Xcel Energy®

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March 1, 2016

—Via Electronic Filing—

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

RE: CRITERIA POLLUTANTS ISSUES LIST
INVESTIGATION INTO ENVIRONMENTAL AND SOCIOECONOMIC COSTS
MPUC DOCKET NO. E999/CI-14-643
OAH DOCKET NO. 80-2500-31888

Dear Judge Schlatter:

Please find attached the Issues List for the Criteria Pollutants (CP) phase of the Environmental Externalities docket. Parties continue to reserve their rights to file comments on this Issues List, which under the current procedural schedule would be due April 15, 2016.

For your convenience, a hard copy of the CP Issues List is being sent via U.S. Mail.

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 List

OAH 80-2500-31888
MPUC Docket No. E-999/CI-14-643

STATE OF MINNESOTA
OFFICE OF ADMINISTRATIVE HEARINGS

FOR THE PUBLIC UTILITIES COMMISSION

In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3	**Criteria Pollutants ($PM_{2.5}$, SO_2, and NO_x) Issues List**

Disclaimer and limitation on use of Criteria Pollutants Issues List:

This Issues List should not be viewed as an advocacy document. Instead it is designed to identify the important issues under discussion in this proceeding and connect them with references to where these issues were discussed in pre-filed testimony. If any issue is not mentioned in the document, parties can still argue that issue. Similarly, the brief descriptions here do not prevent parties from describing the issues differently or in greater detail in their briefs or post-hearing argument. The Issues List does not limit advocacy, nor should it be used to attempt to show an inconsistent position of a party. The proposed Findings of Fact and briefs of the parties should cite to the record, and do not need to be tied to the issues as described in this Issues List. To prepare this Issues List, each party assumed responsibility for the descriptions of the testimony of its witnesses; other parties do not, merely by joining in the submission of this document, agree to the descriptions of testimony of witnesses offered by other parties. To be clear, where the summary of the position of a witness in this Issues List references the testimony of another witness, the party whose witness testimony is being referenced is not responsible for how that testimony of its witness is being characterized.

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I: SUMMARY OF THE RECOMMENDED METHOD AND VALUES

Record Citations:
Muller Direct at 4-12, 18-20, 36-45, 48-72, Attachment 2 pp. 33-52, Attachment 3
Muller Surrebuttal at 25-26
Marshall Direct (Ex. 115) at 5:15 – 29:3
Marshall Surrebuttal (Ex. 119) at 1:14 – 4:6.
Desvousges Direct at 5-6, 15-27; Schedule 2; Schedule 3
Desvousges Rebuttal at 19-21, 32-33
Desvousges Surrebuttal at 2-14

Agencies: Dr. Muller used the AP2 reduced-form model to estimate marginal damage value (i.e., the monetary damage resulting from the emissions of one additional ton of a pollutant) ranges for emissions of $PM_{2.5}$, SO_2 and NO_x for sources within Minnesota and within 200 miles of the state's borders (Muller Direct p. 11, 15-16, 18-20). Sources included six large power plants in Minnesota as well as values for each of Minnesota's 87 counties where a power plant could hypothetically be sited. Additionally, Dr. Muller estimated values for twenty-six large power plants within 200 miles of the state borders and from each county within 200 miles of Minnesota's borders (368 counties). This resulted in damage estimates for each of the three pollutants for 487 different sources.

For each source and each pollutant, Dr. Muller estimated a damage value range where the upper value of the range was derived from a set of high-damage assumptions (e.g., choice of concentration-response risk factors, choice of value of a statistical life, etc; see further discussion under other issues below) and the lower end of the range was derived from a set of low-damage assumptions (Muller Direct pp. 36-42 and Attachment 2). Estimating ranges in this manner accounts for the uncertainty and most likely contains the true damage value within each range.

The AP2 integrated assessment model translates emissions to air quality changes, to pollution exposures, to health and environmental impacts, and finally to monetized damages of those impacts. Dr. Muller modeled the changes in ambient fine particulate matter and ozone and the impacts of these pollutants on human health and crop production (see discussion under Issue 5 below). In modeling impacts, Dr. Muller included all impacts within the continental U.S. (see discussion under Issue 4 below). A summary of Dr. Muller's damage value estimates (from Table 6 in Muller Direct p. 49), showing the average monetized estimated damage value across all 93 sources within Minnesota (6 large power plants plus 87 counties) as well as the minimum and maximum under both high and low damage assumptions is presented below. A full list of all estimated damage ranges for each of the 93 Minnesota as well as the 394 sources outside of Minnesota can be seen in Attachment 3 to Dr. Muller's Direct Testimony.

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

	Low Damage Assumptions			High Damage Assumptions		
Pollutant	**Average (Std. Dev.)**	**Min. Value**	**Max. Value**	**Average (Std. Dev.)**	**Min. Value**	**Max. Value**

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

The same information for out-of-state sources is summarized in Table 8 on page 63 of Dr. Muller's Direct Testimony. In his Direct Testimony, Dr. Muller went on to aggregate the sources into quintiles from lowest to highest damages. He also separated damages within Minnesota from damages outside of Minnesota in case the Commission wants the information on what portion of the damage occurs within the state compared to the damage outside the state (but within the continental U.S.) Dr. Muller maintained that having many separate damage values gives the Commission the most versatility for the Commission to apply them (Muller Surrebuttal pp. 25-26). Finally, Dr. Muller used population and income projections to estimate damages in future years up to 2040, indicating, that these values could easily be updated in the future as more information is acquired.

CEO: Dr. Marshall calculated damage costs of $PM_{2.5}$, NO_x, and SO_2 using the reduced-form model known as the Intervention Model for Air Pollution, or "InMAP." Using InMAP, Dr. Marshall first calculated impacts caused by emissions from each county in Minnesota at three different effective stack heights. Dr. Marshall also calculated "generic" values based on the weighted average of damages from emissions from existing power plants in Minnesota. The generic values (in year 2015 dollars) calculated by Dr. Marshall are:

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

Dr. Marshall made four key decisions related to this general process: which Value of a Statistical Life (VSL) to use, which concentration-response function to use, the geographic scope of damages that should be considered, and that it is important to account for the variation of damages based on plant location. For VSL, Dr. Marshall selected the EPA Science Advisory Board-recommended figure, which is the central tendency value of a meta-analysis of 26 studies. Dr. Marshall used the concentration response functions found in Krewski et al. (2009) and LePeule et al. (2012). These two studies are the same epidemiological studies as the EPA uses for regulatory impact analysis, and are the most recent studies involving the largest and most widely analyzed cohorts—the Harvard Six Cities cohort and the American Cancer Society cohort. Dr. Marshall calculated damages based on changes to ambient air concentrations calculated by InMAP throughout the continental U.S. Finally, to account for the geographic variability of damages based on emission location, he calculated changes in $PM_{2.5}$ concentrations caused by emissions of the three pollutants from each county in Minnesota and counties that fall within 200 miles of the Minnesota border.

MLIG: Under Minnesota law and the ALJ's prior orders, parties proposing a change to externalities values bear the burden of proof under a preponderance of the evidence standard. The MLIG asserts that the Agencies, CEOs, and Xcel Energy fail to satisfy this burden of proof. On behalf of the MLIG, Dr. McClellan testified that the primary (or health) damages conclusions reached by Drs. Muller, Marshall, and Desvousges based on national concentration-response data, rather than local data, and without considering the community-exposure level, are invalid. Dr. McClellan further testified that the assumptions and corresponding calculations underlying the ranges proposed by the Agencies, CEO, and Xcel Energy are too speculative and lack evidentiary support. This testimony is further detailed under various sections of the Issues described below.

Xcel Energy: Dr. Desvousges estimated values for $PM_{2.5}$, SO_2, and NO_x for rural, metropolitan fringe, and urban scenarios based on the practice established in the original externalities proceeding. For each scenario, he modeled one hypothetical, new, coal-fired power plant for each hour of the year to estimate changes in atmospheric chemistry over baseline concentrations. He used the photochemical grid model (PGM) CAMx (Comprehensive Air Quality Model with Extensions) to model a hypothetical Black Dog facility in Dakota County, a hypothetical Sherco facility in Sherburne County, and a hypothetical Marshall facility in Lyon County. Air quality changes were estimated in Minnesota and parts of Iowa, Wisconsin, Michigan, Illinois, Nebraska, South Dakota, and North Dakota within 100 miles from the Minnesota border to form a rectangular grid study area. Dr. Desvousges integrated CAMx results into separate economic models to estimate the potential effects of these air quality changes on human health (premature mortality and morbidity), agriculture (crop production), materials (corrosion and soiling), and visibility. The effects were then monetized by estimating values for each type of environmental cost for each scenario. Dr. Desvousges conducted an extensive literature review of current studies (e.g., population, health status, mortality risk evaluation, value of a statistical life) and explained the reasons why certain studies were included in or excluded from the damage cost analysis. He used a sophisticated Monte Carlo simulation to estimate and monetize potential mortality effects from increased concentrations of $PM_{2.5}$. Xcel Energy's recommended externality values are presented in Table 1 below (per short ton in 2014 dollars). The low and high values within each scenario are based on the 25th percentile and 75th percentile estimates of the distribution.

Table 1: Recommended Environmental Values (per Short Ton in $2014)

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

II: ISSUES

Issue 1: Models Used for Estimating Damage Values: AP2 (Reduced Form Model) or InMAP (Reduced Form Model) or CAMx (Photochemical Model)

a. Agencies: AP2 Model

Record Citations:
Muller Direct at 4-12, 12-14, Attachment 2 pp. 5-32
Muller Rebuttal at 12-16
Muller Surrebuttal at 11-12
Marshall Direct (Ex. 115) at 14:11 – 15:16.
Marshall Surrebuttal (Ex. 119) at 6:4 – 6:10, 7:1 – 9:2
Desvousges Direct at 17
Desvousges Rebuttal at 5, 17, 19, 33-35, 37, 46

Agencies: Dr. Muller used the AP2 integrated assessment model to estimate damage values for emissions of $PM_{2.5}$, SO_2 and NO_x from sources within Minnesota and within 200 miles of the state's borders. AP2 is a reduced-form model that was developed exactly for this purpose – to estimate marginal (per-ton) damage values from emissions of criteria pollutants from specific sources or a large set of hypothetical sources. The Commission directed the Agencies to use reduced-form modeling to estimate damage values. The AP2 model is a reduced-form model that employs data and parameter values that are widely used in the scientific literature for estimating the damages from air pollution, and has been used in many peer-reviewed studies (Muller Direct pp. 12-14). Dr. Muller observed that the AP2 model is better suited than full photochemical modeling for this particular application (Muller Direct pp. 8-12). Because the impacts of emissions vary significantly according to the location of the emission source, reduced-form modeling allows multiple emission sources (representing multiple power generation facilities) to be modelled. The impacts of emissions of different pollutants also vary considerably, and because AP2 focuses on changing emissions of one pollutant at a time for each emission source, it is very well-suited to isolate the impacts of each pollutant considered.

Dr. Muller acknowledged that AP2 (and reduced-form models in general) does not take into account all the atmospheric complexity that a photochemical model does take into account, but he maintained that the performance of AP2 has been checked against the output of a photochemical model in order to verify the reliability of the reduced-form model's predictions (Muller Direct pp. 9-10).

Dr. Muller noted that AP2 (and its predecessor, APEEP) have been publicly available since 2007 (Muller Surrebuttal pp. 11-12). The current version of the model (which uses 2011 emissions and other input data) has recently finished peer review and is publicly available to anyone who wants to use it.

CEO: Dr. Marshall testified that in comparison to four critical decisions of modeling pollutant damages, the decision between reduced-form models is less important. A reduced-form model is appropriate for these proceedings because it may be run a sufficient number of times to account for the geographic variability of $PM_{2.5}$, SO_2, and NO_x emissions. Dr. Marshall recommends InMAP because it was specifically designed to address some weaknesses of other reduced-form models. Weaknesses of reduced-form models such as AP2 include:

- using a simpler strategy for estimating pollutant transport: assuming that pollution travels at constant speeds in a number of directions, based on wind speed and direction in the county where emitted, and assuming that the pollution slowly and uniformly spreads out as it travels;
- assuming all emissions occur at the exact center of the county and not providing for greater spatial resolution beyond the county level;
- disallowing for transformation secondary $PM_{2.5}$ back to gas-phase chemicals. Instead, in AP2, a constant, unidirectional rate of change from gas-phase to particulate pollution is assumed; and
- using a constant deposition rate rather than using coefficients for dry and wet deposition that vary spatially.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges noted that AP2 is a reduced-form model, which assumes all emissions occur at the exact 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 relies on science and data that is old and from different time periods: it uses annual average meteorological data from 1990, emissions data from 2011, and an air quality dispersion model approach that was developed in 1973. 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. 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. 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. Dr. Desvousges stated that EPA air modeling guidelines (40 CRF Part 51) recommend that reduced-form models that rely on a steady-state Gaussian plume model formulation, such as AP2, should not be used beyond 50 kilometers. In this docket the AP2 model was used to estimate changes in ambient concentrations nationally, well beyond the 50 kilometer limit. EPA guidelines also recommend that reduced-form models not be used to model ozone and secondary $PM_{2.5}$ because of the highly simplified chemical transformation algorithms and that models used should be non-proprietary and have received a scientific peer-review. The version of AP2 used in this proceeding was for a time designated trade secret while undergoing peer-review.

b. CEO: InMAP Model

Record Citations:
Muller Rebuttal at 3-12,14-16
Marshall Direct (Ex. 115) at 8:14 – 16:10.
Marshall Rebuttal (Ex. 116) at 6:14 – 6:18.
Marshall Surrebuttal (Ex. 119) at 7:11 – 9:2; sched. 1 at 9284 – 9302.
Desvousges Rebuttal at 8, 20, 23-24, 62-66
Desvousges Surrebuttal at 5

Agencies: Dr. Muller noted that InMAP bears considerable similarities to AP2: both are reduced-form integrated assessment models used to estimate the marginal damage costs associated with emissions of $PM_{2.5}$, SO_2 and NO_x (Muller Direct p. 3). He also noted that Dr. Marshall produced similar damage value estimates using InMAP as did Dr. Muller using AP2 (Muller Rebuttal pp. 8-11). Dr. Marshall used similar, but not identical, modeling assumptions to those used by Dr. Muller (Muller Rebuttal pp. 5-8, 11-12). Dr. Muller did point out, however, that applying model evaluation diagnostics (see discussion under Issue 2 below) shows that AP2 is more reliable than InMAP in terms of predicting national or regional ambient $PM_{2.5}$ concentrations (Muller Rebuttal pp. 14-16).

