135] Ex. 604 (Desvousges Direct), Schedule 2 at 55.

commonly accepted best practice that discourages supplementing meta-analyses with single studies in a Monte Carlo analysis, if reasonable and relevant research rationales justify the inclusion of a particular individual study. It was also appropriate to give the Kniesner et. al. (2012) study a weight of 15 percent, because the Monte Carlo analysis used a range from that study ($4 million to $10 million), not a central estimate. Including this study was also a conservative choice, because its results slightly increased the final low, high, and central VSL estimates.[136]

Finally, CEO believes that Dr. Desvousges should have adjusted the VSL values for changes in real income. However, as Dr. Desvousges has pointed out, there is no general agreement on income adjustment and it is not certain whether the VSL would increase, decrease, or stay the same due to changes in the economy and income. For instance, as household income increases and the economy grows, individual choices, access to safer goods, use of advanced technologies, and public policy changes to protect human health may reduce mortality risk. Typically the willingness to pay should decrease when the risk decreases.[137]

Dr. Marshall used one very outdated meta-analysis to determine his VSL value and two single studies to determine his mortality risk value. He selected one extremely high point estimate for his only VSL value, and a low and a high point estimate for his mortality risk. Dr. Marshall's approach does not reflect the most recent and best science, the diversity of existing epidemiological and economic studies, the variability of results in these studies, or the uncertainty involved in estimating health impacts from $PM_{2.5}$.

[136] Ex. 608 (Desvousges Surrebuttal) at 55-56.
[137] Ex. 608 (Desvousges Surrebuttal) at 57-59.

Dr. Marshall has emphasized that the determination of a VSL value is one of the key issues in this proceeding, yet he had difficulty discussing the basis and source used for his own VSL value, as well as EPA publications and other studies reviewed for his VSL determination.[138] Similarly, as MLIG pointed out in its Initial Brief, Dr. Marshall was unfamiliar with NAAQS regulation, the scientific information underlying NAAQS, and the process to arrive at NAAQS.[139] In addition, Dr. Marshall did not recall a basic fact of his own air quality modeling: how many incremental tons of emissions were modeled for each county source.[140]

V. PROPOSALS TO GROUP OR AVERAGE MODELING RESULTS WERE MADE TOO LATE AND EXTERNALITY VALUES SHOULD CONTINUE TO BE UPDATED BASED ON AN INDEX

The Agencies have suggested in Surrebuttal Testimony and Initial Brief that their proposed county- and source-specific values can be easily grouped to accommodate more practical application. The Agencies list several options, for instance, averaging all estimates per pollutant, grouping values according to quantiles per pollutant, and computing an average per pollutant for urban, metropolitan-fringe, and urban locations.[141] CEO has suggested that the Commission could adopt damage values based on the average results of AP2 and InMAP modeling.[142]

However, the Agencies and CEO did not recommend any of these approaches in their Direct or Rebuttal Testimony, and they have not calculated or proposed any specific values based on them. These suggestions are not timely, have not been

[138] Hearing Transcript, Vol. 6 at 163-175 (Marshall).
[139] MLIG Initial Brief at 43; Hearing Transcript, Vol. 6 at 58, 72-73, 101-102 (Marshall).
[140] Hearing Transcript Vol. 6 at 203 (Marshall).
[141] Ex. 811 (Muller Surrebuttal) at 25-26; Agencies Initial Brief at 51-52.
[142] Ex. 119 (Marshall Surrebuttal) at 7; CEO Initial Brief at 64.

examined by other Parties or supported by evidence in the record, and should therefore be disregarded.

The ALJ, at the evidentiary hearing, asked each witness to discuss how much time and effort it would take to change their modeling parameters and re-run the models. Dr. Desvousges responded that it would be straightforward and easy to change the assumptions regarding mortality risk and VSL, which are estimated outside the CAMx model. Any changes that affect the CAMx air quality modeling, such as the geographic scope, would take more time and labor. For example, using CAMx to model a national scope would require at least a month.[143]

We oppose Dr. Muller's proposal, which updates his damage values in five-year increments out to the year 2040 by projecting changes in population and mortality rates without any mechanism for a true-up along the way.[144] After the new externality values for $PM_{2.5}$, SO_2, and NO_x are established, we suggest that the Commission continue to update them based on an annual index that measures inflation, such as the Gross Domestic Product (GDP) Price Deflator Index that is currently used for annual updates. Another possible option would be to use the Consumer Price Index. This approach updates the values accordingly to the state of the overall economy. Once the externality values are set based on the best available science and modeling, we believe that the Commission could rely on them for a reasonably long time, as long as they are updated for inflation. Therefore, it is critical in this proceeding to use the best air quality modeling and valuation assumptions in order to establish the most accurate externality values.[145]

[143] Hearing Transcript, Vol. 7 at 129-132 (Desvousges).
[144] Ex. 605 (Desvousges Rebuttal) at 61-62.
[145] Hearing Transcript, Vol. 7 at 144-146 (Desvousges).

VI. CONCLUSION

The Commission should adopt externality values that are reasonable, practicable, and the best available measure of the criteria pollutants' cost. Xcel Energy proposed values based on the photochemical grid model CAMx, which is the only model in this proceeding that meets EPA's current air quality modeling guidelines; models the three criteria pollutants simultaneously with chemical interaction as would be present in an actual power plant plume; uses hourly, varying three-dimensional wind speed and direction; and incorporates full-science atmospheric chemistry algorithms. CAMx is peer-reviewed, thoroughly tested by the scientific community, and regularly used by EPA, state agencies, researchers, and others who need reliable air quality modeling.

Dr. Desvousges performed CAMx air quality modeling, which produced results that are reliable, accurate, and consistent with what is known about the science of air dispersion and chemistry.

Dr. Desvousges' mortality risk and VSL analysis relied on the most recent meta-analyses and individual studies, took into account the variability of the studies, and addressed the inherent uncertainty involved in estimating human health effects from $PM_{2.5}$ exposure. Dr. Desvousges used Monte Carlo simulations to create a combined mortality risk and VSL distribution, and then selected the 25^{th} and 75^{th} percentile values from that distribution to represent the low and high risk values, hence excluding the most unlikely values.

A preponderance of the evidence shows that AP2 and InMAP models are not appropriate for the analysis needed in this proceeding and are unable to provide reasonably accurate air quality modeling results. Similarly, Dr. Muller and Dr. Marshall did not base their mortality risk valuation on the best or most recent science.

A preponderance of the evidence also shows that it is not reasonable or practicable to estimate nationwide damages from Minnesota emissions or to establish county-specific externality values.

We recommend that the Commission adopt the externality values proposed by Xcel Energy, because they are based on the most accurate modeling, reasonable, practicable, and the best available measure of the criteria pollutants' cost.

Respectfully submitted by:

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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 PROPOSED FINDINGS OF FACT, CONCLUSIONS OF LAW, AND RECOMMENDATION ON CRITERIA POLLUTANT ISSUES ($PM_{2.5}$, SO_2, AND NO_x)

April 15, 2016

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XCEL ENERGY'S PROPOSED FINDINGS OF FACT, CONCLUSIONS OF LAW, AND RECOMMENDATION ON CRITERIA POLLUTANT ISSUES

This matter came before Administrative Law Judge (ALJ) LauraSue Schlatter for evidentiary hearing on January 12-14, 2016 in St. Paul, Minnesota. A public hearing was held in St. Paul, Minnesota on August 26, 2015. The following appearances were made:

Leigh Currie and Hudson Kingston, Attorneys at Law, Minnesota Center for Environmental Advocacy (26 East Exchange Street, Suite 206, St. Paul, Minnesota 55101), appeared on behalf of Minnesota Center for Environmental Advocacy, The Izaak Walton League of America – Midwest Office, Fresh Energy and Sierra Club (Clean Energy Organizations, CEO).

James R. Denniston, Assistant General Counsel (414 Nicollet Mall, Minneapolis, Minnesota 55401), appeared on behalf of Northern States Power Company, d/b/a Xcel Energy (Xcel Energy).

Marc A. Al and Andrew P. Moratzka, Attorneys at Law, Stoel Rives, LLP (33 South Sixth Street, Suite 4200, Minneapolis, Minnesota 55402), appeared on behalf of Minnesota Large Industrial Group (MLIG).

Linda S. Jensen, Assistant Attorney General (445 Minnesota Street, Suite 1800, St. Paul, Minnesota 55101), appeared on behalf of the Minnesota Department of Commerce, Division of Energy Resources and the Minnesota Pollution Control Agency (the Agencies).

Tricia Debleeckere, Michelle Rebholz, and Sean Staples participated as representatives of the staff of the Minnesota Public Utilities Commission.

STATEMENT OF THE ISSUE

The Commission referred this issue to the Office of Administrative Hearing (OAH) for a contested case proceeding on October 15, 2014. According to the Commission's Order, the purpose of the proceeding is to determine "appropriate values for $PM_{2.5}$, SO_2, and NO_x under Minn. Stat. § 216B.2422, Subd. 3."[1]

The ALJ later in her Third Prehearing Order excluded "testimony regarding the efficacy of renewable energy or renewable energy policy" as presumably irrelevant, unless "its relevance is specifically demonstrated."[2]

Based on the Findings of Fact that follow below, the ALJ makes the following:

RECOMMENDATIONS

The Minnesota Public Utilities Commission (the Commission) should:

1. Determine that the geographic scope of externality values for $PM_{2.5}$, SO_2, and NO_x should be established based on impacts in Minnesota and within 100 miles from the Minnesota border and that it is not practicable to estimate criteria pollutant damages across the entire contiguous United States.