CEO: InMAP is a reduced-form model that relies on the output of more complex models in order to include only those atmospheric processes that are most important for answering the question at hand. Dr. Marshall, one of InMAP's authors/designers, testified that he and Dr. Christopher Tessum designed the model to be more practical to run than comprehensive air pollution models and to improve upon weaknesses of other reduced-form models. Drs. Marshall and Tessum designed InMAP to calculate accurate and spatially detailed estimates of the human health impacts of changes in air pollutant emissions that can be used by non-specialists.

InMAP leverages pre-processed physical and chemical information from the output of a state-of-the-science chemical transport model (WRF-Chem). Phenomena modeled by WRF-Chem include (but are not limited to):

- Weather conditions, including wind speed and direction, clouds and precipitation;
- Transport of air pollution in the atmosphere by wind and turbulence after it is emitted;
- Transformation of pollutants into different types of pollutants as they interact with sunlight and with each other; and,
- Removal of air pollution by surfaces, clouds, and precipitation.

Output from WRF-Chem is used to calculate wind speed in six directions in each InMAP grid cell. Because the majority of $PM_{2.5}$ impacts occur due to annual exposures, relying on WRF-Chem's output captures the most important information from WRF-Chem while freeing up computational capacity within InMAP. InMAP can perform simulations that are several orders of magnitude less computationally intensive than comprehensive model simulations (such as CAMx).

InMAP also uses variable grid sizes when calculating changes in concentration due to marginal increases in emissions, which allows for higher spatial resolution in more densely-populated areas and low resolution in remote and high-altitude areas. The horizontal edge-lengths of InMAP grid cells range between 1 kilometer (km) and 48 km. The vertical edge-lengths of the grid cells vary between 57 meters (m) and 1,400 m. This optimally focuses computational resources on understanding exposures and health impacts in populated areas—which is important when the goal of a modeling exercise is to estimate impacts to human health.

Improvements in InMAP compared to other reduced-form models include:

- calculating how pollution is transported based on the wind speed, direction, and turbulence properties in each grid cell;
- providing a higher spatial resolution;

- calculating the transformation of $PM_{2.5}$ precursors into $PM_{2.5}$ while allowing for transformation of gas-phase pollutants to $PM_{2.5}$ and $PM_{2.5}$ back to gas-phase chemicals.
- using coefficients for dry and wet deposition that vary spatially to account for pollutant removal.

InMAP is publicly available and, like all reputable models, will continue to be refined and updated. InMAP is straightforward to run and should the Commission decide to use inputs different from those chosen by Dr. Marshall, Dr. Marshall testified that InMAP could be easily re-run with those inputs. Each InMAP model run takes approximately 45 minutes to complete on a desktop computer, requiring a factor of ~ 25,000 less computational power than required to produce results from a chemical transport model.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges testified that InMAP is a new, non-standard model in the experimental stage of design. He pointed out that InMAP is unlike any other model typically used for air quality modeling and it does not fit any of the EPA's air quality model categories. InMAP was designated trade secret until November 13, 2015 and lacks history of performing well in past applications, both of which are recommended by EPA's 2005 air quality modeling guidelines. 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. Dr. Desvousges noted that InMap uses gridded annual average wind speed, direction, and turbulence data by averaging Weather Research Forecast WRF-Chem data over 12 months, and assumes emissions are evenly emitted over each county, which means that a generating source is modeled as an area source rather than a point source. He also pointed out that in order for the InMAP results to correlate well with WRF-Chem results, Dr. Marshall needed to apply two calibration factors to InMAP equations.

c. Xcel Energy: CAMx Model

Record Citations:
Muller Direct at 8-10
Muller Rebuttal at 25-26, 35-36, 39-46
Marshall Rebuttal (Ex. 116) at 6:19 – 11:3; 17:14 – 18:5.
Marshall Surrebuttal (Ex. 119) Sch. 1 at 9283
Desvousges Direct at 16-20; Schedule 2 at 17-19; Schedule 3 at 1-3, 10-12
Desvousges Rebuttal at 2, 5, 18, 20, 35-37
Desvousges Surrebuttal at 4-6

Agencies: Dr. Muller noted that CAMx is a full photochemical model and not a reduced-form model and pointed out that the Agencies were directed by the Commission to used reduced-form modeling and thus did not employ a photochemical model. As a full photochemical model, CAMx has both advantages and disadvantages. The advantages stem from the fact that as a state-of-the-art photochemical model, CAMx takes into account far more of the complexity inherent to the translation of changes in emissions to the resulting changes in ambient air concentrations. However, Dr. Muller explained, a reduced-form modeling is a more appropriate choice here, and the time and expense resulting from the computational complexity of CAMx makes reduced-form modeling more appropriate for this application (Muller Direct, pp. 8-9, Muller Rebuttal pp. 35-36). Dr. Muller noted that much of the complexity that CAMx considers is unnecessary for calculating marginal damage value when considering *the annual average* concentration of a pollutant (versus, for example, the calculation of an hourly air-quality value). Use of a reduced-form modeling allows one to develop damage value estimates for each of Minnesota's counties (as well as counties outside the state), which gives the Commission more flexibility in determining values for each situation that it needs them. Dr. Muller explained that a key reason that Dr. Desvousges modeled only three sources (see discussion under Issue 3 below), is because modeling many more sources with CAMx is computationally infeasible. Finally, Dr. Muller compared AP2's estimates of air quality changes resulting from emissions to those of CAMx at the national, regional and state levels (Muller Direct, p. 10) and compared results of each model to actual air monitoring readings done by the EPA (Muller Rebuttal pp. 39-46). In comparing results from AP2 and CAMx, Dr. Muller noted that they were very close and that in comparisons of each model to monitored air quality data, Dr. Muller reported that AP2 performed at least as well as CAMx.

CEO: Dr. Marshall testified that in some situations, such as this proceeding, reduced-form models are preferable to comprehensive photochemical models. CAMx is a comprehensive photochemical model and, therefore, attempts to provide highly realistic and detailed information about hourly air pollution concentration changes in order to calculate annual averages. In spite of this advantage for some contexts, photochemical models are highly computationally intensive. A single simulation can take multiple days to run on a high performance computing system. Due to the large number of computations, running this model is too time-consuming for effective use in these proceedings. This time intensity caused two problems for these proceedings: it could only model a small number of emission locations, and it cannot be re-run easily to update values, test assumptions, or, in these proceedings, for other witnesses to test Dr. Desvousges's results. Dr. Desvousges in fact ran the model only twice before filing his direct testimony. Dr. Marshall also testified that a third run, to test whether running two locations simultaneously affected his results, was finished just before parties filed rebuttal testimony, and only evaluated Marshall results' effect on Sherco results without assessing whether Sherco results affected Marshall results. The computational intensity led to results for only three locations, which are too few to represent highly variable results by emission location.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges used a state-of-the-science air quality model, CAMx, which incorporates hourly, varying, three-dimensional wind speeds and direction as well as full-science chemistry algorithms to model air quality changes. He noted that CAMx is the only model in this proceeding that can accurately determine the dispersion of emissions throughout the year. CAMx was specifically designed to simultaneously model criteria pollutant emissions and is recommended by EPA for modeling ozone and secondary $PM_{2.5}$ formation. Dr. Desvousges stated that CAMx has been subject to hundreds of peer-reviewed journal articles and used in numerous EPA rulemakings such as the July 2011 Cross-State Air Transport Rule (CSPAR) and the July 2015 Transport for the March, 2008 Ozone National Ambient Air Quality Standards (NAAQS) analysis. Therefore, CAMx has been thoroughly tested and approved by the scientific and academic community. CAMx and all the supporting software have been publicly available for free for over ten years.

d. EPA Guidelines for Air Quality Modeling

Record Citations:
Muller Surrebuttal at 6, 29-30, Attachment 3

Marshall Surrebuttal (Ex. 119) at 11:6 – 11:11.
Desvousges Direct, Schedule 2 at 10-11
Desvousges Rebuttal at 2-3, 21-24, 35-37

Agencies: Dr. Muller disagreed with the criticism that EPA guidance precludes the use of reduced-form modeling for air quality changes at distances beyond 50 km of the emissions source (Muller Surrebuttal p. 6). He noted that the Agencies were required to use reduced-form modeling in this proceeding and that if AP2 pollution estimates beyond 50 km were unreliable, the model would not be able to estimate pollution level results that are as strongly correlated with available monitor data as Dr. Desvousges' CAMx model results. Dr. Muller also pointed out that it is inconsistent for Dr. Desvousges to cite EPA guidance in this area, while failing to follow EPA's approaches to the choice of value of a statistical life and concentration-response parameters. Dr. Muller also pointed out that EPA, in its Section 812 Analysis of the Clean Air Act, did in part use AP2's predecessor, APEEP, in its analyses of benefits of the Clean Air Act (Muller Surrebuttal pp. 29-30 and Attachment 3).

CEO: Dr. Marshall has testified that the EPA guidance on air pollution models that Dr. Desvousges discussed applies specifically to the regulatory context of states demonstrating compliance with National Ambient Air Quality Standards (NAAQS) and is therefore not relevant to this case. Because NAAQS apply state-by-state, modeling in that context requires a focus on individual states, and, therefore, a smaller geographic area of primary concern. Dr. Marshall has also testified, in response to Xcel Energy's witness Mr. Rosvold, that other aspects of the federal regulation of these pollutants are irrelevant to the question of how much damage can be attributed to the emission of these pollutants in Minnesota.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges testified that his use of CAMx meets all EPA's current and proposed air quality modeling guidelines and guidance. The current EPA air quality modeling guidelines from 2005 (40 CRF Part 51) state that relying on a steady-state Gaussian plume model, such as AP2, is appropriate to use when modeling SO_2, NO_x and $PM_{2.5}$ impacts from a source to receptors located up to 50 kilometers away. Dr. Desvousges noted that EPA has set the 50 kilometer limit for the use of steady-state Gaussian plume models because of gross overestimation bias at further downwind distances. The most recent, proposed EPA air quality modeling guidelines from 2015 recommend using a PGM, such as CAMx, that incorporates full-science atmospheric chemistry for the modeling of ozone and secondary $PM_{2.5}$ concentrations. Also, EPA's current (2007) and proposed (2014) guidance for ozone and $PM_{2.5}$ modeling recommend using PGMs for the modeling of these two pollutants. Dr. Desvousges stated that the current EPA guidelines for air quality modeling (40 CRF Part 51, Appendix W) set several other criteria for air quality models: the model should be non-proprietary and publicly available; have received a scientific peer-review; shown to have performed well in past applications; be appropriate for the specific application on a theoretical basis; and be applied consistently with an established protocol on methods and procedures. Dr. Desvousges said that the current versions of AP2 and InMAP do not meet several of these criteria while CAMx meets all of the criteria.

Issue 2: Performance Evaluation

a. Agencies: AP2 Evaluation

Record Citations:
Muller Direct at 9-10, 22-36, Attachment 2 pp. 53-58
Muller Rebuttal at 13-16, 39-46
Muller Surrebuttal at 20-21, 28-30
Marshall Rebuttal (Ex. 116) at 4:1 – 5:16
Marshall Surrebuttal (Ex. 119) at 7:1 – 7:15
Desvousges Rebuttal at 7, 51-55

Agencies: Dr. Muller extensively evaluated the performance of AP2. Some of this evaluation takes place before the model is run for a specific purpose, in this case for the estimation of damage cost values for emissions from power plants within and near Minnesota (se Muller Direct pp. 9-10). Dr. Muller used elements of photochemical modeling to inform his results throughout the development of AP2. He also checked the performance of AP2 against the output of a photochemical model in order to verify the reliability of AP2's predictions. Specifically, to assess the performance of AP2's air quality model in predicting ambient pollutant concentrations for both $PM_{2.5}$ and O_3, he evaluated AP2's predictions against predictions of CAMx (Muller Direct p. 22). He also compared AP2's predictions with ambient air monitor data publicly available from the EPA.

After comparing AP2 ambient predictions to CAMx predictions and to monitoring data, Dr. Muller utilized the two main diagnostics which were established in earlier air quality modeling performance studies (Boylan and Russell 2006): the mean fractional bias (MFB) and mean fractional error (MFE) (Muller Direct pp. 23-33 and Attachment 2). Dr. Muller used these diagnostics to compare the performance of AP2's ambient concentration predictions and CAMx's predictions at national, regional and state-level scales. Employing these criteria and a few others, Dr. Muller's general finding was that AP2 performs "close to the best a model can be expected to achieve" relative to the CAMx model at all three scales and for both $PM_{2.5}$ and O_3.

Dr. Muller also did numerous tests to evaluate AP2's specific $PM_{2.5}$ ambient concentrations for this proceeding and compare those ambient concentrations to Dr. Marshall's InMAP results (Muller Rebuttal, pp. 13-16) and Dr. Desvousges' CAMx results (Muller Rebuttal pp. 39-46). In the comparisons with InMAP, Dr. Muller found that the AP2 model is at least equally reliable in this context. In comparisons of AP2 $PM_{2.5}$ predictions with the CAMx predictions for the three hypothetical plants modeled by Dr. Desvousges and for each of the three emitted pollutants ($PM_{2.5}$, SO_2 and NO_x), Dr. Muller found that AP2 predicted slightly higher ambient levels of $PM_{2.5}$ from $PM_{2.5}$ emissions than CAMx, but he found that the main driver of this difference was Dr. Desvousges' choice to limit the geographic scope of the analysis to the "grid box" encompassing Minnesota (discussion under Issue 4 below). For predictions of ambient $PM_{2.5}$ resulting from SO_2 emissions from the three hypothetical plants, Dr. Muller found the AP2 and CAMx results highly correlated, but that CAMx generally predicted higher $PM_{2.5}$ concentrations than AP2; but again, this was driven by Dr. Desvousges' choice to limit the analysis to the grid box around Minnesota. Finally, in comparing the ambient $PM_{2.5}$ predictions resulting from NO_x emissions from the three hypothetical plants, Dr. Muller again found strong positive association between the two models, but that AP2 generally predicted lower $PM_{2.5}$ concentrations. He did not, however, think this under-prediction of AP2 (relative to CAMx) undermined AP2's reliability for three reasons. First, his performance evaluation of AP2 relative to monitor data and CAMx results showed that AP2 predictions passed accepted model performance criteria. Second, because this comparison was done for emissions from only three sources, drawing general inferences about the two models is more tenuous than comparisons over many sources. Third, Dr. Muller's comparative analysis of predicted $PM_{2.5}$ from AP2 and CAMx at national, regional and state-level scales showed that AP2 performs at least as well as CAMx. In general, Dr. Muller found that his evaluation of AP2 relative to CAMx and to monitoring data showed AP2 to be a reliable and credible model.