2. Determine that the damage values for $PM_{2.5}$, SO_2, and NO_x should be estimated for three types of locations – rural, metropolitan-fringe, and urban areas – and that it is not practicable to estimate county-specific externality values.

3. Determine that the rural, metropolitan-fringe, and urban values for $PM_{2.5}$, SO_2, and NO_x will be used for out-of-state resources within 200 miles from the Minnesota border, as appropriate based on the location of the source.

4. Determine that Xcel Energy's proposed methodology and externality values are reasonable, practicable, and the best available measure to estimate environmental cost of $PM_{2.5}$, SO_2, and NO_x.

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[1] *In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216.B.2422, Subd. 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 by name and date only.

[2] THIRD PREHEARING ORDER, April 16, 2015. Order Point 3.

5. Adopt the environmental cost values for $PM_{2.5}$, SO_2, and NO_x, as proposed by Xcel Energy for rural, metropolitan-fringe, and urban locations, as listed in Table 1 of Dr. Desvousges' Direct Testimony.[3]

6. Determine that the Commission should continue its current practice to update environmental values for $PM_{2.5}$, SO_2, and NO_x annually based on the Gross Domestic Product (GDP) Price Deflator Index.

FINDINGS OF FACT

I. Procedural History

1. In 1997, the Commission established environmental values under Minn. Stat. § 216B.2422 Subd. 3.[4] In December 2000, the Commission initiated an investigation into whether the environmental cost values should be updated or expanded.[5] Starting in 2001, the Commission authorized increasing the environmental cost values each year to account for inflation.[6] Currently the highest range of values (Urban), as updated in May 2015, is $6,514 – $9,376 for PM_{10}, $542 – $1,428 for NO_x, and $0 for SO_2 (in 2014 dollars per ton).[7]

2. On October 9, 2013, the CEO filed a motion to reopen the investigation into environmental and socioeconomic costs under Minn. Stat. § 216B.2422 Subd. 3 and requested that the Commission update the values for carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) and establish a cost value for particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) based on the current state of science.

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[3] Ex. 604 (Desvousges Direct) at 6.

[4] *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3.* Docket No. E-999/CI-93-583. ORDER ESTABLISHING ENVIRONMENTAL COST VALUES, January 3, 1997. Hereafter referred as Commission January 1997 Order. ORDER AFFIRMING IN PART AND MODIFYING IN PART ORDER ESTABLISHING ENVIRONMENTAL COST VALUES, July 2, 1997.

[5] *In the Matter of the Petition of Northern States Power Company for Review of its 1999 All Source Request for Proposals.* Docket No. E-002/M-99-888. ORDER REJECTING REQUEST FOR FURTHER INVESTIGATION, APPROVING FINAL BID SELECTIONS, AND OPENING DOCKET REGARDING EXTERNALITY VALUES, February 7, 2001.

[6] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216.B.2422, Subd. 3.* Docket No. E-999/CI-00-1636. ORDER UPDATING EXTERNALITY VALUES AND AUTHORIZING COMMENT PERIODS ON CO_2, $PM_{2.5}$, AND APPLICATION OF EXTERNALITY VALUES TO POWER PURCHASES, May 3, 2001.

[7] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216.B.2422, Subd. 3.* Docket No. E-999/CI-00-1636. NOTICE OF UPDATED ENVIRONMENTAL EXTERNALITY VALUES, May 27, 2015.

3. On February 10, 2014, the Commission issued an Order in Docket No. E-999/CI-00-1636, reopening its investigation into environmental costs of generating electricity under Minn. Stat. § 216B.2422 Subd. 3.[8] The scope of the investigation was limited to four pollutants: CO_2, $PM_{2.5}$, SO_2, and NO_x. Before referring the matter to OAH, the Commission sought input on the scope of the investigation and possible retention of an expert from a stakeholder group convened by the Minnesota Department of Commerce (the Department) and the Minnesota Pollution Control Agency (MPCA).

4. On June 10, 2014, as a result of the stakeholder process, the Agencies filed a report stating that "there was little consensus arising out of the stakeholder meeting or in subsequent written comments."[9] Nevertheless, the Agencies made specific recommendations to the Commission regarding the development of environmental values for CO_2, $PM_{2.5}$, SO_2, and NO_x.

5. On October 15, 2014, the Commission issued an Order referring the further investigation of environmental cost values for CO_2, $PM_{2.5}$, SO_2, and NO_x to the OAH for contested case proceedings.[10]

6. On November 25, 2014, a first prehearing conference was held before the ALJ.

7. On December 9, 2014, the ALJ issued her First Prehearing Order, which bifurcated the proceedings into two separate tracks (CO_2 and Criteria Pollutants) and established an initial schedule for both tracks.[11] The following were named as Parties:

- Clean Energy Organizations,
- The Department of Commerce,
- Peabody Energy Corporation,
- Otter Tail Power,
- Minnesota Power,
- Lignite Energy Council,
- Xcel Energy,

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[8] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216.B.2422, Subd. 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.

[9] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216.B.2422, Subd. 3.* Docket No. E-999/CI-00-1636. Comments of the Minnesota Department of Commerce and the Minnesota Pollution Control Agency. June 10, 2014 at 3.

[10] NOTICE AND ORDER FOR HEARING, October 15, 2014.

[11] FIRST PREHEARING ORDER, December 9, 2014.

- Large Industrial Group,
- Great River Energy, and
- Minnesota Chamber of Commerce.

8. On March 3, 2015 a second prehearing conference was held before the ALJ.

9. On March 5, 2015, the ALJ issued a Protective Order to facilitate discovery and protect trade secret information and other not public data.[12]

10. On March 11, 2015, the ALJ issued a Recommendation for Public Hearings and Public Notice Plan.[13]

11. On March 19, 2015, the ALJ issued an Order Granting Intervention to MPCA.[14]

12. On March 19, 2015, the ALJ issued her Second Prehearing Order, which established the final schedule for the bifurcated proceedings.[15]

13. Parties filed Memoranda of Law on February 4, 2015 and Responsive Memoranda of Law on February 18, 2015 regarding burden of proof issues. The ALJ issued an Order Regarding Burdens of Proof on March 27, 2015.[16]

14. On April 16, 2015, the ALJ issued her Third Prehearing Order, which encouraged jointly filed testimony and briefs, and limited testimony regarding the efficacy of renewable energy.[17] The ALJ also issued the same day an Order Granting Intervention to Doctors for a Healthy Environment, Clean Energy Business Coalition, and Interstate Power and Light Company.[18]

15. On May 27, 2015, the Commission issued an Order Requiring Public Hearing, which directed that one public hearing be held in the Commission's Large Hearing Room in St. Paul.[19]

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[12] PROTECTIVE ORDER, March 5, 2015.
[13] RECOMMENDATION FOR PUBLIC HEARINGS PLAN AND PUBLIC NOTICE PLAN, March 11, 2015.
[14] ORDER GRANTING INTERVENTION TO MINNESOTA POLLUTION CONTROL AGENCY, March 19, 2015.
[15] SECOND PREHEARING ORDER, March 19, 2015.
[16] ORDER REGARDING BURDENS OF PROOF, March 27, 2015.
[17] THIRD PREHEARING ORDER, April 16, 2015.
[18] ORDER GRANTING INTERVENTION TO DOCTORS FOR A HEALTHY ENVIRONMENT, CLEAN ENERGY BUSINESS COALITION, AND INTERSTATE POWER AND LIGHT COMPANY, April 16, 2015.
[19] ORDER REQUIRING PUBLIC HEARING, May 27, 2015.

16. On August 4, 2015, the ALJ issued her Fourth Prehearing Order, which scheduled a third prehearing conference and encouraged in-person attendance.[20]

17. On August 14, 2015, a third prehearing conference was held before the ALJ.

18. A public hearing was held on August 26, 2015 at the Commission's Large Hearing Room in St. Paul (121 7th Place E, Suite 350, St. Paul, MN 55101), starting at 2 pm. More than 2,000 postcards, and several written comments or letters were also received.

19. On August 28, 2015, the ALJ issued her Fifth Prehearing Order regarding the CO_2 Track procedural schedule.[21]

20. On September 23, 2015, the ALJ issued an Amended Protective Order.[22]

21. On October 14, the ALJ issued her Sixth Prehearing Order, which updated the procedural schedule for the Criteria Pollutants Track.[23]

22. On November 2, 2015, a fourth pre-hearing conference was held before the ALJ.

23. On November 6, 2015, the Agencies and CEO filed motions to exclude and strike certain Rebuttal Testimony of MLIG's witness Dr. McClellan and Xcel Energy's witness Mr. Rosvold.

24. On November 9, 2015, the ALJ issued her Seventh Prehearing Order, which updated the procedural schedule for the Criteria Pollutants Track.[24]

25. On November 24, 2015, the ALJ issued an Order that denied the Agencies' and CEO's motions to exclude and strike Rebuttal Testimony.[25]

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[20] FOURTH PREHEARING ORDER, August 4, 2015.
[21] FIFTH PREHEARING ORDER, August 28, 2015.
[22] AMENDED PROTECTIVE ORDER, September 23, 2015.
[23] SIXTH PREHEARING ORDER, October 14, 2015.
[24] SEVENTH PREHEARING ORDER, November 9, 2015.
[25] ORDER ON MOTIONS BY DEPARTMENT OF COMMERCE, POLLUTION CONTROL AGENCY AND CLEAN ENERGY ORGANIZATIONS TO EXCLUDE AND STRIKE TESTIMONY, November 24, 2015.