CEO: Dr. Marshall testified that comparisons between models' pollutant concentration predictions are less relevant than the fundamental trade-off of using a reduced-form model or a comprehensive photochemical model. As between InMAP and AP2, Dr. Marshall believes that InMAP better assesses certain questions of air pollutant modeling better than most other reduced-form models.

After adjusting for VSL and concentration response functions, the damage estimates using AP2 and InMAP were reasonably comparable. Dr. Marshall testified that it would be reasonable for the Commission to choose either AP2 or InMAP to calculate damage costs for $PM_{2.5}$, SO_2 and NO_x, or, alternatively, that the Commission could adopt damage values based on the average of results produced by InMAP and AP2, consistent with a scientific approach called ensemble prediction.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges disputes the reliability of Dr. Muller's performance evaluation for several reasons; Dr. Muller: misused the Boylan and Russell (2006) performance goals and criteria that were developed for daily average $PM_{2.5}$ visibility observations by applying them to his results that are based on annual averages; collapsed the CAMx hourly data into an annual average by grid and county; did not present any graphical displays of model performance (e.g., time series, soccer plots) as recommended by EPA guidance; did not analyze separately his results within 50 kilometers and beyond 50 kilometers from the source; and, most importantly, compared only absolute baseline levels of ambient concentrations instead of evaluating the predicted marginal changes in ambient concentrations. Dr. Desvousges noted that therefore Dr. Muller's performance evaluation did not address the key question of how well AP2 is able to predict ambient air concentration changes due to marginal changes in emissions.

b. CEO: InMAP Evaluation

Record Citations:
Muller Rebuttal at 8-10, 14-16
Marshall Direct (Ex. 115) at 15:17 – 16:10.
Marshall Surrebuttal (Ex. 119) at 23:12 – 24:47; Sch. 1 at 9285, 9297 – 9301, figs. 2-10 at 9312 – 20.
Desvousges Rebuttal at 9, 75-77

Agencies: Dr. Muller noted that as a reduced-form model, InMAP bears considerable similarity to AP2, and Dr. Muller found that the two models produced similar damage value estimates. More than the choice of model, however, Dr. Muller indicated that the similar results were caused by the choice of similar model inputs, (geographical scope of damages, concentration-response parameters, value of a statistical life) (Muller Rebuttal pp. 8-10). In comparing the ambient air quality results and diagnostic evaluations of InMAP and AP2, however, Dr. Muller generally found AP2 to outperform InMAP at national, regional and state-level scales (Muller Rebuttal pp. 14-16). InMAP had higher levels of bias (MFB) and larger amounts of error (MFE) than AP2, and AP2 air-quality predictions generally agreed more closely with monitoring data than those of InMAP. Dr. Muller's comparison of the two models showed that AP2 is more reliable in terms of prediction of $PM_{2.5}$ than InMAP. Dr. Muller did not contend that InMAP is unreliable, but rather that AP2 is at least equally reliable within this context.

CEO: Dr. Marshall compared InMAP results to the photochemical WRF-Chem predictions of changes in $PM_{2.5}$ concentrations, creating eleven scenarios of marginal changes in emissions and running them in both InMAP and WRF-Chem. Dr. Marshall testified that in his opinion, InMAP recreated WRF-Chem predictions of changes with excellent accuracy, with a population-weighted mean fractional error and bias less than 10%, and precision, with a population-weighted R^2 around 0.99. Fractional error and bias is assessed based on how near it is to zero, with values less than 50% considered acceptable for air quality models. The R^2 value of 0.99 means that 99% of variation in one model is matched by the other model. The effect of the simplifications incorporated into InMAP is relatively small; InMAP applies empirical correction factors to the InMAP advection and ammonia chemistry processes to improve agreement between InMAP and WRF-Chem results. InMAP and WRF-Chem's agreement was strongest when comparing primary $PM_{2.5}$, and weakest when comparing secondary $PM_{2.5}$ from NO_x.

InMAP was also compared to another reduced-form model—COBRA. These results showed that spatial patterns in concentration changes were similar in InMAP, COBRA, and WRF-Chem.

InMAP was also compared to measurements of ambient concentration for the year 2005. InMAP is not designed to predict ambient concentrations (it is designed to model the changes in pollutant concentrations caused by marginal changes in emissions), but Drs. Marshall and Tessum performed this comparison to understand the limits of using InMAP. The results of this comparison showed that InMAP tends to underpredict observed total $PM_{2.5}$ concentrations with a mean fractional error of predictions only somewhat higher than WRF-Chem. This result was encouraging because it means that InMAP meets air quality model performance criteria published by Boylan and Russell (2006).

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges disputes the reliability of Dr. Marshall's InMAP performance evaluation because of several flaws. Dr. Marshall compared InMAP results to the results of 11 WRF-Chem control scenarios developed for mobile sources looking at alternative light-duty automobile controls (e.g., gasoline, several types of ethanol, electric vehicles with different electricity sources). Dr. Desvousges criticized this approach because mobile source emissions are modeled as low to ground area sources, while power plant emissions are modeled as atmospheric release point sources. In addition, 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). Dr. Desvousges noted that the use of calibration factors demonstrates InMAP's inability to accurately estimate marginal changes in emission concentrations. He pointed out that even with the calibration factors, InMAP showed very poor $PM_{2.5}$ performance when model predictions were compared with annual average observations (e.g., mean fractional bias of negative 137 percent for sulfate.)

c. Xcel Energy: CAMx Evaluation

Record Citations:
Muller Direct at 11-12, 22, 24-26, 27-32, 44
Muller Rebuttal at 39-46
Marshall Rebuttal (Ex. 116) at 7:7 – 7:19, 18:6 – 20:9
Marshall Surrebuttal (Ex. 119) at 19:1 – 20:2.
Desvousges Direct at 17-18; Schedule 2 at 19-21; Schedule 3 at 3-5, 26-63
Desvousges Rebuttal at 53

Agencies: Dr. Muller acknowledged that CAMx is a state-of-the-art photochemical air-quality model, often used by the EPA and the Minnesota Pollution Control Agency (Muller Direct p. 22). As such, he made numerous comparisons of air-quality predictions and model evaluation criteria of CAMx with air-quality predictions and model evaluation criteria of his own model, AP2, in order to assess the performance of AP2 (Muller Direct pp. 24-26, 27-32, 44). His general conclusion is that AP2's air quality model replicated CAMx very closely. Comparing the air-quality predictions of nitrate and sulfate species (the types of $PM_{2.5}$ produced by emissions of SO_2 and NO_x) of AP2 to CAMx at national, regional and state-level scales, Dr. Muller found that at each spatial scale and for each species, AP2 predictions were strongly correlated with CAMx predictions. Moreover, he found that CAMx and AP2 perform to a similar degree of accuracy when evaluated against air-quality monitoring data. Dr. Muller found similar results in comparing the abilities of CAMx and AP2 to predict ozone concentrations: AP2 predicts at least as well as CAMx at national, regional, and state-level scales. He noted that both CAMx and AP2 significantly under-predict ozone concentrations at national scales.

Dr. Muller also compared the air-quality predictions of CAMx and AP2 for emissions from the three hypothetical power plant locations modeled by Dr. Desvousges and found that the results are nearly perfectly correlated (Muller Rebuttal pp. 39-46). He explained that the reason he and Dr. Desvousges produced different damage cost estimates had very little to do with the differences between CAMx and the air-quality model of AP2. In this context, the only difference between reduced-form models and photo-chemical models is the air-quality modeling stepi.e., translating changes in emissions to changes in ambient air quality). The main factors leading to different damage costs estimates between Dr. Muller and Dr. Desvousges, however were the choices of model inputs (geographic scope of impacts, concentration-response parameters, value of a statistical life).

Dr. Muller acknowledged that CAMx considers far more specific information that AP2 and has the capacity to produce far more specific predictions. For instance, CAMx can predict hourly $PM_{2.5}$ and O_3 concentrations while AP2 predicts annual average $PM_{2.5}$ and seasonal average O_3. He observed that, for the purpose of estimating damage cost values for these pollutants, this extra detail (in both the model inputs and the model outputs) is extraneous and unnecessary. Modeling the impacts (premature mortality, health impacts, crop damages, etc) of these pollutants uses only annual average pollution concentrations (or seasonal averages for O_3), so much of the complexity that CAMx provides is irrelevant in this context.

<u>CEO</u>: Although CAMx's third evaluative run was performed in order to assess how much combining the model runs for Marshall and Sherburne County plants affected the results, Xcel Energy only evaluated one direction of influence. This performance evaluation run only tested how much impacts from the Marshall location influenced Sherburne County impacts, and did not

evaluate whether or how much Sherburne County emissions may have influenced Marshall impacts in the combined model run.

Dr. Marshall testified that comparisons between models' pollutant concentration predictions are less relevant than the fundamental trade-off of using a reduced-form model or a comprehensive photochemical model.

After adjusting for Desvousges's assumptions about the geographic scope of damages that should be considered, the VSL that should be used, and the concentration-response functions that should be used, results from InMAP were approximately 2.6 times higher than CAMx's results for $PM_{2.5}$ emissions, while CAMx results were approximately 2.5 times higher than InMAP results for SO_2 emissions. InMAP and CAMx results for NO_x emissions were similar.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges conducted extensive evaluation and testing of his CAMx modeling, as explained in detail in Schedule 3 of his Direct Testimony. CAMx used Weather Research Forecast (WRF) meteorological conditions, such as temperature, precipitation, wind speed, and wind direction, for the most recent 12-month period available (October 2012 through September 2013). Dr. Desvousges noted that both WRF and CAMx were subjected to comprehensive model performance evaluations that compare the modeling results against concurrent observations during the base year base case modeling period. Both models were compared against commonly used, EPA-recommended, air quality modeling performance goals and criteria, which were achieved a majority of the time. For example, CAMx achieved the ozone goal for bias and error 86 percent of the time and the $PM_{2.5}$ criteria for bias and error 93 percent of the time across monitoring sites in the Minnesota modeling domain. Dr. Desvousges concluded that CAMx is an accurate and reliable tool for estimating air quality changes, and if anything, has a slight overestimation bias for both $PM_{2.5}$ and ozone.

Issue 3: Emission Sources

a. Number and Location Specificity of Emissions Sources Modeled

Record Citation:
Muller Direct at 10, 15-16, Attachment 2 p. 29
Muller Rebuttal at 5-6, 34-38
Muller Surrebuttal at 25-26
Marshall Direct (Ex. 115) at 16:11 – 18:18.
Marshall Surrebuttal (Ex. 119) at 3:6 – 3:19.
Desvousges Direct at 18
Desvousges Rebuttal at 3-4, 24-27, 40-41
Desvousges Surrebuttal at 61-63
Rosvold Rebuttal at 24-26

Agencies: Dr. Muller modeled damage values from sources within Minnesota as well as outside of Minnesota but within 200 miles of the state borders (Muller Direct pp. 15-16 and Attachment 2).

Sources within Minnesota included six large power plants as well as each of Minnesota's 87 counties where a power plant could hypothetically be sited. Outside of Minnesota, Dr. Muller estimated values for a set of large power plants within 200 miles of the state borders and from each county within 200 miles of Minnesota's borders. This resulted in damage estimates for 487 different sources. He explained that it is important to have this large number of sources and to consider the specific location of each source because the impacts of emissions vary significantly according to the location of the emission source (Muller Direct p. 10). For this reason, he disagreed with Dr. Desvousges' choice to model only three separate sources to represent all "Urban", "Metropolitan Fringe" and "Rural" areas of the state, arguing that this lumping ignores the heterogeneity within each category and results in inaccurate, non-representative and impractical values (Muller Rebuttal pp. 34-38, Muller Surrebuttal p. 26). He pointed out specific examples where emissions from two different counties (both of which would be lumped into Dr. Desvousges' "Rural" category) result in vastly different damage value estimates (Muller Rebuttal pp. 5-6).

Dr. Muller maintained that having so many separate damage value estimates is not impractical, and rather gives the Commission the most versatility for the Commission to apply them (Muller Surrebuttal pp. 25-26). He suggested several different ways that the Commission could aggregate the county- and source-specific values produced by him (or those produced by Dr. Marshall), for example, by using an overall average for each pollutant across all sources, grouping sources according to quantiles according to the distribution of damage value estimates, or developing average values for each pollutant according to the land-use designations used by Dr. Desvousges ("Urban", "Metropolitan Fringe" and "Rural").

CEO: Dr. Marshall modeled emissions from Minnesota's 87 counties in order to account for the high dependence of damages on the emission source location. Dr. Marshall used counties as the unit of spatial aggregation because counties are small enough to capture how damages vary with emission location but the number of counties in Minnesota is not so large as to create an excessive computational burden.

For each county, InMAP calculates how emissions in that county impact pollution concentrations in each of about 50,000 ground-level grid cells covering the entire contiguous U.S. Each grid cell is between 1 km^2 and 48 km^2. Dr. Marshall testified that the location of the emission source is the largest source of variability in damages per ton of emissions (up to a factor of 100).

In addition to county-specific values, Dr. Marshall also calculated "generic" values for use when the location of a proposed emission source is unknown. To calculate these values, he took the weighted average of damages caused by Minnesota's existing fleet of power plants.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

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

b. Modeling of Out-of-State Sources

Record Citations:
Muller Direct at 15-16, 19-20, Attachment 2 p. 29
Muller Rebuttal at 5-6
Muller Surrebuttal at 26-27
Marshall Direct (Ex. 115) at 17:12 – 17:16.
Desvousges Rebuttal (Ex. 605), Sch. 2 (CEO response to NSP IR 16)
Desvousges Rebuttal at 4, 24-27, 30-31
Rosvold Rebuttal at 24-26

Agencies: Dr. Muller modeled damage values from sources (twenty-six specific large power plants and hypothetical power plants in 368 individual counties) within 200 miles of Minnesota's borders. Generally, he chose to use this limit of 200 miles based on the notion that emissions from these sources have an effect on air quality in Minnesota, and that power generated by these sources may meet electricity demand in Minnesota (Muller Direct, pp. 15-16). He separately modeled damage values for only sources within Minnesota, noting that the Commission could choose to use or not use the values for the out-of-state sources at its discretion. He disagreed with Dr. Desvousges' opinion that establishing damage cost values for sources outside of Minnesota is unnecessary and impractical (Muller Surrebuttal pp. 26-27). Dr. Muller noted that the Commission may wish to know what the impacts from emissions produced outside of the state are and that it does not suffice to assume, with no analysis, that estimated damage values from a rural location within Minnesota will accurately represent impacts from out-of-state sources. He again suggested that having these values for out-of-state sources will give the Commission more versatility and that the Commission could choose to use the out-of-state values in various ways. For example, it could develop overall averages for each pollutant for all out-of-state sources, it could subdivide out-of-state sources into quantiles according to the distribution of damage value estimate, or use the same three land-use designations that Dr. Desvousges proposed for classifying sources within the state.

CEO: Dr. Marshall modeled emissions from counties within 200 miles of Minnesota's borders, excluding the portions of Canada within 200 miles of Minnesota's border. To do so, Dr. Marshall created a 200 mile buffer polygon around the polygonal border of Minnesota, and calculated impacts for each county that fell at least partly within that 200 mile buffer.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges and Mr. Rosvold testified that it is unnecessary and impractical to estimate county-specific values for nearly 400 counties outside of Minnesota, as was done by Dr. Muller and Dr. Marshall. In the original externalities proceeding, Minnesota rural values were adopted as such to be used for out-of-state resources (within 200 miles from the Minnesota border), and no sources outside of Minnesota were modeled. Dr. Desvousges explained that he followed this Commission precedent, which has been used in the resource planning process for nearly 20 years. He also noted that since the county-specific values would not be used in resource planning, and since the Commission does not have jurisdiction over siting new generating sources outside of Minnesota, the nearly 400 out-of-state values would only be relevant in considering possible long-term power purchases from facilities in other states. Dr. Desvousges stated that it is not necessary or practical to develop nearly 400 separate values for only this situation.

c. Type of Emission Sources Modeled

Record Citations:
Muller Direct at 18-19, Attachment 2 p. 29
Muller Rebuttal at 5-6, 33-38
Muller Surrebuttal at 21-23
Marshall Direct (Ex. 115) at 16:11 – 20:19.
Desvousges Surrebuttal (Ex. 608), Sch. 3 (CEO responses to NSP IR 11).
Marshall Surrebuttal (Ex. 119) at 22:3 – 23:11.
Desvousges Direct at 17; Schedule 2 at 22
Desvousges Rebuttal at 5, 17, 19, 33-35, 37-39, 46, 63-65
Desvousges Surrebuttal at 3, 14-15, 60

Agencies: Dr. Muller modeled six large power plants within Minnesota, and modeled each of Minnesota's 87 counties whether or not a county has an operational power plant. The intention of modeling each county separately was to represent the damage from emissions if a power plant were to be located in that county the future (Muller Direct pp. 18-19 and Attachment 2). Thus, for each pollutant, he estimated 93 different damage value ranges. He agreed with Dr. Marshall for essentially making the same choice for type (as well as number) of sources to model (Muller Rebuttal pp. 5-6). He not only disagreed with Dr, Desvousges' decision to model only three sources to represent all damage values, but he also objected to Dr. Desvousges' initial choice to combine two of those sources (Sherburne County and City of Marshall) into one run, which made it impossible to separate the effects of each plant's emission from the other plant's emissions (Muller Rebuttal p. 33).

Dr. Muller defended his choice to model both existing plants and hypothetical plants in the same county because the damage values for the existing plants and for the counties in which those plants are located are different pieces of information intended for different purposes (Muller Surrebuttal pp. 21-22). The purpose of modeling the actual power plants was to capture the damage values for some of the largest emitters in the state using facility-specific specifications while the county value estimates are intended to represent the damages if a new plant were to be located in any of those counties in the future. He explained that the value estimates for existing plants were generally lower than the values for hypothetical source locations due to the existing plants having higher effective stack heights than the stack height assumed for a hypothetical new plant. Finally, he disagreed with Dr. Desvousges' claim that by modeling one identical facility he ensures consistency in analysis and comparisons (Muller Surrebuttal pp. 22-23). Dr. Muller pointed out that Dr. Desvousges' simulation featured SO_2 and NO_x emissions that roughly correspond to a coal-fired power plant and $PM_{2.5}$ emissions that correspond to a natural gas fired power plant. He observed that this design calls into question the viability of the environmental cost values produced by Dr. Desvousges because the design is not representative of the emissions profile from a real power plant.

CEO: For county-specific damage values, Dr. Marshall assumed that pollutant emissions were evenly spread among InMAP grid cells within a county. By doing so, he assumed that a power plant was equally likely to be located anywhere within the county. Dr. Marshall modeled marginal increases in pollutants of 1,000 tons per pollutant, emitted simultaneously in a given county. Each county was modeled in a separate run.

Dr. Marshall modeled these county-specific values at three effective stack heights. An "effective" stack height is the height of the smoke stack plus the additional height that the emission plume rises due to buoyancy and initial upward velocity of the emissions. In InMAP, each vertical grid layer represents a range of effective stack heights where all emissions within the range cause the same projected impacts. The vertical centers of these three ranges are 29 m, 310 m, and 880 m. The lowest grid cell represents the 25th percentile of effective stack heights, the middle grid cell represents the 75th percentile of effective stack heights, and the highest grid cell represents the average height weighted by SO_2 emissions (as recorded by U.S. EPA's 2011 National Emissions Inventory).

Modeling stack height is important because elevation of the source of emissions can have a large impact on the transport of pollutants. In addition, natural gas plants tend to have shorter effective stack heights than coal plants. Having results from a variety of effective stack heights will allow for a better estimate of the actual damage costs from power plants whose location and stack height are known.

To calculate generic values for use when the location of a power plant is unknown, Dr. Marshall used InMAP to calculate damages caused by the fleet of existing power plants in Minnesota using information about power plant location, stack properties, and emission amounts from the U.S. EPA's 2011 National Emission Inventory. He then took the weighted average of these emitters to calculate generic damage values.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges developed externality values based on one identical hypothetical facility (using Sherco Unit 1 operational data from 2014) in order to ensure consistency in analysis and comparisons. This hypothetical facility is substantial in size, and produces quantities of emissions that provide a representative upper bound for any source that may be sited in the future (3,508 tons of NO_x per year; 1,169 tons of SO_2 per year; and 9 tons of $PM_{2.5}$ per year). The facility was modeled in three locations as a point source, using hourly-calculated plume rise, representative emission rates, representative stack parameters (e.g., height, stack gas exit flow velocity, and temperatures), and hourly-varying meteorological conditions.

Dr. Desvousges explained that for each county, Dr. Muller and Dr. Marshall modeled a set incremental amount of SO_2, NO_x and $PM_{2.5}$; Dr. Muller modeled each pollutant in isolation of one another; Dr. Marshall modeled these pollutants simultaneously. Neither model accounted for any chemical interaction among the pollutants to resemble a point source plume. Dr. Muller modeled one incremental ton and Dr. Marshall modeled 1,000 incremental tons of each pollutant. They did not consider such factors as emission rates, fuel sources, or flue gas chemistry in their modeling. Dr. Desvousges pointed out that in reality, most fossil fuels (e.g., coal, oil and natural gas) emit NO_x, SO_2, and direct $PM_{2.5}$ together, and they interact chemically within a point source plume. Also, the ratio of NO_x, SO_2, and direct $PM_{2.5}$ are not equal in the source point plume. Modeling an equal amount of each pollutant separately overestimates the impacts of SO_2 and NO_x on secondary $PM_{2.5}$ formation.

Dr. Desvousges stated that 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. 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.

Dr. Desvousges noted that in addition to modeling one ton of each pollutant for each county from a hypothetical facility, Dr. Muller also modeled six named existing power plants (Sherco, High Bridge, Clay Boswell, Riverside, Black Dog, and A.S. King) as well as all other existing power plants located in Minnesota and within 200 miles of the Minnesota border. Dr. Desvousges said the externality values Dr. Muller reported for each county are therefore inconsistent, because they are based on different types of sources – some existing, some hypothetical, and some counties have two different values derived from one of these six specific plants and one or more different existing sources or a hypothetical source.

Issue 4: Geographic Scope of Damages

Record Citations:
Muller Direct at 15-16, Attachment 2 pp. 28-29
Muller Rebuttal at 6-7, 19-25, 26-32
Muller Surrebuttal at 10-11, 12-15, 24-25, 32
Marshall Direct (Ex. 115) at 18:1 – 18:18.
Marshall Rebuttal (Ex. 116) at 11:13 – 12:6.
Marshall Surrebuttal (Ex. 119) at 9:10 – 15:19; 27:10 – 28:2; Sch. 2.
McClellan Rebuttal (Exs. 441 &441A (errata)) at 20-21 and Appendix 2 at 7-10, 16,17
Desvousges Direct at 5, 19-20
Desvousges Rebuttal at 2, 27-30
Desvousges Surrebuttal at 33-35, 46
Rosvold Rebuttal 1-24

Agencies: To develop his damage value estimates of emissions from sources in and near Minnesota, Dr. Muller modeled damages in all counties of the continental U.S. (Muller Direct p. 15 and Attachment 2). Because emissions of the pollutants at issue may travel long distance, it is important to allow a model to track those impacts accurately over a large region. He objected to Dr. Desvousges' choice to only model damages within the "grid box" consisting of a rectangle that includes Minnesota and extends approximately 100 miles from the state's borders. Dr. Muller cited this modeling choice as the most significant reason why Dr. Desvousges damage value estimates differed from his (as well as from Dr. Marshall's estimates). Dr. Muller pointed out multiple pieces of evidence showing that emissions from Minnesota sources reach beyond the grid box, including the figures in Dr. Desvousges' own testimony (Muller Rebuttal pp. 26-29). Dr. Muller stated that there is no scientific basis to artificially truncate the analysis according to the limits of this "grid box" drawn around Minnesota (Muller Rebuttal pp. 29, 32; Muller Surrebuttal pp. 12-15). He pointed out that Dr. Desvousges acknowledged that these pollutants travel longer distances. That is, Dr. Desvousges' method of estimating baseline conditions within the "grid box" considered emissions within the "grid box" as well as emissions from far outside the "grid box," including emissions from southern Canada and northern Mexico (Muller Rebuttal pp. 29-30). Dr. Muller pointed out that Dr. Desvousges justified this limited geographic scope based on adherence to the methodology used in the previous proceeding to establish environmental cost values in the 1990s, but also pointed out that Dr. Desvousges deviated from the methodology employed in the previous proceeding in several other significant ways, including using a state-of-the-science photochemical air quality model that could not have been applied 20 years ago (Muller Rebuttal p. 32, Muller Surrebuttal p. 12).

Dr. Muller provided other evidence that emissions from Minnesota sources have been shown to affect air quality in distant states, including EPA's analysis to support its Cross State Air Pollution Rule(CSAPR) (Muller Surrebuttal pp. 10-11, 15, 24-25). Based on this evidence, Dr. Muller disagreed with Mr. Rosvold's claim that Minnesota emissions are not significantly contributing to air concentrations in any other states now that CSAPR has been implemented (Muller Surrebuttal p. 32), and with Dr. Desvousges' choice to limit his model to damages within a "grid box" that extends only approximately 100 miles outside of Minnesota's borders.

<u>*CEO*</u>: Dr. Marshall used InMAP to calculate how emissions from each county (and from each Minnesota power plant for the generic values) impact pollution concentrations in each of about 50,000 ground-level grid cells covering the contiguous U.S.

Dr. Marshall testified that when estimating public health damages it is normal practice to model where the pollution actually travels rather than making an arbitrary boundary and then only considering damages relatively close to the source of emissions. Because a large fraction of the damages caused by emissions from Minnesota power plants occur outside the border of Minnesota, it is both practicable and necessary to include these damages in estimates for externality values for Minnesota-based emissions.

Dr. Marshall testified that he found no justification for Dr. Desvousges's limited geographic scope. Dr. Desvousges does not claim that impacts from the three hypothetical emission sources that he modeled do not extend beyond the Minnesota modeling domain, and, in fact, he provided results from CAMx showing changes in ambient concentrations of the three pollutants across the continental U.S. domain. Dr. Desvousges simply chose not to use these results to calculate damages. Dr. Marshall, however, used these continental U.S. CAMx results to calculate damages. Dr. Marshall presented his calculations of damages using CAMx's results in Tables 1 – 3 of his surrebuttal testimony. Including these changes in concentration outside of Dr. Desvousges's Minnesota domain would have more than doubled Dr. Desvousges's damage values. In response to Dr. Desvousges's claim that the results from CAMx at the broader geographic domain were less reliable than the results for Dr. Desvousges's Minnesota domain, Dr. Marshall testified that it was his expert opinion that the CAMx results at the broader domain were more accurate than an assumption that there are no damages outside of Minnesota.

Whether Minnesotan emissions significantly contribute to other states' attainment of NAAQS is irrelevant to the question at hand for the commission: how much damage they cause.

<u>*MLIG*</u>: The extraterritorial damages issue, like damages within Minnesota, is a function of downwind damages. Under Minnesota law and the Administrative Law Judge's prior orders, parties proposing a change to externalities values bear the burden of proof under a preponderance of the

evidence standard. The MLIG asserts that the Agencies, CEOs, and Xcel Energy fail to satisfy this burden of proof. On behalf of the MLIG, Dr. McClellan testified that in areas in Minnesota and Wisconsin that are in attainment relative to the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS), *i.e.*, the annual mean averaged over 3 years is at 12 $\mu g/m^3$ or below, there is no medical or other scientific basis for projecting mortality related to current or projected levels of $PM_{2.5}$. Further, Dr. McClellan testified that it is important to recognize that for downwind areas that may not be in attainment of the $PM_{2.5}$ NAAQS, any calculated increase in mortality attributable will be extraordinarily small related to the baseline mortality, as shown in the findings of Lepeule et al (2012). Dr. McClellan concluded that the primary (or health) damages conclusions reached by Drs. Muller, Marshall, and Desvousges based on national concentration-response data, rather than local data, and without considering the community-exposure level, are invalid. Dr. McClellan further testified that the assumptions and corresponding calculations underlying the ranges proposed by the Agencies, CEO, and Xcel Energy are too speculative and lack evidentiary support.