26. On December 18, 2015, a fifth pre-hearing conference was held before the ALJ.

27. On December 22, 2015, the ALJ issued her Eight Prehearing Order, which updated the schedule and evidentiary hearing procedures for the Criteria Pollutants Track.[26]

28. On January 12-14, 2016, the ALJ held evidentiary hearings on the Criteria Pollutants Track in St. Paul, Minnesota.

II. Applicable Law

A. Applicable Statute

29. This proceeding arises due to legislative directives contained in Minn. Stat. §216B.2422 Subd. 3(a). This statute codifies a process for utilities' resource planning and selection. Subd. 3(a) sets the requirements for environmental costs, which are at issue in this case. Minn. Stat. §216B.2422 Subd. 3(a) reads:

> Subd. 3. Environmental Costs. (a) 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 statute explicitly requires that the Commission establish a range of environmental costs. In addition, the Commission specifically ordered in this proceeding that the Parties must use a damage cost approach to valuing environmental costs.[27]

B. Burden of Proof

30. After providing an opportunity for the Parties to provide Memoranda and Responsive Memoranda on burden of proof issues, the ALJ issued an Order Regarding Burden of Proof on March 27, 2015.[28]

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[26] EIGHTH PREHEARING ORDER, December 22, 2016.
[27] NOTICE AND ORDER FOR HEARING, October 15, 2014, Order Point 4.
[28] ORDER REGARDING BURDENS OF PROOF, March 27, 2015.

31. The ALJ ordered that any Party proposing that the Commission adopt a new value(s) for PM2.5, SO2, or NOx 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."29 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.30

32. The ALJ also ordered that any Party that opposes a particular proposed environmental cost value must demonstrate that the particular proposal does not meet the required preponderance of the evidence standard.[31]

C. Rule of Evidence

33. In an Order regarding MLIG and Peabody motions to strike testimony, the ALJ confirmed that the appropriate rule of evidence to apply in this case is the rule of the OAH.[32] 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.

III. Summary of Parties' Proposals

34. Three Parties – the Agencies, CEO, and Xcel Energy – conducted air quality modeling to estimate damages from $PM_{2.5}$, SO_2, and NO_x emissions and proposed externality values based on their modeling. They all used the same general approach: 1) model ambient air concentration changes from emissions, 2) estimate the impacts of these air quality changes, and 3) monetize the impacts to estimate damage values.[33] Although the Parties' methodologies shared the same basic principles, there were significant differences, for example, in the type of air quality models used, the number and type of emission sources modeled, and the scope and type of damages estimated. One Party, MLIG, argued that externality values should not be established

[29] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order Point 2.
[30] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order Point 8.
[31] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order Point 5.
[32] ORDER ON MOTIONS BY MINNESOTA LARGE INDUSTRIAL GROUP AND PEABODY ENERGY CORPORATION TO EXCLUDE AND STRIKE TESTIMONY, September 15, 2015.
[33] *See*, for example, Ex. 604 (Desvousges Direct) at 15.

at all for areas that are in attainment with the National Ambient Air Quality Standards (NAAQS) and where the annual level of exposure to $PM_{2.5}$ is less than 12 $\mu g/m^3$.

35. $PM_{2.5}$ can be emitted directly (primary $PM_{2.5}$), but can also be formed secondarily from SO_2 (ammonium sulfate, $AmmSO_4$) and NO_x (ammonium nitrate, $AmmNO_3$). In all Parties' modeling, 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 series of complex, non-linear photochemical reactions involving concentrations of NO_x and volatile organic compounds. Both Dr. Muller (the Agencies) and Dr. Desvousges (Xcel Energy) attributed ozone impacts to NO_x in their analysis.[34]

A. The Agencies

36. Dr. Muller testified for the Agencies. His analysis included SO_2, NO_x (also ozone from NO_x), and direct and secondary $PM_{2.5}$, 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. 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. 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.[35]

37. Dr. Muller modeled one incremental ton each of $PM_{2.5,}$ SO_2, and NO_x separately in isolation of one another, unlike a real point source plume. In addition to modeling one ton of each pollutant in each Minnesota county (87 sources), he also modeled an incremental ton of each pollutant in each county within 200 miles from the Minnesota border (368 sources), assuming that the emissions are dispersed from the county centroid (geometric center). Dr. Muller also modeled six named existing power plants in Minnesota (Sherco, High Bridge, Clay Boswell, Riverside, Black Dog, and A.S. King) as well as all other larger existing power plants located within 200 miles of the Minnesota border (a total of 26 sources), based on their actual location and stack height.[36] Dr. Muller used a $PM_{2.5}$ concentration-response function of 6

[34] Ex. 604 (Desvousges Direct) at 16.

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

[36] Ex. 808 (Muller Direct) at 17-20, 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.

percent and 14 percent for a 10 $\mu g/m^3$ change in $PM_{2.5}$ and a value of a statistical life (VSL) of $3.7 million at the low end and $9.5 million at the high end.[37]

38. Dr. Muller proposed that the Commission adopt separate externality values for the 487 different sources he modeled, as listed in Schedule 3 of his Direct Testimony. His county-specific values are based on inconsistent sources – some are based on modeling existing power plants, some are based on modeling hypothetical facilities, and some are based on a combination of both.[38] Dr. Muller did not propose a generic value or values.

B. CEO

39. Dr. Marshall testified for CEO. He used a new reduced-form model InMAP, developed by his research team at the University of Minnesota. Similarly to Dr. Muller, Dr. Marshall also developed nearly 500 county-by-county values and estimated damages in the contiguous United States. He used three different effective stack heights to model the county specific-values. Dr. Marshall's modeling of hypothetical facilities assumed that 1,000 incremental tons of each pollutant were evenly emitted over each county, modeling each generating source as an area source rather than a point source.[39] InMAP uses gridded annual average wind speed, direction, and turbulence data by averaging Weather Research Forecast WRF-Chem data over 12 months.[40]

40. In addition to modeling a hypothetical source in nearly 500 counties, Dr. Marshall modeled all existing power plants in Minnesota, based on their actual location, stack height and emissions.[41] He proposed a generic value based on the weighted average results from the existing Minnesota power plants.[42] Dr. Marshall used a $PM_{2.5}$ concentration-response function of 7.8 percent and 14 percent for a 10 $\mu g/m^3$ change in $PM_{2.5}$ and a value of a statistical life of $9.8 million.[43] Dr. Marshall's analysis did not include impacts from direct emissions of SO_2 or NO_x, ozone impacts

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[37] Ex. 808 (Muller Direct) at 39-42.
[38] Ex. 808 (Muller Direct) at 18-19, Schedule 2 at 29; Ex. 605 (Desvousges Rebuttal) at 5-6, 40-41; Xcel Energy's Initial Brief at 12-13.
[39] Ex. 115 (Marshall Direct) at 7, 8-9, 19; Ex. 608 (Desvousges Surrebuttal), Schedule 3 at 3 (CEO Supplemental Response to Xcel Energy IR No. 11).
[40] Ex. 115 (Marshall Direct) at 9; Ex. 606 (Desvousges Rebuttal Non-Public) at 8.
[41] Ex. 115 (Marshall Direct) at 18; Ex. 608 (Desvousges Surrebuttal), Schedule 3 at 3 (CEO Supplemental Response to Xcel Energy IR No. 11). However, because InMAP assumes that concentrations change linearly with marginal changes in emissions for all three criteria pollutants, the amount of emissions does not ultimately affect the results.
[42] Ex. 115 (Marshall Direct) at 28.
[43] Ex. 115 (Marshall Direct) at 21-22, 25.

from NO_x emissions, or any damages other than premature mortality due to direct and secondary emissions of $PM_{2.5}$.[44]

41. Dr. Jacobs and Dr. Polasky also testified for CEO. Dr. Jacobs supported Dr. Marshall's selected values for concentration-response function (7.8 percent and 14 percent per every 10 $\mu g/m^3$ increase in $PM_{2.5}$), but also stated that Dr. Muller's values (6 percent and 14 percent) would be reasonable.[45] Dr. Polasky supported Dr. Marshall's VSL value of $10.1 million ($2014, adjusted for income), but also stated that a VSL value of $7.7 million ($2014, adjusted for income, combined hedonic wage and stated preference estimate) from the Kochi et. al. (2006) study would be appropriate.[46]

C. MLIG

42. Dr. McClellan testified for MLIG. He argued that epidemiological studies do not show medical evidence of any excess mortality due to $PM_{2.5}$ emissions below concentrations of 12 $\mu g/m^3$, the current level of NAAQS. He stated that it is therefore inappropriate to establish externality values or estimate any damages from $PM_{2.5}$ for areas that are in attainment with the NAAQS and where the annual level of exposure to $PM_{2.5}$ is less than 12 $\mu g/m^3$. Dr. McClellan maintained that the current levels of ambient $PM_{2.5}$ in Minnesota and nearby states are below the levels that would cause additional mortality on top of natural causes. He noted 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 argued that there is no medical evidence of the linearity at very low $PM_{2.5}$ concentrations.[47]

D. Xcel Energy

43. Dr. Desvousges testified for Xcel Energy. He proposed externality values for $PM_{2.5}$, SO_2, and NO_x (including ozone from NO_x) for rural, metropolitan-fringe, and urban locations, based on modeling a hypothetical power plant in Dakota County, Sherburne County, and Lyon County. Dr. Desvousges used the photochemical grid model CAMx (Comprehensive Air Quality Model with Extensions) to model the hypothetical Black Dog, Sherco, and Marshall facilities as a

[44] Ex. 115 (Marshall Direct) at 28.
[45] Ex. 117 (Jacobs Rebuttal) at 5-7.
[46] Ex. 118 (Polasky Rebuttal) at 4-8.
[47] Ex. 441 (McClellan Rebuttal) at 12-20; Hearing Transcript, Vol. 7 at 174-178 (McClellan).

point source, based on Sherco Unit 1 operational data from 2014.[48] CAMx modeling used 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. Dr. Desvousges estimated ambient air quality changes in Minnesota and parts of Iowa, Wisconsin, Michigan, Illinois, Nebraska, South Dakota, and North Dakota, extending approximately 100 miles from the Minnesota border.[49] He integrated post-processed, county-level CAMx results into separate economic models to estimate and monetize the impacts 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.[50]

44. 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 is designed to isolate the separate contributions from multiple hypothetical facilities. Therefore, running the Sherco and Marshall hypothetical facilities together in one CAMx source apportionment simulation (Scenario 1) did not affect the results. Based on the critiques received from the other Parties, Dr. Desvousges tested this later in the process by running Scenario 3 (including only the hypothetical facility located at Sherco) and Scenario 4 (including only the hypothetical facility located in Marshall). 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.[51]

45. 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 $PM_{2.5}$. However, the use of Riverside $PM_{2.5}$ emissions rate did not affect Dr. Desvousges' proposed $PM_{2.5}$ externality values because of the linear nature of increased ambient concentrations of $PM_{2.5}$ from direct $PM_{2.5}$ emissions. For all other necessary operating parameters, such as stack height, flue gas exit velocity and temperature, and MBtu consumption rate, Dr. Desvousges' modeling was correctly based on Sherco Unit 1 data for $PM_{2.5}$, SO_2, and NO_x.[52]

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[48] Ex. 604 (Desvousges Direct) at 16-18. For $PM_{2.5}$, Riverside emission rate of 9.1 tons was used mistakenly, but this did not affect the results due to the linear nature of direct $PM_{2.5}$.

[49] Ex. 604 (Desvousges Direct) at 16-19, Schedule 2 at 16-24, Schedule 3 at 1, 19-20.

[50] Ex. 604 (Desvousges Direct) at 21, Schedule 3 at 6.

[51] Ex. 604 (Desvousges Direct), Schedule 3 at 19-21; 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).

[52] Xcel Energy corrected this error 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

46. Mr. Rosvold also testified for Xcel Energy. He explained that NAAQS are set at levels protective of human health and the environment and Minnesota is currently not significantly contributing to ambient air concentrations of $PM_{2.5}$, SO_2, and NO_x in any other state.[53] He also testified that county-specific externality values are not practicable in resource planning or resource acquisition.[54]

IV. Public Policy Questions and Definition of Practicable

47. This proceeding involves complex issues of science, economics, and public policy. The main focus has been on scientific matters, such as model features, modeling parameters, air dispersion and chemistry of emissions, accuracy of air quality modeling results, and estimating and monetizing risk of premature mortality. The ALJ believes that there are three scientific questions that are the most critical in this proceeding: what model to choose, how well that model is able to predict ambient concentration changes, and how to estimate and monetize impacts on human health.

48. In addition, there are two significant, disputed public policy questions that substantially affect the outcome of this proceeding. The Agencies and Xcel Energy have both suggested that the geographic scope of damages estimated is ultimately a policy decision for the Commission, and the ALJ agrees. The statute is silent on the geographic scope of damages and does not require or deny Minnesota, national, or global scope. In fact, the statute is currently used to estimate both global (CO_2) and Minnesota (criteria pollutants) damages.[55] Another significant policy issue involves the geographic sensitivity and specificity in emissions sources, in other words, how many sources should be modeled to achieve representative results.

49. Minnesota courts grant deference to administrative interpretations of statutes, and the level of deference increases when the agency's construction of a statute it administers is long-standing.[56] If an agency wants to change its long-standing precedent and interpretation of a statute, it must explain its reasoning and support it by substantial evidence in view of the entire record submitted.[57]

Surrebuttal) at 3, 11-14; Ex. 811 (Muller Surrebuttal), Schedule 1 (Xcel Energy Supplemental Response to DOC IR No. 16).

[53] Ex. 607 (Rosvold Rebuttal) at 2-14; Ex. 617 (Rosvold Opening Statement) at 1-2.

[54] Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.

[55] Xcel Energy Reply Brief at 4-5.

[56] *See McAfee v. Dept. of Revenue*, 514 N.W.2d 301(Minn. App. 1994).

[57] *Pet. of N. States Power Gas Util.*, 519 N.W.2d 921 (Minn. App. 1994).

50. 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 pollutant emissions were estimated in Minnesota, not nationwide. These two decisions can be characterized as long-standing Commission precedent and interpretation of Minn. Stat. § 216B.2422, Subd. 3, and any changes to them must be supported by substantial evidence in view of the entire record submitted.

51. Minn. Stat. § 216B.2422, Subd. 3 requires that the Commission shall, "to the extent practicable," quantify and establish a range of environmental costs. In addition, the ALJ ordered that any Party proposing an externality value bears the burden of showing that the value is "reasonable, practicable, and the best available measure of the criteria pollutant's cost."[58] The Parties have offered differing opinions about the meaning of the term "practicable." CEO suggested that practicability should be defined narrowly as "whether there are enough data in the record to establish a value for a particular pollutant on a national scale."[59] Xcel Energy advocated for a broader definition that would also take into account uncertainty and consider whether the externality values can be used for their intended purpose and will provide useful information in their application.[60]

52. The ALJ agrees with Xcel Energy that the term practicable should not be defined too narrowly. As already determined in the original externalities proceeding, one definition of practicability is that it is feasible or achievable to establish the externality values. The Commission also noted in the initial proceeding that "the quantification of all environmental impacts, however slight, difficult to measure, or irrelevant," would be a "bottomless and highly speculative task."[61] Therefore, practicability should also consider whether there is an unreasonable amount of uncertainty or ambiguity involved in the development of the environmental values. Finally, the ALJ agrees with Xcel Energy that it would not make sense at all if the externality values adopted cannot be used or give irrelevant or inaccurate information.[62] Therefore, practicability also requires that the environmental values can be used for their intended purpose and provide useful information in their application.

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[58] ORDER REGARDING BURDENS OF PROOF, March 27, 2015, Order Point 2.
[59] CEO Initial Brief at 19.
[60] Xcel Energy Reply Brief at 3-4.
[61] Commission January 1997 Order at 12; *see* also ALJ March 1996 Report, Order Point 31 at 11 in the same docket, *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3*. Docket No. E-999/CI-93-583, FINDINGS OF FACT, CONCLUSIONS, RECOMMENDATION, AND MEMORANDUM. March 22, 1996. Hereafter referred as ALJ March 1996 Report.
[62] Xcel Energy's Initial Brief at 7, 52-53; Xcel Energy Reply Brief at 3-4.

V. Criteria for Reviewing the Models and Proposals (Issue 11)

53. Dr. Desvousges proposed in his Direct Testimony standard of review criteria, which would give guidance how to evaluate the diverse methods and values recommended by the Parties throughout this proceeding. He proposed the following criteria: using a damage cost approach; developing the most accurate and credible estimates; addressing inherent uncertainty; using sound science and models; minimizing subjective judgments; establishing practicable values; and using transparent, replicable, and updatable methods. [63]

54. These criteria align with the ALJ's Order Regarding Burdens of Proof, which stated that the environmental values selected for $PM_{2.5,}$ SO_2, and NO_x should be "reasonable, practicable, and the best available measure of the criteria pollutant cost."[64] The ALJ believes that the externality values should be based on the best available science and model that produce the most accurate and practicable externality values.

55. The ALJ finds that Xcel Energy's standard of review criteria are reasonable, appropriately reflect the nature of this proceeding, and are helpful in assessing the various proposals made in this proceeding.

VI. Geographic Scope of Damages (Issue 4)

56. Xcel Energy estimated potential damages from criteria pollutant emissions within Minnesota and an area that extends approximately 100 miles from the Minnesota borders to the south, east, and west.[65] The Agencies and CEO estimated damages in the contiguous United States.[66]

57. The geographic scope of damages is one of the most significant policy questions in this proceeding. 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 there was a strong preference to focus on protecting Minnesota's economy, environment, and residents.

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

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

[65] Ex. 604 (Desvousges Direct) at 19-20.

[66] Ex. 808 (Muller Direct) at 15; Ex. 115 (Marshall Direct) at 9.

The original Commission interpretation, which estimated criteria pollutant impacts only in Minnesota, is consistent with the legislative history.[67]

58. In the original externalities proceeding, the ALJ and the Commission concluded that unlike CO_2, impacts from criteria pollutant emissions are mainly local and regional by nature. The Commission found it reasonable to "focus on the effects of by-products that cause the most significant costs," and for criteria pollutant emissions this meant "quantifying the damage they cause in Minnesota."[68]

59. The ALJ agrees with Xcel Energy that there are still many reasons today that speak against adopting a national scope for criteria pollutant damages, and when all these factors are considered together, it is not reasonable or practicable to calculate nationwide damages from emissions generated in Minnesota.