See further MLIG summary for issue 6(c), "Risk of Premature Mortality for Ambient $PM_{2.5}$ — Existence of Damages at Ambient Concentration Below the $PM_{2.5}$ Primary NAAQS," incorporated as if fully set forth herein.

Xcel Energy: Dr. Desvousges testified that his analysis estimates the potential damages in an area that includes Minnesota and extends out approximately 100 miles from the Minnesota borders. The 100-mile range was a practical decision that reflects several important factors: First, this geographic area is generally consistent with the prior case 20 years ago and the current externality values for $PM_{2.5}$, NO_x, and SO_2 are based on a similar geographic scope. There have been no changes to the underlying statute that is the basis for the values. Second, based on our knowledge of the dispersion of criteria pollutants, the majority of the changes in ambient concentrations would occur within this geographic area as the criteria pollutants disperse from the sources modeled. Third, there has been considerable change in the regulation of the interstate transport of emissions by EPA through the National Ambient Air Quality Standards (NAAQS) and the Cross State Air Pollution Rule (CSAPR), which have limited potential impacts of emissions across state lines. EPA has determined that Minnesota is not significantly contributing to ambient air concentrations of $PM_{2.5}$, NO_x, and SO_2 in any other state. Fourth, there is substantial uncertainty in the model predictions, even CAMx predictions, at distances further from the source modeled and the estimates become less reliable the further one goes from a source. Fifth, there is additional uncertainty because the air quality models are estimating damages based on very small concentration changes, and none of the models have incorporated any estimate of the variance around the predicted results. Therefore, it is difficult to determine whether the predicted concentration changes are statistically different than zero. Dr. Desvousges emphasized that the national scope of damages, proposed by Dr. Muller and Dr. Marshall, hinges on the ability of AP2 and InMap to accurately model changes in ambient air concentrations on a national basis, and he disputes the ability of AP2 and InMAP to do this.

Mr. Rosvold testified that from a public policy perspective, there is no need to estimate damages in this proceeding on a national basis, because federal rules and regulations are already in place to minimize damages due to the interstate transport of emissions. NAAQS are set at levels that are protective of human health and the environment, and EPA has determined through CSAPR modeling and required reductions that Minnesota is not significantly contributing to ambient air concentrations of $PM_{2.5}$, SO_2 or NO_x in any other state. Mr. Rosvold pointed out that several significant regulatory changes have taken place since the last externalities proceeding in the mid-1990s. First, EPA has been timely in reviewing and updating the NAAQS and the NAAQS are now set at lower and more protective levels than they were 20 years ago. Second, EPA has specifically addressed the interstate transport of SO_2 and NO_x emissions through CSAPR, which requires strict emission reductions to eliminate any significant impacts of upwind state contributions to ambient air quality in downwind states. Third, other federal regulation (e.g., Mercury and Air Toxic Standards [MATS]) and voluntary utility actions taken since the original externalities proceeding have resulted in significant emission reductions from Minnesota sources.

Issue 5: Ambient Pollutants and Impacts to Consider

Record Citations:
Muller Direct at 14-15, Attachment 2 pp. 7, 10-23
Muller Rebuttal at 11-12
Marshall Direct (Ex. 115) at 11:4 – 11:11; 22:14 – 23:8; 28:15 – 28:21.
Marshall Rebuttal (Ex. 116) at 21:1 – 21:14.
McClellan Rebuttal (Exs. 441 & 441A (errata)) at 20-21 and Appendix 2 at 7-10, 16,17
Desvousges Direct pg 15-16, 21
Desvousges Rebuttal pg 32

Agencies: Dr. Muller modeled the impacts of ambient fine particulate matter (particles with diameter less than 2.5 microns, or $PM_{2.5}$) and ozone (O_3) (Muller Direct, pp. 14-15 and Attachment 2). Exposures to $PM_{2.5}$ and O_3 capture the major effects of emissions of NO_x, SO_2 and $PM_{2.5}$. The main adverse impacts of these pollutants include impacts on human health (both premature mortality and illness), reduced crop and timber yields, reduced visibility, and acidification. Dr. Muller chose to model the impacts that comprise the vast majority of monetary damages, including premature mortality, respiratory and cardiovascular impacts, and impacts on economically important crops (barley, corn, potatoes, soybeans and spring wheat).

Dr. Muller acknowledged that the vast majority of impacts of $PM_{2.5}$ and O_3 in monetary terms is from the increased mortality risk due to exposure to ambient $PM_{2.5}$. Thus, he did not strongly object to the CEO's choice to only model the premature mortality impacts of $PM_{2.5}$ and to not consider other impacts of $PM_{2.5}$ nor impacts of O_3, and he acknowledged that not considering these impacts does not have a substantial effect on the overall damage estimates (Muller Rebuttal, pp. 11-12).

CEO: Dr. Marshall testified that air pollution exposure causes a range of health impacts, including stroke, heart attack, heart disease, asthma, lung disease, lung cancer, and acute lower respiratory infection. Dr. Marshall only included increased risk of premature mortality due to $PM_{2.5}$ exposure in his damage values because, although there are many pollutants in the atmosphere, $PM_{2.5}$ causes most of the overall monetized health impacts from air pollution. Dr. Marshall did not include the many non-mortality health impacts from $PM_{2.5}$ exposure, the direct health impacts from exposure to SO_2 or NO_x, or other economic damages such as agricultural or industrial damages in his damage values. Dr. Marshall explained that these additional impacts are economically small (i.e. 5 – 10 percent) relative to the damages caused by increased risk of premature mortality and that excluding these damages therefore added clarity without substantially influencing the results. Dr. Marshall testified that by only considering the damage due to increased risk of premature mortality related to $PM_{2.5}$ exposure, his damage values should be considered conservatively low. Should the Commission find non-mortality damages appropriate to include, however, Dr. Marshall testified that InMAP could be used to account for these additional damages.

MLIG: Dr. McClellan testified that the primary (or health) damages conclusions reached by Drs. Muller, Marshall, and Desvousges based on national concentration-response data, rather than local data, and without considering the community-exposure level, are invalid.

Xcel Energy: Dr. Desvousges' 2015 study estimated potential air quality changes and potential effects in Minnesota and parts of Iowa, Wisconsin, Michigan, Illinois, Nebraska, South Dakota, and North Dakota. Using CAMx (high resolution capability, state of science modeling and EPA-recommended for modeling ozone and secondary PM2.5 formation) changes in ambient concentrations resulting from hypothetical new emission sources were estimated. These air quality changes were evaluated to determine the potential effects from $PM_{2.5}$, SO_2, NO_x and ozone on human health (premature mortality and morbidity), agriculture (crop production), materials (corrosion and soiling) and visibility. Damages were estimated including direct PM emissions (primary PM) and secondary PM formation from NO_x and SO_2 emissions, with secondary $PM_{2.5}$ attributed to NO_x and SO_2, as appropriate. Ozone, formed through a set of complex nonlinear photochemical reactions involving NOx and volatile organic compounds, is included in Dr. Desvousges' study and its effects are attributed to NOx emissions. The effects were then monetized by estimating values for each type of environmental cost for each scenario.

Issue 6: Risk of Premature Mortality from Ambient $PM_{2.5}$

a. Concentration-Response Function

Record Citations:
Muller Direct at 16-17, 39-40, Attachment 2 pp. 11-12
Muller Rebuttal at 8, 18-19
Muller Surrebuttal at 17-19, 30-31
Marshall Direct (Ex. 115) at 8:11 – 8:13; 21:1 – 22:13; 23:9 – 24:3.
Marshall Rebuttal (Ex. 116) at 3:1 – 3:17; 13:1 – 16:17.
Marshall Surrebuttal (Ex. 119) at 16:1 – 16:22.
Jacobs Rebuttal (Ex. 117) at 3:12 – 14:14.
McClellan Rebuttal (Exs. 441 & 441A (errata)) at 20-21 and Appendix 2 at 2-10, 16,17
Desvousges Direct at 22-23; Schedule 2 at 27-38; Appendix A.
Desvousges Rebuttal at 49-51, 74-75
Desvousges Surrebuttal at 46-55

Agencies: Dr. Muller used the most recent updates of the two most widely cited studies that connect $PM_{2.5}$ pollution exposure and mortality rates (the American Cancer Society study and the Harvard Six-Cities study) to develop his damage value estimates (Muller Direct pp. 16-17 and Attachment 2). These are the most long-running and widely cited studies and thus comprise the current conclusions of the epidemiological evidence as to the most viable values for the concentration-response parameter governing mortality risk from $PM_{2.5}$ exposure. They have also been used by the EPA in multiple analyses of air pollution impacts. Dr. Muller used the results from the most recent update of the American Cancer Society study (Krewski et al, 2009) for the low ends of his estimated damage value ranges and the results of the Harvard Six-Cities study (Lepeule et al, 2012) for the high ends of the damage value ranges.

Dr. Muller pointed out that these are also the same two studies used by Dr. Marshall in his damage value estimates (Muller Rebuttal p. 8) and that Dr. Desvousges also used these same two studies (in addition to a third meta-analysis by Hoek *et al*) in his values estimates (Muller Rebuttal p. 18). He disagreed with Dr. Desvousges, however, that choosing to frame the ranges by these two concentration-response values skews Dr. Muller's distribution towards higher damage value estimates (Muller Surrebuttal pp. 18-19). Instead, Dr. Muller said that choosing both low- and high-value concentration response parameters accurately characterizes the uncertainty around the true concentration-response relationship between $PM_{2.5}$ and premature mortality.

CEO: Dr. Marshall testified that although there are several types of studies of the health effects of air pollution, results from "cohort" studies are considered the most robust. Cohort studies are those that follow a group of people for an extended period of time. Dr. Marshall used studies from what are likely the two most widely studied cohorts used for estimating the increased mortality risk associated with $PM_{2.5}$ exposure: LePeule et al. (2012) and Krewski et al. (2009). LePeule et al. studied the Harvard Six Cities cohort, tracking 8,096 people and Krewski et al. studied the American Cancer Society Cohort, tracking approximately 500,000 people. Dr. Marshall testified that he chose these two studies because they are recommended by the EPA's Scientific Advisory Board and used by the U.S. EPA for regulatory impact analysis and were based on large, diverse populations. Dr. Marshall used LePeule et al.'s finding that mortality risk increases by 14% for every 10 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentration to represent his "high" damage values and he used Krewski et al.'s finding that mortality risk increases by 7.8% for every 10 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentration to represent his "low" damage values. Dr. Marshall testified that the 7.8% figure from Krewski et al. accounts for ecologic covariates while the 6% figure that Dr. Muller used (also citing Krewski et al. as the source) does not.

Dr. Marshall testified that Dr. Desvousges's decisions related to concentration-response functions result in major under-estimations of the damages from criteria air pollutants from power plants. Dr. Marshall testified that Dr. Desvousges's approach (i.e. his decision to create a distribution to reflect the product of VSL by concentration response function using a Monte Carlo analysis) was inappropriate. To confirm this point, Dr. Marshall created a Monte Carlo simulation similar to Dr. Desvousges and found that doing so effectively removed two of his three selected studies from consideration. Dr. Marshall testified that Dr. Desvousges's approach misleads the reader of his testimony to believe that Dr. Desvousges considered more studies than are accounted for in his final numbers.

Dr. Jacobs testified that he would be reluctant to use unadjusted data as Dr. Muller did when he selected 6% from Krewski et al. Dr. Muller's selected value from the Krewski et al. meta-study differs only slightly from the adjusted value that Dr. Marshall used, which makes the decision to use an unadjusted value more reasonable. The adjusted factor is more likely to be correct because the ecologic covariates that the adjusted value corrects for are not likely to have a causal relationship with $PM_{2.5}$.

Dr. Jacobs testified that Dr. Desvousges's weighting and mixing of different kinds of studies of concentration-response function was unreasonable. Dr. Desvousges used three studies to create his own concentration-response function. One was a meta-analysis of other studies (Hoek et al.), one was LePeule, and one, Jerrett et al., analyzed a particular sub-population of the American Cancer society cohort, namely, Californians. This study of Californians may not be appropriate to apply when assessing damages for the population in and around Minnesota. Additionally, pooling a meta-analysis with two individual studies is not common practice, and new studies should be weighted with other studies within a meta-analysis according to their precision. Dr. Desvousges also compared these studies by applying arbitrary weights to them. Although he lists factors that contributed to his decision to weigh the studies, he did not clarify which led to his choices of studies or the weights assigned. Dr. Desvousges stated that he wished to favor Hoek et al., but to do so he could have used *any* weight greater than 33.3%. Although Monte Carlo analysis, in Dr. Jacobs's opinion, is a valid method to incorporate known uncertainty, arbitrarily weighting the inputs beforehand may have failed to accomplish this purpose in this case.

<u>*MLIG*</u>: *See* MLIG summary for issue 6(c), "Risk of Premature Mortality for Ambient $PM_{2.5}$ — Existence of Damages at Ambient Concentration Below the $PM_{2.5}$ Primary NAAQS," incorporated as if fully set forth herein.

<u>*Xcel Energy*</u>: Dr. Desvousges testified that his Monte Carlo simulations were designed to characterize the uncertainty in overall damages, which are jointly determined by the relative risk of premature mortality from $PM_{2.5}$ and the value of a statistical life (VSL). Therefore, the Monte Carlo simulation first takes a draw from the relative risk distribution and then another draw from the VSL distribution, and multiplies them together to form a combined distribution. Dr. Desvousges' Monte Carlo simulation is an advanced approach that incorporates both the mean and standard error values, and therefore takes into account the variability in the underlying studies. Dr. Desvousges' analysis of the concentration-response function used data from three different studies: a meta-analysis by Hoek et. al. (2013), the most recent paper on the Harvard Six Cities cohort (LePeule et. al. 2012), and a recent paper on the American Cancer Society cohort (Jerret et. al. 2013). 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 based on his professional judgment to each of the three studies (75 percent, 12.5 percent, and 12.5 percent respectively). 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 25^{th} percentile value) and a high relative risk value of 7.3 percent (the 75^{th} percentile value). Dr. Desvousges criticized Dr. Muller's and Dr. Marshall's approaches, because they both selected one point estimate from the Krewski et. al. (2009) single study to represent the low risk and one point estimate from the LePeule et.al. (2012) single study to represent the high risk. Neither used a meta-analysis in their approach. In addition, Krewski et. al. (2009), which they both relied on, was not the most recent, available paper on the American Cancer Society cohort.

b. Estimating Damage Values for Small Changes in Ambient $PM_{2.5}$

Record Citations:
Marshall Surrebuttal (Ex. 119) at 18; Sch. 3.
Jacobs Rebuttal (Ex. 117) at Sch. 3, 967 – 68; 970
McClellan Rebuttal (Exs. 441 & 441A (errata)) at 20-21 and Appendix 2 at 2-10, 16,17
Desvousges Direct, Schedule 2 at 31
Desvousges Rebuttal at 39-40
Desvousges Surrebuttal at 42-45

Agencies: Dr. Muller's testimony on this issue was not prefiled, and is in the hearing transcript.