60. First, impacts from criteria pollutant emissions are mainly local and regional by nature – the majority of air quality changes from Minnesota sources will occur in Minnesota or in close proximity to the Minnesota border. Changes to ambient air concentrations from direct $PM_{2.5}$, SO_2, and NO_x emissions concentrations are generally highest near the source of emissions and decrease 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, tends to travel further, however, the majority of concentration changes will still take place within 100 miles (160 kilometers) from the source.[69]

61. Second, there is substantial uncertainty in estimating national damages from criteria pollutant emissions. The national scope of damages hinges on the ability of models to accurately predict changes in ambient air concentrations throughout the contiguous United States. Uncertainty is significantly increased and estimates become less reliable the further the modeling distance is from the emission source. This is especially true for models that rely on Gaussian plumes, such as AP2, but also applies to other reduced-from models and photochemical grid models.[70]

62. Third, estimating the national scope of damages involves additional uncertainty, because the models are predicting very small ambient air concentration

[67] Xcel Energy's Initial Brief at 8-9.
[68] Commission January 1997 Order at 15.
[69] Ex. 608 (Desvousges Surrebuttal) at 35; Ex. 119 (Marshall Surrebuttal), Schedule 2 (Xcel Energy Response to CEO IR No. 11 and No. 12); Xcel Energy Initial Brief at 52-53.
[70] Ex. 608 (Desvousges Surrebuttal) at 46; Xcel Energy Initial Brief at 55.

changes at further distances (e.g., 0.00000298 $\mu g/m^3$ or 0.000000643 $\mu g/m^3$).[71] Epidemiological research has not addressed adverse health effects at very low ambient concentration levels or examined whether the linear application of concentration-response function is appropriate at very low concentration levels.[72] AP2, InMAP, and CAMx do not have a limit on how small concentration changes can be calculated, 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.[73]

63. The very small concentration changes, when summed across the contiguous United States, have a significant impact on the externality values. To estimate mortality damages from $PM_{2.5}$, these concentrations are 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. When 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 or 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.[74]

64. Fourth, 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 the U.S. Environmental Protection Agency (EPA) has determined through Cross State Air Pollution Rule (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.[75] At the time of the original externalities proceeding, EPA had not kept the NAAQS updated; NAAQS did not reflect the latest scientific knowledge; and regulations on the interstate transport of emissions did not exist.[76]

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[71] AP2 and InMAP average change in ambient $PM_{2.5}$ concentrations from the Sherco facility beyond one hundred miles of Minnesota. See Ex. 608 (Desvousges Surrebuttal) at 43.
[72] Ex. 608 (Desvousges Surrebuttal) at 42-44; Hearing Transcript, Vol. 7 at 113-117 (Desvousges).
[73] Ex. 608 (Desvousges Surrebuttal) at 44; Hearing Transcript, Vol. 7 at 115 (Desvousges).
[74] Hearing Transcript, Vol. 7 at 113 (Desvousges); Hearing Transcript, Vol. 8 at 33-34 (Muller); Xcel Energy Initial Brief at 55-60.
[75] Ex. 607 (Rosvold Rebuttal) at 2-14; Ex. 617 (Rosvold Opening Statement) at 1-2.
[76] ALJ March 1996 Report, Finding 46 at 23.

65. In order for the Commission to change the current geographic scope of criteria pollutant damages, which is based on a long-standing precedent and interpretation of statute, the Commission would have to explain its reasoning and support it by substantial evidence in view of the entire record as submitted.[77] The request by the Agencies and CEO are not supported by such substantial evidence in this case.

66. The Agencies and CEO have argued that their modeling shows that a large proportion of damages from Minnesota emission sources occur beyond 100 miles from the Minnesota border in faraway states, and therefore, the scope of damages should be national. Dr. Muller and Dr. Marshall also reported very different and conflicting proportions of damages within Minnesota and outside of Minnesota, based on their separate modeling.[78]However, as will be discussed in more detail in section X below, the ALJ believes that the AP2 and InMAP air quality modeling results are not accurate enough to draw any conclusions regarding the proportion of damages within Minnesota and outside of Minnesota.

67. Additional evidence presented by the Agencies and CEO in the record, attempting to estimate the geographic scope of damages, is contradictory, incorrect, or unconvincing. For example, Dr. Muller conducted an analysis of EPA's CSAPR modeling data, but his analysis had serious flaws, such as including all types of emission sources and not correcting for the irregular number of monitoring sites in each state.[79] Dr. Marshall prepared figures that show that the vast majority of $PM_{2.5}$ concentration changes occur within the Minnesota domain, based on his analysis of CAMx hourly results from a lower spatial grid (36 kilometers).[80]

68. The ALJ agrees with Xcel Energy that there is substantial evidence on the record to conclude that the majority of concentration changes from $PM_{2.5}$, SO_2,

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[77] *See Pet. of N. States Power Gas Util.*, 519 N.W.2d 921 (Minn. App. 1994).

[78] Xcel Energy Initial Brief at 54; Ex. 608 (Desvousges Surrebuttal) at 38; Ex. 810 (Muller Rebuttal) at 22; Ex. 116 (Marshall Rebuttal) at 12. For example, Dr. Muller reported that for $PM_{2.5}$, 60 percent of his calculated damages are 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.

[79] Xcel Energy Initial Brief at 54-55; Ex. 811 (Muller Surrebuttal) at 24-25; Hearing Transcript, Vol. 8 at 97-110 (Muller).

[80] 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), Xcel Energy does not believe these results are therefore accurate or reliable. *See* Xcel Energy Initial Brief at 57-60; 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).

and NO_x emissions generated in Minnesota will take place in Minnesota and within 100 miles from the Minnesota border. This is the domain that Dr. Desvousges used in his CAMx modeling. Although a small proportion of concentration changes may occur outside this domain, the ALJ believes it is not practicable or reasonable to estimate criteria pollutant damages from Minnesota emissions nationwide, considering the mostly local and regional nature of criteria pollutants, the significant uncertainty involved in estimating national damages, and the protection of human health through NAAQS and CSAPR regulations.

VII. County-Specific Values (Issues 3 and 8)

69. In the original externalities proceeding, criteria pollutant values were established for three locations to account for geographic sensitivity: urban, metropolitan-fringe, and rural areas. Although the Commission also created values for a fourth category – within 200 miles of Minnesota – no separate damage values were estimated or sources modeled outside of Minnesota, instead, the rural values were used as such, unchanged.[81]

70. In the determination of criteria pollutant values, the geographic sensitivity and specificity of emission sources is another significant policy question. The Agencies and CEO modeled a source in each county in Minnesota (87 counties) and in each county within 200 miles from the Minnesota border (almost 400 counties), a total of nearly 500 sources. They argued that the county-specific values would provide useful information for the Commission about the variability of damages based on source location.[82]

71. Xcel Energy modeled one identical source at three representative locations – Marshall (Lyon County), Sherco (Sherburne County), and Black Dog (Dakota County) – to estimate externality values for a rural, metropolitan-fringe, and urban location. Xcel Energy stated that these three types of locations were selected because they are consistent with the geographic groupings adopted in the original proceeding, are realistic potential locations for a new power plant, and constitute a representative, cautious approach. Xcel Energy maintained that the city of Marshall has a larger population than a typical rural setting and is located in the western part of the state, allowing air dispersion over a greater part of Minnesota. The Sherco site is located upwind from the Twin Cities in the predominant wind pattern, and the Black Dog site is located in the largest urban area in the state.[83]

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[81] Ex. 605 (Desvousges Rebuttal) at 27; Commission January 1997 Order at 15-16.
[82] Ex. 813 (Muller Opening Statement) at 2; Ex. 120 (Marshall Opening Statement) at 2.
[83] Ex. 608 (Desvousges Surrebuttal) at 61; Ex. 616 (Desvousges Opening Statement) at 2.

72. The ALJ agrees with Xcel Energy that it is more important to model a few, representative sources accurately than nearly 500 sources inaccurately. The Commission will not gain any useful information if the county-specific externality values are incorrect because they are based on unreliable air quality modeling. The disputed need for county-specific values cannot be the reason to choose less accurate reduced-form modeling over more accurate photochemical grid modeling.[84]

73. In addition, Xcel Energy has argued that it is not practicable to develop county-specific values, because they could not be used for their intended purpose in the resource planning process and would not provide useful information in the resource acquisition process. The ALJ agrees.

74. 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. Resource planning determines the size, type, and timing of resource additions or reductions – the location of a new resource is typically unspecified, and therefore resource planning uses a generic resource without a specific location.[85]

75. In resource acquisition, externality values are used in the final stage of the process when specific proposals are weighted against each other by the Commission. However, proposals to build new fossil-fueled resources and the location of those resources are driven by other factors than the externality values: 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 a specific location. Location-specific externality values would not provide important or useful information in the resource acquisition process.[86]

76. Since the Commission does not have jurisdiction over siting new generating sources outside of Minnesota, the nearly 400 out-of-state values proposed by the Agencies and CEO would only be relevant in considering possible long-term power purchases from facilities in other states.[87] The ALJ does not believe it is practicable to develop county-specific values for this situation only.

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[84] Xcel Energy Initial Brief at 62-63.
[85] Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.
[86] Ex. 607 (Rosvold Rebuttal) at 25-26; Ex. 617 (Rosvold Opening Statement) at 6.
[87] Ex. 605 (Desvousges Rebuttal) at 30-31.

77. The ALJ believes that nearly 500 county-specific values provide an overwhelming amount of information, especially if they are proposed at three different stack heights. In many cases there is not much variability in the values from county to county.[88] County-by-county values falsely imply precision and specificity that does not exist, considering that the values were produced by reduced-form models, which use annual average data and highly simplified atmospheric chemistry algorithms.[89]

78. Xcel Energy modeled sources in three representative locations and proposed externality values for urban, metropolitan-fringe, and urban areas consistent with the original externalities proceeding. The Agencies or CEO have not presented substantial evidence that would support changing the Commission's long-standing precedent to establish criteria pollutant values for urban, metropolitan-fringe, and urban areas.

79. Xcel Energy recommended using the three externality values also for out-of-state resources that are within 200 miles from the Minnesota border, based on the source location.[90] The ALJ agrees that it is not practicable to establish separate externality values for resources located outside of Minnesota.[91] The ALJ believes it is reasonable to use the rural, metropolitan-fringe, and urban values for out-of-state resources within 200 miles from the Minnesota border, as appropriate based on the location of the source.

80. The Agencies have not proposed a generic value. CEO proposed a generic value for each pollutant based on "separately calculating the impacts of each existing power plant in Minnesota and taking an average of the values weighted by total damages caused by each plant."[92] However, CEO has not supported their proposed generic values with any evidence in the record. For instance, the record does not show how many or which existing power plants were modeled, where the plants are located, or if the locations are dominated by urban, metropolitan-fringe, or rural locations.[93] There is no information in the record to evaluate the accuracy or representativeness of the generic values proposed by CEO, and therefore, the ALJ finds that a preponderance of the evidence does not support adopting CEO's generic values.

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[88] Ex. 608 (Desvousges Surrebuttal) at 62.
[89] Ex. 605 (Desvousges Rebuttal) at 26, 65.
[90] Ex. 605 (Desvousges Rebuttal) at 31.
[91] Ex. 605 (Desvousges Rebuttal) at 30; Xcel Energy Initial Brief at 63-64.
[92] Ex. 115 (Marshall Direct) at 28; see also CEO Initial Brief at 65.
[93] Xcel Energy Reply Brief at 14.

VIII. Models (Issue 1)

A. The AP2 Model

81. Agencies used AP2, a reduced-form model developed by Dr. Muller, to predict air quality changes, estimate their impacts, and monetize the resulting damages. 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 trade secret and undergoing peer-review.[94] The trade secret status was lifted on the first day of the evidentiary hearings, on January 12, 2016.[95]

82. AP2 is based on simplified air dispersion modeling, which assumes all emissions occur at the 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 depends on science and data from different time periods: it relies on annual average meteorological date from 1990, uses emissions data from 2011, and is based on an air quality dispersion model approach that was developed more than 40 years ago in 1973.[96]

83. 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.[97]

84. EPA publishes air quality modeling guidelines and guidance that detail their recommended modeling approaches for different applications. EPA air modeling guidelines (40 CFR Part 51, Appendix W)[98] 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

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[94] Ex. 605 (Desvousges Rebuttal) at 17.
[95] Hearing Transcript Vol. 6 at 150-151.
[96] Ex. 605 (Desvousges Rebuttal) at 5, 19, 33-34, Schedule 1 at 8 (Department Response to Xcel Energy IR No. 10); Ex. 811 (Muller Surrebuttal) at 3.
[97] Ex. 605 (Desvousges Rebuttal) at 19, 34.
[98] 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

gross overestimation bias at further downwind distances.[99] Contrary to EPA guidance, AP2 was used to assess impacts beyond 50 kilometers.

85. In addition, AP2 uses simplified chemical transformation algorithms to model ozone and secondary $PM_{2.5}$ concentrations.[100] 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 colder periods.[101] EPA's current (2007)[102] and proposed (2014)[103] guidance for ozone and secondary $PM_{2.5}$ modeling recommends using photochemical grid models, such as CAMx, which incorporate full-science atmospheric chemistry.[104]

86. Since AP2 is a reduced-form model, it does not include flue-gas chemistry and models SO_2, NO_x, and $PM_{2.5}$ emissions in isolation from one another, unlike a real power plant plume. Dr. Muller modeled an equal amount of each pollutant separately, one incremental ton, for all sources.[105] In reality, power plants emit all three criteria pollutants together in unequal quantities and they interact chemically in the point source plume.

87. The ALJ finds that AP2 is an inappropriate model to use in this proceeding, because it was applied contrary to EPA's air quality modeling guidelines and guidance. In addition, the simplified features of AP2 significantly reduced its capability to provide reliable or reasonably accurate air quality modeling results, which are discussed further in section X below.

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[99] Ex. 604 (Desvousges Direct), Schedule 3 at 2-3; Ex. 605 (Desvousges Rebuttal) at 21-22.
[100] Dr. Muller himself acknowledges that AP2 models chemical reactions in the atmosphere "in a very simple way." Hearing Transcript, Vol. 8 at 29 (Muller).
[101] Ex. 605 (Desvousges Rebuttal) at 34.
[102] 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
[103] 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
[104] Ex. 605 (Desvousges Rebuttal) at 35-37.
[105] This is true for his modeling of existing power plants as well: for the actual plants, Dr. Muller used their exact location and stack height, but still modeled one incremental ton of each pollutant separately.

B. The InMAP Model

88. InMAP is a 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.[106] According to Dr. Marshall himself, "[T]o our knowledge, the modeling approach developed here is the first of its kind for air pollution."[107]

89. The current EPA guidelines for air quality modeling (40 CRF Part 51, Appendix W) set criteria for air quality models and require that the models are non-proprietary and publicly available; have received a scientific peer-review; and have performed well in past applications.[108] 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.[109] InMAP has not been used in any prior federal or state 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.[110]

90. There are several other reasons why InMAP is not a reliable model to use in this proceeding. When modeling a hypothetical county source, 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 secondary $PM_{2.5}$ formation can begin immediately thereby likely overstating the ozone and $PM_{2.5}$ impacts.[111]

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[106] 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.

[107] Ex. 119 (Marshall Surrebuttal), Schedule 1 at 5 (9285).

[108] Ex. 606 (Desvousges Rebuttal Non-Public) at 17, 22-24.

[109] The authors are Tessum, Hill, and Marshall. See Ex. 119 (Marshall Surrebuttal), Schedule 1; Hearing Transcript, Vol. 6 at 157 (Marshall).

[110] Ex. 605 (Desvousges Rebuttal) at 17; Hearing Transcript, Vol. 6 at 29 (Xcel Energy Opening Statement).

[111] Ex. 605 (Desvousges Rebuttal) at 8, 63-64, Schedule 2 at 17 (CEO response to Xcel Energy IR No. 15).

91. Dr. Marshall modeled the same amount of each pollutant – 1,000 tons each of SO_2, NO_x, and $PM_{2.5}$ – for the county-by-county values, and similarly to Dr. Muller, he did not account for any chemical interaction among the pollutants to resemble a power plant plume.[112] Modeling each pollutant independently from one another[113] typically overestimates 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 $PM_{2.5}$.[114] For modeling existing Minnesota power plants, Dr. Marshall used their actual location, stack height, and emissions. However, because InMAP assumes that concentrations change linearly with marginal changes in emissions, the amount of emissions does not ultimately affect the results.[115]

92. 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 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). Since InMAP was calibrated to correlate with mobile source scenarios, it does not mean that the model results would correlate equally well when emissions are modeled from a power plant. [116]

93. The ALJ agrees with Xcel Energy that the Commission should not make significant and long-lasting decisions regarding externality values based on a new, first of its kind model that has not yet been tested or approved by the scientific community. Simply because InMAP was made available to the other Parties does not mean that it received similar testing and scrutiny, possibly detecting errors in code, as review by the scientific community would provide.[117] Likewise, InMAP has not been used in any federal rulemaking or state-level regulatory proceeding. Finally, the ALJ believes that the simplified features of InMAP significantly reduced its capability to provide reliable or reasonably accurate air quality modeling results, which are

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[112] Hearing Transcript, Vol. 6 at 182 (Marshall); Ex. 608 (Desvousges Surrebuttal), Schedule 3 at 3 (CEO Supplemental Response to Xcel Energy IR No. 11).
[113] Although InMap models the three pollutants at the same time, it in effect treats them separately because there is no chemical interaction among the pollutants.
[114] Hearing Transcript, Vol. 7 at 135-137 (Desvousges).
[115] Ex. 119 (Marshall Surrebuttal), Schedule 3 (CEO Supplemental Response to Xcel Energy IR No. 11).
[116] Ex. 606 (Desvousges Rebuttal Non-Public) at 8-9, 62-63, 75-77.
[117] Xcel Energy Reply Brief at 17.

discussed further in section X below. The ALJ therefore concludes that InMAP is an inappropriate model to use to establish externality values in this proceeding.

C. The CAMx Model

94. Xcel Energy used a photochemical grid model CAMx, which incorporates hourly, varying, three-dimensional wind speeds and directions as well as full-science chemistry algorithms to model air quality changes. 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 modeling used realistic emission profiles and rates from a real power plant 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).[118]

95. CAMx was specifically designed to model criteria pollutant emissions simultaneously 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. CAMx and all the supporting software have been publicly available for free for over ten years and the model has been downloaded more than 1,200 times in the last two years alone.[119] Therefore, CAMx has been thoroughly tested and approved by the scientific and academic community.

96. Although the Agencies and CEO have argued that it is unnecessary, expensive, and time-consuming to use a photochemical grid model to estimate externality values in this proceeding,[120] the ALJ believes that the most important criteria for choosing the model is that it can accurately predict ambient air concentration changes from power plant emissions. Predicting air quality changes is the first step in the process of estimating externality values, and the subsequent steps attempt to estimate and monetize the impacts. If this first step 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.[121]

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[118] 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.
[119] Ex. 605 (Desvousges Rebuttal) at 18, 21-24, 35-37; Ex. 608 (Desvousges Surrebuttal) at 6; Ex. 616 (Desvousges Opening Statement) at 1.
[120] E.g., Ex. 116 (Marshall Rebuttal) at 7; Ex. 810 (Muller Rebuttal) at 35.
[121] Xcel Energy's Initial Brief at 3.