CEO: InMAP assumes that concentrations change linearly with marginal changes in emissions and uses linear concentration response functions to calculate increased risk of premature mortality from changes in concentration. InMAP modeled changes in ambient $PM_{2.5}$ concentrations in approximately 50,000 grid cells in the contiguous United States. Some of the changes in concentration were quite small.

MLIG: As set forth in more detail in 6(c) *infra*, Dr. McClellan testified that the primary (or health) damages conclusions reached by Drs. Muller, Marshall, and Desvousges based on national concentration-response data, rather than local data, and without considering the community-exposure level, are invalid and that the use of linear air concentration-response models implies that the calculated damage values are applicable to all emissions irrespective of whether the air quality in a particular area is in attainment relative to current National Ambient Air Quality Standards (NAAQS) for the specific pollutants, which is incorrect. Dr. McClellan testified that a damage value may be calculated mathematically for $PM_{2.5}$ (annual) concentrations increasing from 10 $\mu g/m^3$ to 11 $\mu g/m^3$, but in Dr. McClellan's medical opinion, and based on a review of medical literature, the calculated damage values are not valid for air concentrations of $PM_{2.5}$ below 12 $\mu g/m^3$ and that a statistically significant effect is not observed below approximately 13.5 $\mu g/m^3$ for all-cause mortality, nor below 13.8 $\mu g/m^3$ for cardiopulmonary and lung-cancer mortality, or 13.2 $\mu g/m^3$ for all-other-cause mortality (Ex. 441, Appendix 2 at 16), with the central tendency for each trending below 0 toward the lower exposure end of the spectrum and even the upper confidence bound for lung-cancer mortality trending below 0 at that point, suggesting that either exposure is protective of health or that the data is simply unreliable at lower exposure levels.

Xcel Energy: Dr. Desvousges pointed out that the $PM_{2.5}$ air concentration changes analyzed in this proceeding are extremely small (estimated to the hundred thousandth by all Parties) compared to those that are reported in the epidemiology literature or used by EPA to set standards for protecting human health. For example, the primary NAAQS standard for $PM_{2.5}$ is set at 12 $\mu g/m^3$, and the range of $PM_{2.5}$ concentration changes in the 13 key long-term cohort studies published since 2000 and reviewed by Dr. Desvousges ranged from 8 to 23 $\mu g/m^3$. The risk of premature mortality is typically presented as a percentage change per $PM_{2.5}$ concentration change of 10 $\mu g/m^3$. Dr. Desvousges noted that the results of health studies are treated linearly, meaning that the relationship between mortality risk and $PM_{2.5}$ concentration change are considered the same whether the concentration change is 10 $\mu g/m^3$ or 0.00001 $\mu g/m^3$. However, this linear relationship has been established based on correlations seen at the 8-23 $\mu g/m^3$ range and has not been evaluated at very low concentration levels – it is assumed that the very small values are statistically different than zero, although there is no existing research to support that conclusion. Dr. Muller's AP2 results show that the average change in ambient $PM_{2.5}$ concentrations beyond a100 mile radius of Minnesota is 0.00000298 $\mu g/m^3$ due to emissions from the Sherco facility; for Dr. Marshall's InMAP results, the corresponding $PM_{2.5}$ change in ambient concentration is 0.000000643 $\mu g/m^3$.

c. Existence of Damages at Ambient Concentrations Below the $PM_{2.5}$ Primary NAAQS

Record Citations:
Muller Surrebuttal at 32, 33-34
Marshall Direct (Ex. 115) at 21:15 – 21:17.

Jacobs Rebuttal (Ex. 117) at Sch. 2, 119; Sch. 3, 967 – 68; 970
McClellan Rebuttal (Exs. 441 & 441A (errata)) at 20-21 and Appendix 2 at 2-10, 16,17
Rosvold Rebuttal at 1-24

Agencies: Dr. Muller disagreed with Dr. McClellan's assertion that there are no significant health risks for ambient concentrations that achieve the National Ambient Air Quality Standards (NAAQS) (Muller Surrebuttal, pp. 33-34). Dr. Muller observed that the peer-reviewed epidemiological literature (of which he cited some noteworthy examples) shows that the NAAQS does not represent a threshold below which no health impacts occur. Many of these studies have analyzed health impacts at concentrations well below the current $PM_{2.5}$ and O_3 NAAQS (12 μg/m3 annual average and 70 ppb seasonal average, respectively.) Additionally, several EPA studies have shown no known safe concentration thresholds and health risks below the NAAQS.

In response to Mr. Rosvold's argument that since Minnesota is in attainment of the NAAQS it is not "significantly" contributing to air pollution in any other states, Dr. Muller explained that emissions from Minnesota do affect ambient $PM_{2.5}$ concentrations in other states regardless of whether the emission source locations are in achievement of the NAAQS (Muller Surrebuttal, p. 32).

CEO: Dr. Marshall testified that the consensus among epidemiological studies is that $PM_{2.5}$ exposure causes an increased likelihood of death and that there is no safe level for $PM_{2.5}$ concentrations; in other words, $PM_{2.5}$ causes increased rates of mortality even at the lowest observed levels. Krewski et al. and LePeule et al. similarly found that there was no evidence of a threshold exposure level within the range of observed $PM_{2.5}$ concentrations. LePeule et al.'s study states that "[t]he concentration response relationship was linear without any threshold, even at exposure levels below the U.S. annual 15-ug/m^3 standard." Dr. Marshall testified that Dr. McClellan's testimony that there is no increased risk at concentrations below the national ambient air quality standards is incorrect and not supported by the scientific literature.

MLIG: Under Minnesota law and the ALJ's prior orders, parties proposing a change to externalities values bear the burden of proof under a preponderance of the evidence standard. The MLIG asserts that the Agencies, CEOs, and Xcel Energy fail to satisfy this burden of proof. On behalf of the MLIG, Dr. McClellan testified that the primary (or health) damages conclusions reached by Drs. Muller, Marshall, and Desvousges based on national concentration-response data, rather than local data, and without considering the community-exposure level, are invalid. Dr. McClellan further testified that the assumptions and corresponding calculations underlying the ranges proposed by the Agencies, CEO, and Xcel Energy are too speculative and lack evidentiary support.

Dr. McClellan testified that he is personally very knowledgeable of the scientific information available regarding the Criteria Pollutants and the process by which scientific information on the pollutants is obtained, reviewed, integrated, and used to establish National Ambient Air Quality Standards (NAAQS). His knowledge is based on his professional education and experience in comparative medicine, toxicology, aerosol science and risk assessment. Since the mid-1970s, he has been actively involved in the EPA advisory process, reviewing the scientific evidence that informs the policy judgments leading to the EPA Administrator's promulgation of NAAQS for each of the Criteria Pollutants. His involvement has included participation on and chairing of EPA's Clean Air Scientific Advisory Committee (CASAC), and he has written extensively on the process by which the NAAQS are set and, most importantly, published reviews on how scientific information on each of the pollutants is integrated and used to inform policy judgment made in setting the NAAQS.

Dr. McClellan testified that an understanding of the potential hazard of any airborne pollutant requires an evaluation of the science extending from (a) emissions from particular sources, (b) transport and potential transformations in the atmosphere, (c) exposure of receptor populations, (d) the uptake and translocation of the inhaled material by individuals, (e) mechanisms of detoxification, damage and repairs, and (f) the occurrence of disease over and above that occurring naturally or from other causative factors. Dr. McClellan further testified that it is recognized that all of us breathe throughout life a complex mixture of gases and particulate matter. What is in the air varies considerably between our homes, schools, work places and other environs we may live and work in over a lifetime. It is important to recognize there are substantial differences in ambient (*i.e.*, outdoor) air across the United States and around the world.

Dr. McClellan testified that the NAAQS consist of four elements; (a) an indicator, (b) averaging time, (c) concentration, and (d) a statistical form. The current NAAQS for PM, SO_2, and NO_2 are shown in Table 1 of Appendix 2 to his rebuttal. As described in McClellan (2010a and b), the primary or health NAAQS are set by the EPA Administrator to be protective of public health with an adequate margin of safety without consideration of cost of achieving the standard.

The primary health NAAQS are set based on scientific information from multiple sources. This includes (a) epidemiological studies, (b) controlled exposure studies with volunteers, (c) investigations using laboratory animals, (d) studies with cells and tissues, and (e) use of mechanism-based mathematical models. The epidemiological findings are from studies conducted across the USA and around the world. According to Dr. McClellan, it is obvious the positive epidemiological evidence comes from studies that include the most heavily exposed individuals, *i.e.* those living in the most polluted areas. Importantly, according to Dr. McClellan, the air quality in the baseline cities of Portage, Wyocena, and Pardeeville, Wisconsin, in the Harvard Six Cities Study is not remarkeably different from that found in most communities across Minnesota (*see also* Ex. 443 for detailed explanation in response to CEO question for supporting data for statement made in Rebuttal Report).

Dr. McClellan testified that the use of linear air concentration-response models implies that the calculated damage values are applicable to all emissions irrespective of whether the air quality in a particular area is in attainment relative to current NAAQS for the specific pollutants, which is incorrect. Dr. McClellan further testified that the NAAQS are set and periodically updated by the EPA at levels intended to protect public health with an adequate margin of safety. In his expert opinion, ambient air levels that meet the applicable NAAQS may be defined as being acceptable with regard to protecting public health. For example, a damage value may be calculated mathematically for $PM_{2.5}$ (annual) concentrations increasing from 10 $\mu g/m^3$ to 11 $\mu g/m^3$, but the $PM_{2.5}$ annual NAAQS is currently set at 12 $\mu g/m^3$ because this level and the associated statistical form are protective of public health. In Dr. McClellan's medical opinion, and based on a review of medical literature, the calculated damage values are not valid for air concentrations of $PM_{2.5}$ below the current NAAQS. While Lepeule *et al* (2012) reported that a small signal of adverse health effects was still present with a linear concentration-response function for all-cause mortality for $PM_{2.5}$ down to 8 $\mu g/m^3$, Dr. McClellan emphasized that using a linear model, the lowest air concentrations measured dictates the lowest level of linearity, and that it is important to recognize that the increased risk is dominated by the measurements and population of the dirtiest cities. Dr. McClellan further testified that Greven *et al.* (2011) conducted a large retrospective cohort study of Medicare enrollees, linking ambient levels of $PM_{2.5}$ to mortality data by monitor site during the period 2000-2006 and that Greven in this seminal paper reported an increase in the national life expectancy for reductions in the yearly average $PM_{2.5}$, but that the observation is based on national trends in $PM_{2.5}$ and mortality and that Greven calls attention to confounding by other variables trending on the national level. Dr. McClellan noted that, most importantly relative to the present case, Greven observed major differences across the United States using sophisticated spatial modeling techniques, which included a local coefficient $ß_1$ that measures the association between local trends in $PM_{2.5}$ and mortality and a global coefficient $ß_2$ that measures the association between the $PM_{2.5}$ national trend and the national trend in mortality. Greven found estimates of the local coefficient $ß_1$ to be approximately zero and non-significant nationally and in all three regions of the United States (East, Center and West). Estimates of $ß_1$ indicate that after adjusting for the association between national trends in mortality and $PM_{2.5}$, there is no significant association between an increase in the local yearly average $PM_{2.5}$ concentrations and the risk of dying in a given month. Dr. McClellan testified that this important finding is illustrated graphically in Figure 6 of his report (Ex. 441, Appendix 2 at 17).

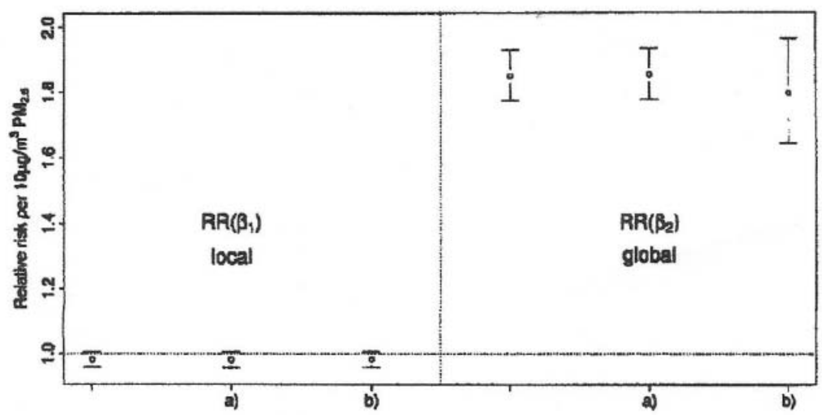

Figure 6. Sensitivity analysis using data on 173 locations with additional variables from the BRFSS-SMART survey. The left-most estimate shows estimate $ß_1$ and $ß^2$ from model (3) for this subset of the data. a) indicates the analysis including additional variables on the level of the monitor's county; the proportion of current smokers and of nonwhites, and the mean income and body mass index. b) gives the results for the same analysis allowing separate coefficients for the four variables' global and local trends [Greven, Dominici and Zeger, 2011]

In other words, according to Dr. McClellan, there is no statistical or medical evidence of an association between exposure to $PM_{2.5}$ and adverse health effects in the Greven study at the local level. For areas downwind that are in attainment, Dr. McClellan's accordingly opined, with a reasonable degree of medical certainty, that the current and projected levels of ambient $PM_{2.5}$ under consideration in this case will not cause additional mortality over and above that occurring naturally and from other causes, while for downwind areas that may not be in attainment of the $PM_{2.5}$ NAAQS, any calculated increase in mortality attributable will be extraordinarily small related to the baseline mortality.

Dr. McClellan further testified that data from the American Cancer Society study as reflected in Figure 5 in Appendix 2 to his rebuttal testimony shows that a statistically significant effect is not observed below approximately 13.5 $\mu g/m^3$ for all-cause mortality, nor below 13.8 $\mu g/m^3$ for cardiopulmonary and lung-cancer mortality, or 13.2 μg/m^3 for all-other-cause mortality (Ex. 441, Appendix 2 at 16), with the central tendency for each trending below 0 toward the lower exposure end of the spectrum and even the upper confidence bound for lung-cancer mortality trending below 0 at that point, suggesting that either exposure is protective of health or that the data is simply unreliable at lower exposure levels:

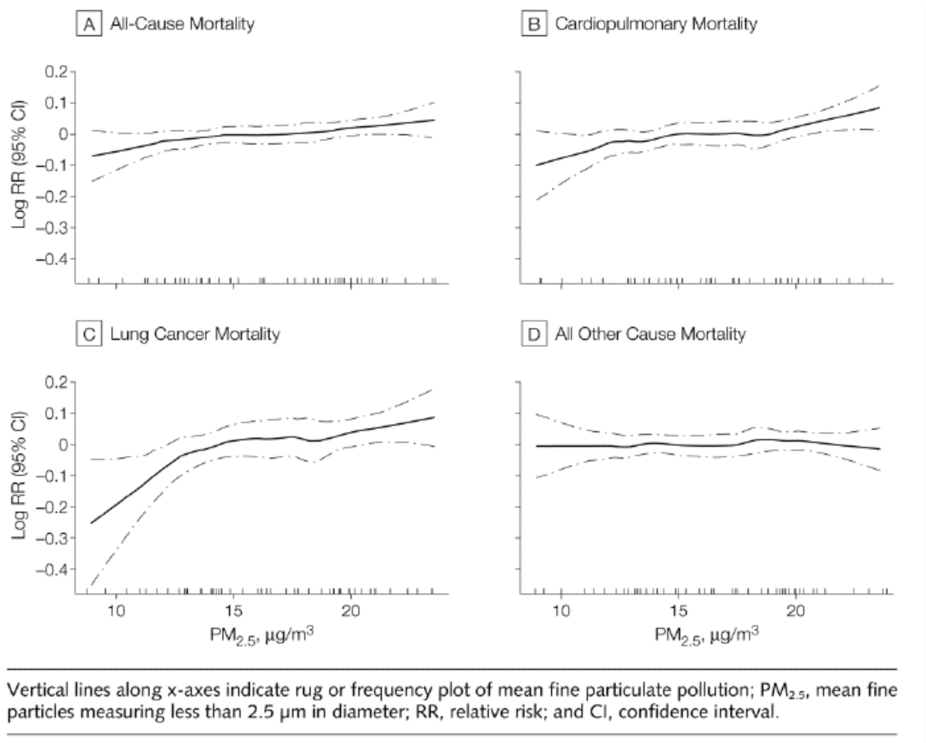

Figure 5. Non-parametric smoothed exposure-response relationship. Vertical lines along the x-axes indicate a rug or frequency plot of mean fine particulate pollution. CI, confidence interval; $PM_{2.5}$, fine particles measuring less than 2.5 μm in diameter; RR, relative risk.

Dr. McClellan testified that according to these studies, relied upon by Drs. Muller, Marshall, and Desvousges, there is no medical evidence of any excess deaths associated with these low ambient concentrations of $PM_{2.5}$, such that in areas in Minnesota and Wisconsin that are in attainment relative to the $PM_{2.5}$ NAAQS, *i.e.*, the annual mean averaged over 3 years is at 12 μg/m^3 or below, there is no medical or other scientific basis for projecting mortality related to current or projected levels of $PM_{2.5}$ and that for downwind areas that may not be in attainment of the $PM_{2.5}$ NAAQS, any calculated increase in mortality attributable will be extraordinarily small related to the baseline mortality, as shown in the findings of Lepeule et al (2012), and that the primary (or health) damages conclusions reached by Drs. Muller, Marshall, and Desvousges based on national data, rather than local data, and without considering the community-exposure level, are accordingly invalid.

Xcel Energy: Mr. Rosvold testified that NAAQS are set at levels that are protective of human health and the environment, and EPA has determined through CSAPR modeling and reduction requirements that Minnesota is not significantly contributing to ambient air concentrations of $PM_{2.5}$, SO_2 or NO_x in any other state.

d. Ability of Models to Estimate Impacts at $PM_{2.5}$ Concentrations Below the Primary NAAQS

Record Citations:
Muller Surrebuttal at 33-34
Marshall Surrebuttal (Ex. 119) at 18; Sch. 3.
Jacobs Rebuttal (Ex. 117) at Sch. 3, 967 – 68; 970.
McClellan Rebuttal (Exs. 441 & 441A (errata)) at 20-21 and Appendix 2 at 2-10, 16,17
Desvousges Surrebuttal pg 42-44.

Agencies: Dr. Muller pointed out that the epidemiological literature that has addressed the relationship between $PM_{2.5}$ pollution and its impacts has generally concluded that the relationship between $PM_{2.5}$ concentration and the mortality or health response (i.e., the concentration-response function) is linear with no known safe threshold.

CEO: InMAP assumes that concentrations change linearly with marginal changes in emissions and uses linear concentration response functions to calculate increased risk of premature mortality from changes in concentration. InMAP modeled changes in ambient $PM_{2.5}$ concentrations in approximately 50,000 grid cells in the contiguous United States. Some of the changes in concentration were quite small.

MLIG: *See* MLIG summary for issues 6(b) and 6(c), "Risk of Premature Mortality for Ambient $PM_{2.5}$ — Estimating Damage Values for Small Changes in Ambient $PM_{2.5}$" and "Risk of Premature Mortality for Ambient $PM_{2.5}$ — Existence of Damages at Ambient Concentration Below the $PM_{2.5}$ Primary NAAQS," both incorporated as if fully set forth herein.

Xcel Energy: NAAQS values are set as whole numbers with the primary standard set at 12 $\mu g/m^3$ and the secondary standard set at 15 $\mu g/m^3$; there is no extrapolation in decimal point. Modeling analyses and resultant changes in this proceeding have been estimated out to at least five decimal points by all parties. Dr. Desvousges testified that none of the models used in this proceeding, including CAMx, incorporate any type of measure of the uncertainty around the predicted changes in emission concentrations. The very small externality concentrations modeled in this proceeding, with significant digits represented to the hundred thousandth decimal point and beyond have a great deal of uncertainty surrounding the results. These very small values of changes in ambient concentrations are being used in damage calculations, and assumed those values are statistically different than zero, when there is no information to support that conclusion.

Issue 7: Value of a Statistical Life (VSL)

Record Citations:
Muller Direct at 40-42, Attachment 2 pp. 23-25
Muller Rebuttal at 7-8, 16, 17-18
Muller Surrebuttal at 15-17, 18-19, 31
Marshall Direct (Ex. 115) at 24:14 – 26:2.
Marshall Rebuttal (Ex. 116) at 2:7 – 2:18; 17:1 – 17:13.

Marshall Surrebuttal (Ex. 119) at 4:21 – 5:8; 6:11 – 6:18.
Polasky Rebuttal (Ex. 118).
Desvousges Direct at 24; Schedule 2 at 46-59
Desvousges Rebuttal at 46-50, 75
Desvousges Surrebuttal at 3, 46-59
Muller Rebuttal at 17-19, 46

Agencies: The VSL is a measure of the monetary value of increased mortality risk and is generally used as a damage value estimate for increased mortality risk from air pollution (and other causes as well). While there are two main techniques for estimating VSLs, stated-preference or revealed-preference techniques, there are many different generally-accepted VSLs in the economic literature. Dr. Muller chose two widely used values (each a meta-analysis derived from several individual studies) to frame lower and upper bounds of his damage value estimates (Muller Direct pp. 41-42 and Attachment 2; Muller Surrebuttal pp. 16-17). For the upper bound, Dr. Muller used the VSL applied by the EPA (approximately $9.5 million in 2011 dollars), which is mostly derived from revealed-preference studies. Dr. Muller's chosen upper bound estimate is very close to the value estimates in a very recent meta-analysis (Viscusi, 2015). For the lower bound, Dr. Muller used the VSL from a widely-cited meta-analysis (Kochi et al, 2006) that was comprised of stated-preference studies, and, in 2011 dollars, is approximately $3.7 million.

Dr. Muller disagreed with Dr. Marshall's choice to only use the higher VSL used by the EPA, maintaining that using VSLs determined from both revealed-preference techniques (the EPA VSL) and stated-preference techniques (Kochi et al, 2006) correctly captures the uncertainty around this estimate and is more likely to frame the true value (Muller Rebuttal pp. 7-8, 16; Muller Surrebuttal p. 31). Furthermore, Dr. Muller generally agreed with Dr. Desvousges' choice of $5.9 million (in 2014 dollars) (Muller Rebuttal pp. 17-18), but similar to his objection to Dr. Marshall's VSL choice, he disagreed with the use of one single VSL estimate. Dr. Muller testified that his choice of two widely-accepted VSLs better captures the uncertainty around this issue than Dr. Desvousges use of Monte Carlo analysis to produce a single value (Muller Surrebuttal pp. 18-19).

CEO: Dr. Marshall and Dr. Tessum selected the central tendency VSL that the EPA Science Advisory Board recommends, which is the average of the results of twenty-six labor market and contingent valuation studies published between 1974 and 1991. After adjusting for changes in currency value and income growth, the VSL used by Dr. Marshall was $9.8 million (year 2015 dollars).

Dr. Polasky testified that this value is reasonable. If the Commission seeks to apply a range to this input, it could adopt a low value for the range reflective of a stated preference value and a high range reflective of a hedonic wage value.

Dr. Polasky testified that Dr. Muller's VSL range relies upon inconsistent end points. There are two ways researchers estimate VSL: hedonic wage estimates and stated preference estimates. Hedonic wage, or real preference, assesses how certain jobs' risks to life affect their wages. Stated preference estimates assess how individuals claim they value risks to life. In general, stated preferences tend to be lower than hedonic wage estimates. The VSL that Dr. Marshall used reflects a summary of a meta-analysis of *both* kinds of studies. Dr. Muller used this number as a high end of a range, and used a stated preference summary value from another study as a low end of a range. This approach inappropriately compares apples to oranges.

Dr. Polasky testified that Dr. Desvousges's VSL is inappropriate for three reasons. He assigned weights arbitrarily, he manipulated the Kochi et al. study, he included an individual study rather than a meta-analysis, and he did not adjust for income growth. Dr. Desvousges manipulated the Kochi et al. values by selecting a sensitivity analysis that included negative values of VSL (which would imply that study participants preferred more dangerous options). Study authors acknowledged these as implausible and cut them out of final results, but Dr. Desvousges included the sensitivity value that did not cut them out, and adjusted other sensitivity values to reflect such implausible results. Dr. Desvousges also compared an individual VSL study, Knieser, and assigned it equal weight to two meta-analyses (incorporating many individual studies), which in Dr. Polasky's estimation was arbitrary, and fails to reduce the effect of errors in any given individual study. Dr. Desvousges assigned weights in effect selected a preferred outcome for VSL.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Dr. Desvousges explained that his Monte Carlo simulation to develop a VSL is superior to using a single point estimate based on one meta-analysis, as was done by Dr. Marshall, or selecting a high value and a low value from two separate meta-analyses, as was done by Dr. Muller. Dr. Desvousges noted that his Monte Carlo approach incorporated data from three different meta-analyses (Kochi et. al. 2006; Mrozek and Taylor 2002; Viscusi and Aldy 2003) and data from a recent individual study by Kniesner et. al. (2012); used both the mean and standard error values from the four studies; assigned appropriate weights to each study (55 percent, 15 percent, 15 percent, and 15 percent respectively); and derived an overall distribution of VSL values. The overall distribution has an average VSL value of $5.9 million, a low VSL value of $4.1 million (the 25th percentile value), and a high value of $7.9 million (the 75th percentile value). Dr. Muller in his Rebuttal Testimony agreed on Dr. Desvousges' VSL and concentration-response functions, and stated that these two areas of solid agreement are very important.

Dr. Desvousges pointed out that both Dr. Muller (for his high VSL value) and Dr. Marshall (for his only VSL value) relied on an outdated EPA meta-analysis from 1999, which included 26 individual studies published during 1974-1991. Besides being dated, this EPA meta-analysis has one of the highest VSL values of any of the studies Dr. Desvousges has reviewed. There are many newer VSL studies that have larger sample sizes, rely on better statistical techniques, and use improved study methods, such as panel data. He noted that the intent of this proceeding is to update the existing externality values based on current scientific data. Dr. Desvousges also recommended using a constant VSL without income adjustment over time, because it is not certain whether the VSL would increase, decrease, or stay the same due to changes in economy and income.

Issue 8: Practicability Regarding Damage Values to be Adopted

Record Citations:
Muller Surrebuttal at 25-27, 32
Marshall Direct (Ex. 115) at 6:1 – 6:13; 8:18 – 8:20; 18:15 – 18:18; 26:3 – 28:9; Sch. 3.
Marshall Rebuttal (Ex. 116) at 15:19 – 17:13.
Marshall Surrebuttal (Ex. 119) at 20:3 – 22:2.
Rosvold Rebuttal at 1-24

Agencies: Dr. Muller explained that his (and also Dr. Marshall's) choice to develop separate value range estimates for each county in Minnesota (as well as counties within 200 miles of Minnesota) does not render them impractical. To the contrary, as described above (discussion under Issue 3), having separate values for each actual and potential location for a power plant gives the Commission ready flexibility and versatility in how to use them (Muller Rebuttal pp. 25-27, 32). He identified a number of potential ways in which the county- and source-specific values could be used and aggregated by the Commission, including coming up with single averages (for each pollutant) across all sources, average values for each quantile according to the distribution of damage values, and average values for each land-use designation used by Dr. Desvousges: urban, metro-fringe and rural.

CEO: Dr. Marshall testified that reduced form models generally, and InMAP in particular, are designed to be more practical to use than comprehensive models such as CAMx (*see also* Issue 1 above).