97. All Parties agree that as a photochemical grid model, CAMx is more reliable than AP2 or InMAP. The ALJ acknowledges that with full-chemistry photochemical grid models, there is a tradeoff between accuracy and the resources, time, and cost it takes to conduct modeling. However, in this proceeding, it is critical that the air quality modeling results are accurate, and therefore CAMx is a more appropriate model to use than AP2 or InMAP. CAMx is regularly used by EPA, state agencies, researchers, and others who need reliable air quality modeling, including the Minnesota Pollution Control Agency. EPA guidelines for air quality modeling represent the best scientific practice, and CAMx is the only model in this proceeding that meets all current EPA modeling guidelines.[122]

IX. Model Performance Evaluations (Issue 2)

98. All Parties conducted a model performance evaluation (MPE) to understand the accuracy and reliability of their air quality modeling. The ALJ tends to agree with Xcel Energy's critiques directed at the AP2 and InMAP evaluations.

99. For his MPE, Dr. Muller compared AP2 and CAMx[123] annual modeling results for baseline ozone and $PM_{2.5}$ against observed ambient data. However, his MPE had several weaknesses: AP2 and CAMx used meteorological data from different years; Boylan and Russell $PM_{2.5}$ performance goals and criteria were inappropriately used for ozone; observed daily $PM_{2.5}$ concentrations and 8-hour ozone concentrations were converted to annual averages; and only total concentrations, not predicted concentration changes, were evaluated.[124]

100. Dr. Marshall's evaluation of InMAP showed poor performance against observed ambient $PM_{2.5}$ data. For instance, for sulfates, (a component of PM), the bias was a negative 137 percent which falls significantly outside of 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.[125] If a model cannot accurately predict baseline concentrations, there is no foundation to suggest that it is able to accurately predict concentration changes.[126] In addition, Dr. Marshall's comparison to WRF-Chem data is not meaningful, because the WRF-

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[122] Xcel Energy Reply Brief at 18.
[123] The CAMx modeling was performed by the Minnesota Pollution Control Agency outside of this docket for another purpose.
[124] Ex. 605 (Desvousges Rebuttal) at 51-53.
[125] 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).
[126] Xcel Energy Initial Brief at 47, 50.

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 low to the ground from multiple sources, while power plant emissions are modeled as elevated emissions from a single point source. InMAP was calibrated to correlate with mobile source scenarios, which does not mean that the model results would correlate equally well when emissions are modeled from a power plant.[127]

101. 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.[128] 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 $PM_{2.5}$ readings to an annual average diminishes the variation in the data and removes the high and low data points.[129] 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.

102. Dr. Desvousges conducted a CAMx performance evaluation that followed standard evaluation practices, used appropriate performance goals and criteria, included graphical displays of model performance, and showed that the CAMx model performed very well. 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.[130] Annual ozone error was only 10.1 percent, which is three times lower than EPA's ozone performance goal of 35 percent.[131] Other Parties have not disputed Dr. Desvousges' MPE.

103. Xcel Energy has questioned the reliability and validity of AP2 and InMAP performance evaluations. The ALJ agrees that the model performance evaluations alone do not show that the AP2 and InMAP air quality modeling results in this proceeding would be accurate.

X. Modeling Results (Issue 10)

104. The three different modeling approaches used by the Agencies, CEO, and Xcel Energy produced very different results, both regarding the ambient air

[127] Ex. 606 (Desvousges Rebuttal Non-Public) at 9, 75-77; see also Ex. 119 (Marshall Surrebuttal), Schedule 1.
[128] Ex. 605 (Desvousges Rebuttal) at 53.
[129] Hearing Transcript, Vol. 8 at 83-84; *see* also Ex. 605 (Desvousges Rebuttal) at 52.
[130] Ex. 604 (Desvousges Direct), Schedule 3 at 4, 29-34, 46-63.
[131] Ex. 604 (Desvousges Direct), Schedule 3 at 4, 29-46, 62-64.

concentration changes (air quality modeling component) and the proposed environmental values (estimating and monetizing impacts). There is little agreement among the AP2, InMAP, and CAMx estimates and the results vary significantly, whether analyzed by pollutant, by individual source, or by geographic scope.[132]

105. No Party has disputed the accuracy of Dr. Desvousges' CAMx air quality modeling results from the Black Dog, Sherco, and Marshall sources within the Minnesota domain. The record shows that CAMx 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.[133]

106. The Agencies and CEO have attempted to discredit Dr. Desvousges' CAMx modeling since it used both Sherco Unit 1 and Riverside data. However, the use of the Riverside 2014 emission rate for direct $PM_{2.5}$ did not have an impact on the $PM_{2.5}$ externality values because of the linear nature of direct $PM_{2.5}$ emissions.[134] Xcel Energy modeled representative amounts of NO_x and SO_2 (3,508 and 1,169 tons respectively), which is important because CAMx includes flue-gas chemistry and treats the secondary formation of $PM_{2.5}$ from NO_x and SO_2 in a nonlinear manner. This is more representative of a real power plant than modeling an equal amount of each pollutant in isolation without chemistry among them as the Agencies and CEO have done.[135]

107. CEO also criticized Xcel Energy for using the actual Sherco stack height in CAMx modeling.[136] The ALJ agrees with Xcel Energy that it was appropriate to use the Sherco Unit 1 parameters because as a coal unit, it emits a substantial amount of each criteria pollutant. For example, a gas facility would emit only a small quantity of

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[132] Xcel Energy's Initial Brief at 19-24.

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

[134] Xcel Energy filed errata on October 13, 2015, well ahead of Rebuttal Testimony, to explain that the error did not affect the damage values. 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. See Ex. 604A (Errata to Exhibit 604); Ex. 605 (Desvousges Rebuttal) at 5, 39-40, 42; Ex. 608 (Desvousges Surrebuttal) at 3, 11-13.

[135] Ex. 608 (Desvousges Surrebuttal) at 14.

[136] CEO Initial Brief at 38-39.

SO_2.[137] In addition, the actual Sherco stack height is much shorter (198 meters) than the high and middle effective stack heights (880 and 310 meters) used in Dr. Marshall's InMAP modeling for county-by-county values.[138]

108. The record shows that AP2's air quality modeling results are unexpected and inconsistent with what is known about the atmospheric dispersion and chemistry of emissions. AP2's random and sporadic modeling results from NO_x emissions skip over most Minnesota counties, but show secondary $PM_{2.5}$ concentration changes in faraway states to the east, west, and south.[139] Similarly, AP2 under-estimates secondary $PM_{2.5}$ concentrations from SO_2 emissions in Minnesota, but significantly over-predicts concentration changes outside of Minnesota.[140] While AP2 shows fairly reasonable results from direct $PM_{2.5}$ emissions in Minnesota, it again significantly over-estimates concentration changes nationwide.[141] In addition, AP2's hypothetical damage values are consistently substantially higher than the values based on the modeling of existing power plants, which calls into question the validity of what Dr. Muller modeled as a hypothetical facility.[142]

109. The record shows that the InMAP results for $PM_{2.5}$, SO_2, and NO_x are clearly biased to the east and overestimate concentration changes and damage values. Several figures presented by Xcel Energy show InMAP's eastern bias.[143] Dr. Desvousges prepared a comparison of CAMx, AP2, and InMAP damage values, included in his Surrebuttal Testimony. 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[144] for $PM_{2.5}$ are more than five times higher than the CAMx values and more than seven times higher than the AP2 values,[145] even though InMAP estimates do not include morbidity damages. For Black Dog, InMAP's damage values for NO_x are more than three times higher than the CAMx values.[146]

110. In addition, InMAP damage values from Black Dog, Sherco, and Marshall sources are consistently higher for the rural Marshall location than for the

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137 Ex. 604 (Desvousges Direct), Schedule 2 at 15; Ex. 608 (Desvousges Surrebuttal) at 13-14.
138 Ex. 115 (Marshall Direct) at 19; Ex. 604 (Desvousges Direct), Schedule 3 at 22.
139 Ex. 608 (Desvousges Surrebuttal) at 21-22, 24-25, 29-30.
140 Xcel Energy's Initial Brief at 41-42; Ex. 605 (Desvousges Rebuttal), Schedule 5 at 3, 6.
141 Ex. 605 (Desvousges Rebuttal), Schedule 5 at 5, 8.
142 Ex. 605 (Desvousges Rebuttal) at 6, 42-43; Xcel Energy Initial Brief at 45-46.
143 E.g., Ex. 608 (Desvousges Surrebuttal) at 26-27, 31-32.
144 Based on modeling the actual Black Dog plant.
145 Based on modeling the actual Black Dog plant.
146 Ex. 608 (Desvousges Surrebuttal) at 17-20.

Black Dog or Sherco location, which is unexpected, contrary to common sense, and unlikely to be correct.[147] A typical pattern is that the highest damages are associated with emissions released in or near large cities, because the damages from human health impacts depend on the size of the population exposed to the emissions.[148] One would especially expect to see this pattern in Dr. Marshall's values, since his analysis only estimated premature mortality effects from direct and secondary $PM_{2.5}$.

111. The ALJ concludes that Xcel Energy used the best air quality model available today to predict air quality changes from Minnesota sources. CAMx is the most reliable model and produced the most accurate estimates of the dispersion and impacts from $PM_{2.5}$, SO_2, and NO_x emissions.

XI. Concentration Response Function and Value of a Statistical Life (Issues 6 and 7)

112. Criteria pollutant values are especially sensitive to two parameters that are used to estimate premature mortality impacts from $PM_{2.5}$: the concentration-response function[149] and the value of a statistical life (VSL). The concentration-response function links the exposure from a particular pollutant to its effects, in this case, the increased risk of premature mortality from $PM_{2.5}$. The risk of premature mortality is typically presented as a percentage change per $PM_{2.5}$ concentration change of 1 $\mu g/m^3$ or 10 $\mu g/m^3$. The VSL is used to monetize the increased mortality risk from $PM_{2.5}$ exposure and represents the value attributed to the risk.

113. There is a vast body of epidemiological literature that estimates the risk of premature mortality from $PM_{2.5}$ exposure, including both cross-sectional and cohort studies as well as meta-analyses and single studies. Since the original externalities proceeding, literally thousands of papers have been published on the impacts of $PM_{2.5}$ on human health. The studies have followed different cohorts (varying by size, location, age, gender, occupation, etc.) and estimated different health effects.[150] There is no consensus in the epidemiological literature on the appropriate value or range of concentration-response function from $PM_{2.5}$ exposure, and it is a disputed issue in this proceeding as well.

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147 See Ex. 810 (Muller Rebuttal) at 21, Table 13.

148 See Agencies Initial Brief at 59.

149 Often also referred to as dose-response function, mortality risk, or relative risk. Concentration-response function is also used to estimate premature mortality impacts from ozone exposure, and Dr. Muller and Dr. Desvousges included ozone impacts in their analysis. However, the focus of this proceeding has been on the appropriate concentration-response function for $PM_{2.5}$, and therefore ozone impacts are not discussed here.

150 Ex. 604 (Desvousges Direct), Schedule 2 at 29-35, Appendix A.

114. Similarly, a substantial number of economic studies focus on estimating a VSL, including stated preference and revealed preference analyses. There are also different opinions whether some adjustments should be made to VSL estimates, for example, for age or income levels. Again, there is no agreement in the economic literature or in this case on the correct value or range of VSL.

A. Concentration-Response Function

115. Dr. Desvousges is the only expert in this proceeding who used Monte Carlo simulations to address the inherent uncertainty in estimating premature mortality damages. 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. Monte Carlo simulation incorporates both the mean and standard error values, and therefore takes into account the variability in the underlying studies.[151]

116. Dr. Desvousges' analysis of the concentration-response function used data from three different studies: a meta-analysis by Hoek et. al. (2013),[152]the most recent paper on the Harvard Six Cities cohort (LePeule et. al. 2012),[153] and a recent paper on the American Cancer Society cohort (Jerret et. al. 2013).[154] The Hoek et. al. (2013) meta-analysis incorporates results from the 11 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 $10\mu g/m^3$ 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).[155]

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151 Ex. 608 (Desvousges Surrebuttal) at 48-49.

152 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.

153 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.

154 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. "Spacial Analysis of Air Pollution and Mortality in California." *American Journal of Respiratory and Critical Care Medicine*. 188(5):593-599.

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

117. Dr. Muller and Dr. Marshall both selected one point estimate from the Krewski et. al. (2009)[156] single study to represent the low mortality risk and one point estimate from the LePeule et.al. (2012) single study to represent the high mortality risk. Dr. Muller's proposed concentration-response values were 6 percent and 14 percent per every 10 $\mu g/m^3$ increase in $PM_{2.5}$, Dr. Marshall recommended 7.8 percent and 14 percent.[157]

118. The ALJ agrees with Xcel Energy that a well-executed, recent meta-analysis should be selected over a single study, because meta-analyses systematically use information from a number of individual studies and prioritize the studies based on the statistical certainty associated with the results (studies with smaller standard errors are assigned higher weights).[158] Dr. Muller and Dr. Marshall should have used the Hoek et. al. (2013) meta-analysis in their estimation of mortality risk. While all Parties used studies involving the American Cancer Society and Harvard Six Cities cohorts to estimate mortality risk, Dr. Desvousges' analysis was the only one that also used nine other studies from Hoek et. al. (2013) that had researched other cohorts (e.g., persons enrolled in the U.S. Medicare system, registered nurses in 11 states, California public health professionals, and Canadian adults mandated to provide detailed census data).[159] Therefore, his analysis was more inclusive and comprehensive than Dr. Muller's or Dr. Marshall's approaches.

B. VSL Value

119. Dr. Desvousges' Monte Carlo simulation for VSL incorporated data from three different meta-analyses (Kochi et. al. 2006;[160] Mrozek and Taylor 2002;[161] and Viscusi and Aldy 2003)[162] and data from a recent individual study by Kniesner et. al. (2012).[163] He again assigned appropriate weights based on his expertise for each

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156 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.

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

158 Ex. 604 (Desvousges Direct), Schedule 2 at 34-37.

159 Ex. 604 (Desvousges Direct), Schedule 2 at 36, 98-102 (Appendix A).

160 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.

161 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.

162 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.

163 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.

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 VSL value of $7.9 million (the 75th percentile value).[164]

120. For his VSL of $9.8 million (2015$), Dr. Marshall relied on an EPA meta-analysis from 1999, which included 26 individual studies published during 1974-1991.[165] Dr. Muller used the same EPA meta-analysis for his high VSL of $9.5 million (2011$), and Kochi et. al. (2006) for his low VSL of $3.7 million.[166]

121. The ALJ finds that 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 that included studies from 1974-1991. EPA is currently in the process of revising its VSL guidance and considering more recent studies. 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.[167]

122. The ALJ believes Dr. Desvousges' selection of studies for his VSL analysis was appropriate, as was his treatment of the Kochi et. al. (2006) study estimates[168] and decision not to adjust the VSL values for changes in real income.[169] Dr. Desvousges used the 25th and 75th percentile values from the combined mortality risk and VSL distribution, hence accounting for the uncertainty and excluding the most unlikely values.[170]

123. Dr. Muller used an approach that made the range of his proposed externality values very wide. He combined a very low mortality risk value (6 percent) with a very low VSL ($3.7 million) and a very high mortality risk value (14 percent) with a very high VSL ($9.5 million). The average high damage values for each criteria

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164 Ex. 604 (Desvousges Direct), Schedule 2 at 54-56; Ex. 117 (Jacobs Rebuttal), Schedule 4 (Xcel Energy Response to CEO IR No. 4).
165 Ex. 115 (Marshall Direct) at 25. EPA 2000. *Guidelines for Preparing Economic Analyses*.
166 Ex. 808 (Muller Direct) at 41-42.
167 Ex. 604 (Desvousges Direct), Schedule 2 at 56; Ex. 608 (Desvousges Surrebuttal) at 55-56; Hearing Transcript, Vol. 6 at 165.
168 Ex. 604 (Desvousges Direct), Schedule 2 at 51-55; Ex. 608 (Desvousges Surrebuttal) at 51-53; Xcel Energy Reply Brief at 34-36.
169 Ex. 608 (Desvousges Surrebuttal) at 57-59.
170 Ex. 608 (Desvousges Surrebuttal) at 47-48; Xcel Energy Reply Brief at 33.

pollutant are about five times higher than the average low damage values.[171] In this wide range, the low and high damage values are uncertain and unlikely to be the "true" values.[172]

124. The ALJ concludes that Dr. Desvousges' mortality risk and VSL analysis relied on the most recent meta-analyses and individual studies, took into account the variability of the studies, and addressed the inherent uncertainty involved in estimating human health effects from $PM_{2.5}$ exposure. His analysis is based on the best available science and a better way to evaluate mortality risk than Dr. Muller's or Dr. Marshall's approaches.

XII. Other Issues: Proposals to Group or Average Values and Updating Values (Issue 9)

125. The Agencies have suggested in Surrebuttal Testimony and Initial Brief that their proposed county- and source-specific values can be easily grouped to accommodate more practical application. The Agencies list several options, for instance, averaging all estimates per pollutant, grouping values according to quantiles per pollutant, or computing an average per pollutant for urban, metropolitan-fringe, and urban locations.[173] CEO has suggested that the Commission could adopt damage values based on the average results of AP2 and InMAP modeling.[174]

126. The Agencies and CEO did not recommend any of these approaches in their Direct or Rebuttal Testimony, and they have not calculated or proposed any specific values based on them. These suggestions are not timely and have not been examined by Parties or supported by evidence in the record. Therefore, the ALJ is not going to consider the Agencies suggestions to group values or CEO's suggestion to average estimates.

127. The ALJ finds it appropriate to continue the practice of updating externality values annually based on the Gross Domestic Product (GDP) Price Deflator Index. This approach updates the values accordingly to the state of the overall economy. Since the externality values are now set based on the best available science and modeling, the Commission can rely on them for a reasonably long time, as long as they are updated for inflation.[175]

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171 Ex. 808 (Muller Direct) at 50-51.
172 Xcel Energy Reply Brief at 33.
173 Ex. 811 (Muller Surrebuttal) at 25-26; Agencies Initial Brief at 51-52.
174 Ex. 119 (Marshall Surrebuttal) at 7; CEO Initial Brief at 64.
175 Ex. 605 (Desvousges Rebuttal) at 61-62; Hearing Transcript, Vol. 7 at 144-146.

CONCLUSION

The ALJ finds that Xcel Energy's proposed environmental values are based on the most accurate air quality modeling results and take into account the uncertainty and variability in estimating human health impacts from $PM_{2.5}$ exposure. The ALJ recommends that the Commission adopt Xcel Energy's proposed environmental values as reasonable, practicable, and the best available measure of the criteria pollutants' cost.