Dr. Marshall calculated high and low county-specific values at three effective stack heights presented as a spread sheet attached as Schedule 3 to his Direct Testimony. To use these values, one could identify the county in which a proposed emission source is located, determine the appropriate stack height, and apply that range of values. Dr. Marshall also calculated "generic" value ranges for use when a utility or the Commission must consider planning for a resource for which specifications such as stack height and location may be undetermined. Generic values were based on a weighted average of damages from existing Minnesota power plants.

Dr. Marshall testified that using county values for resources with a known location would be less burdensome than Dr. Desvousges's proposed process of first determining whether a location should be classified as "urban," "metro-fringe," or "rural" before determining which externality values to use. Dr. Marshall testified that Dr. Desvousges provided no guidance as to which of his three ranges should apply when the location of a proposed emission source is unknown.

Dr. Marshall used inputs for the concentration response functions and VSL from the academic research rather than from a distribution of his own creation as Dr. Desvousges did. This allows these inputs to be updated as EPA or others update guidance.

MLIG: The MLIG has not offered affirmative testimony as to this issue.

Xcel Energy: Mr. Rosvold testified that it is not necessary or practicable to develop nearly 500 different county-specific values for resource planning purposes, as Dr. Muller and Dr. Marshall have done (87 values for each Minnesota county and nearly 400 values for each county within 200 miles from the Minnesota border). He explained that the long-term resource planning process determines the size, type, and timing of resource additions or reductions – what amount and type of resources will be added or retired during the planning period. The location of any new resource is open and unspecified, and therefore resource planning uses a generic resource without a specific location and thus their proposed values would not be used.

Issue 9: Estimation of Future Damage Values

Record Citations:
Muller Direct at 45-48, 66-70, Attachment 2 pp. 30-32, 48-51
Marshall Rebuttal (Ex. 116) at 6:3 - 6:13.
Desvousges Rebuttal at 61-62

Agencies: Dr. Muller estimated marginal damages for each source and each pollutant at five year increments beginning in 2015 and ending in 2040 based on projected changes to population, income, and vital statistics (mortality rates and health incidence data). Due to lack of high quality and defensible projections about how emissions will change over this time frame, he used current (2011) emissions to formulate these estimates. The purpose of these future estimations, in large part, was to assess how sensitive the damage estimates were to these changes and thus to obtain a sense of whether (and how frequently) updates might be necessary (Muller Direct pp. 45-48 and Attachment 2 pp. 30-32). The full results of these projections are provided in Dr. Muller's Direct testimony. Generally, he found that all three pollutants showed a gradual but steady increase in damage values between 2015 to 2040, primarily due to expected increases in population and income. For each of the three pollutants, Dr. Muller projected an increase in damage values in 2040 of approximately 30% relative to 2015 estimates (Muller Direct pp. 66-69 and Attachment 2 pp 48-51). Dr. Muller stated that the AP2 model will be available for future use by the state of Minnesota, along with detailed instructions on how to use the model (Muller Direct p. 48).

CEO: Dr. Marshall testified that if the Commission wishes to incorporate future damages, InMAP may be run to assess them, which would also require decisions concerning future population growth, baseline mortality rate, income levels, and inflation. Were the Commission to adopt damage values that incorporate future damages, it would need to update them more frequently to accommodate future epidemiological discoveries and advances in modeling.

MLIG: The MLIG has not offered affirmative testimony as to this issue. Nonethless, the MLIG reserves its right to submit legal and evidentiary arguments, in brief, in response to other parties' positions on this issue.

Xcel Energy: Dr. Muller proposed updating future externality values through additional modeling. Dr. Desvousges disagrees and recommends that the Commission update externality values based on the Consumer Price Index, as has been the historical practice in this state. Dr. Desvousges questions the accuracy surrounding AP2 model assumptions and results, and in his opinion, externality values should not be set as proposed by Dr. Muller, nor should these be the basis from which to extrapolate future externality values.

Issue 10: Accuracy of Damage Value Estimates

a. Agencies: AP2 Results

Record Citations:
Muller Direct at 4-12, 15-17, 39-42
Muller Rebuttal at 33-38
Marshall Direct (Ex. 115) at 8:14 – 8:20; 9:18 – 9:20; 12:1 – 16:10.
Marshall Rebuttal (Ex. 116) at 2:14 – 2:18; 3:15 – 3:17.

Marshall Surrebuttal (Ex. 119) at 8:4 – 9:2.
Desvousges Rebuttal at 6-7, 42-46, 55-61
Desvousges Surrebuttal at 3, 16-32, 36, 63

Agencies: Dr. Muller explained how AP2 modeling results are credible and accurate and explained that, while reduced-form models fall short of photochemical air-quality models in certain contexts, for this particular application they do at least as well. Moreover, their relative computational simplicity allows the modeler to quickly and easily develop estimates for many sources and many different pollutants, thus producing values with the greatest flexibility and versatility (Issue 1 and 3 above). (Muller Direct pp. 4-12, 15-16). More important than the choice of the model in this proceeding, however, is the modeler's assumptions and choice of input parameters around the geographic scope of damages (Issue 4 and Muller Direct pp. 15-16), the location specificity of sources modeled (Issue 3 and Muller Direct pp. 15-16 and Muller Rebuttal pp. 33-38), the concentration-response parameter for premature mortality associated with $PM_{2.5}$ (Issue 6 and Muller Direct pp. 16-17, 39-40) and the value of a statistical life (VSL) to monetize estimated premature mortality impacts (Issue 7 and Muller Direct pp. 41-42). Dr. Muller defended his choices for each of these parameters (all of which are discussed elsewhere in this Issues List) as producing the most accurate, defensible and credible damage cost values for emissions of $PM_{2.5}$, SO_2 and NO_x from power plants serving Minnesota.

CEO: Dr. Marshall testified that AP2 may produce less accurate predictions because it has a less fine spatial resolution and has a less realistic representation of $PM_{2.5}$ formation from SO_2 and NO_x. Dr. Marshall also testified that Dr. Muller's damage value estimates are likely less accurate because he inappropriately uses the EPA's recommended VSL as a high-end value rather than as the central tendency value that it represents and because one end of his concentration-response function did not correct for ecologic covariates. Dr. Marshall testified that while he did not feel that there is robust evidence regarding whether AP2 or InMAP is more accurate for the question in front of the Commission, he recommended InMAP over AP2 because of InMAP's ability to represent how rates of $PM_{2.5}$ formation from SO_2 and NO_x differ in different locations, as well as the fact that air pollution typically does not travel in straight lines.

MLIG: Subject to Dr. McClellan's testimony as set forth above regarding the invalidity of the primary (health) damages calculations, the MLIG has not offered affirmative testimony as to this issue. The MLIG has specifically not offered testimony regarding secondary (public welfare) damages from exposure to the Criteria Pollutants at issue.

Xcel Energy: Dr. Desvousges compared Dr. Muller's AP2 results from Sherburne, Dakota, and Lyon County sources to his CAMx results from Sherco, Black Dog and Marshall hypothetical facilities. He concluded that Dr. Muller's modeling results from NO_x emissions are clearly incorrect and violate everything known about atmospheric dispersion and chemistry. For example, from a source in Lyon County, AP2 modeling showed changes in secondary $PM_{2.5}$ concentrations (based on NO_x emissions) in only 25 of the 87 Minnesota counties, whereas the CAMx and InMAP modeling results showed increases in every Minnesota county as would be expected. Similarly, the AP2 Sherburne County and Dakota County modeling results showed no impact on secondary $PM_{2.5}$ concentrations from NO_x in the majority of Minnesota counties. While limited impacts were seen in Minnesota, AP2 modeling did show increases in secondary $PM_{2.5}$ concentrations from NO_x emissions in California, Arizona, Maryland, New Jersey, Florida, Utah, and Nevada among others. The random, sporadic AP results associated with NO_x emissions were shown in several figures presented in Dr. Desvousges' Rebuttal and Surrebuttal Testimony. In addition, Dr. Desvousges stated that Dr. Muller's direct $PM_{2.5}$ and SO_2 predictions from the Lyon, Marshall, and Sherburne County sources showed increased ambient concentrations in every county in the contiguous United States. Dr. Desvousges noted that these AP2 results also seem incorrect and are unlike the CAMx or InMAP results. Dr. Desvousges concluded that AP2 under-predicts NO_x impacts in Minnesota and substantially over-predicts $PM_{2.5}$ and SO_2 impacts.

b. CEO: InMAP Results

Record Citations:
Muller Rebuttal at 7-8, 8-10, 11-12, 14-16
Marshall Direct (Ex. 115) at 8:14 – 8:20; 9:18 – 9:20; 12:1 – 16:10.
Marshall Surrebuttal (Ex. 119) at 23:12 – 25:11; Sch. 1.
Desvousges Rebuttal at 9-10, 66-73
Desvousges Surrebuttal at 16-33, 63

Agencies: Dr. Muller did not question the accuracy of InMAP, although he did point out that in the model diagnostic tests that he used to assess the performance of both AP2 and InMAP AP2 generally outperformed InMAP at various spatial scales (Issue 2 and Muller Rebuttal pp. 14-16). Dr. Muller also predominantly agreed with Dr. Marshall's model input choices, although there were some disagreements that led Dr. Muller to question the accuracy of Dr. Marshall's results. He disagreed with Dr. Marshall's choice to use InMAP only to model premature mortality impacts of $PM_{2.5}$ pollution and thus to ignore all other impacts of $PM_{2.5}$ as well as all impacts of O_3 (Issue 5 above and Muller Rebuttal pp. 11-12). Dr. Muller did point out that since premature mortality associated with $PM_{2.5}$ pollution accounts for the vast majority of monetary damages, that this was only a minor concern. He also disagreed with Dr. Marshall's choice to use only one value of a statistical life (VSL) rather than a range. Further, in using only the VSL used by the EPA, which is based mostly on revealed-preference techniques, Dr. Marshall's InMAP results likely over-estimated damage cost values (Issue 7 and Muller Rebuttal pp. 7-8). Revealed-preference studies tend to produce higher VSLs than stated-preference studies and thus Dr. Marshall's choice to not also use results from stated-preference studies likely produced an upwardly-biased choice of VSL that does not take into account the uncertainty in this parameter.

CEO: Dr. Marshall testified that InMAP is designed to represent the atmosphere more accurately than other reduced-form models in some cases. For example, InMAP uses the output from a comprehensive air pollution model called WRF-Chem to extract spatially explicit information about the baseline state of the atmosphere to help make more accurate predictions.

Dr. Marshall testified that there are three main properties of $PM_{2.5}$ that are important to consider when choosing an air pollution model: (1) monetized health effects of $PM_{2.5}$ are most strongly connected to chronic exposures so it is most important to accurately model annual average $PM_{2.5}$ concentrations attributable to emissions; (2) effects of chronic $PM_{2.5}$ exposure vary geographically, even from neighborhood to neighborhood, but can also occur at locations distant from the source so it is important for models of $PM_{2.5}$ transport to cover as large a geographic extent as possible while maintaining the ability to resolve differences in concentrations between neighborhoods; and (3) $PM_{2.5}$ can be emitted directly (primary $PM_{2.5}$) or can form from other emissions (secondary $PM_{2.5}$). InMAP is designed to meet these criteria.

InMAP's ability to model the transformation of gas-phase pollutants to particulate matter and particulate matter back to gas-phase chemicals using reaction properties that vary from location to location results in a more realistic representation of $PM_{2.5}$ formation from SO_2 and NO_x than is available in other reduced form models that generally assume chemical reactions only occur in one direction at a rate that does not vary. InMAP also accounts for pollution removal processes using spatially explicit coefficients for dry and wet deposition. Other reduced form models use a constant deposition rate, which is less representative than reality.

InMAP makes good predictions of damage values without explicitly representing hour-by-hour variations because it relies on annual average concentrations to estimate damage values (as do all three of the air-pollution models used in this proceeding). This simplification allows examination of how damages vary with plant location—a source of greater variability than the choice of air quality model. Dr. Marshall compared the plant-specific values that he used to calculate generic values with the values he calculated for the county in which a particular plant was located. These results showed good correlation. For example, the low-end values calculated by Dr. Marshall for the Sherburne County Generator (Sherco) were \$57,000/ton for $PM_{2.5}$, \$14,000/ton for SO_2, and \$9,000/ton for NO_x. The corresponding low-end county values for any unit in Sherburne County were \$29,000/ton for $PM_{2.5}$, \$15,000/ton for SO_2, and \$5,000/ton for NO_x.

MLIG: Subject to Dr. McClellan's testimony as set forth above regarding the invalidity of the primary (health) damages calculations, the MLIG has not offered affirmative testimony as to this issue. The MLIG has specifically not offered testimony regarding secondary (public welfare) damages from exposure to the Criteria Pollutants at issue.

Xcel Energy: Dr. Desvousges testified that InMAP consistently over-estimates potential externality values from Dakota, Sherburne, and Lyon County sources compared to AP2 and CAMx. Dr. Desvousges standardized the AP2, InMAP, and CAMx results for the differences in geographic scope and valuation assumptions and summarized the comparable values in Table 1 of his Surrebuttal Testimony. For example, Dr. Marshall modeled the actual Black Dog plant, and his low, mean, and high values for direct $PM_{2.5}$ are more than five times higher than CAMx values (based on a hypothetical Black Dog plant) and more than seven times higher than AP2 values (based on the actual Black Dog plant). Dr. Desvousges also noted that InMAP modeling resulted in SO_2 externality values that are much higher for the rural scenario (Lyon County) than for the metropolitan-fringe scenario (actual Sherco plant) or the urban scenario (actual Black Dog plant). In addition, Dr. Desvousges noted that InMAP results are biased to the east, shown in the various figures presented in his testimony, because InMAP modeling relied on annual average WRF meteorological data with wind blowing continuously from the west to the east.

c. Xcel Energy: CAMx Results

Record Citations:
Muller Rebuttal at 17-18, 26-32, 33, 34-38
Muller Surrebuttal at 12-15, 15-19, 25-26
Marshall Rebuttal (Ex. 116) at 7:1 – 18:5.
Marshall Surrebuttal (Ex. 119) at 10:1 – 10:6; 11:19 – 12:5; 15:1 – 15:19; 19:17 – 20:2; 21:19 – 22:2; 23:12 – 24:14.
Desvousges Rebuttal at 7, 55-58
Desvousges Surrebuttal at 23, 28, 37

<u>*Agencies*</u>: Dr. Muller did not question the accuracy of the CAMx model in general; to the contrary, he repeatedly compared his own model's predictions to those of CAMx, using CAMx as a standard with which to evaluate the performance of AP2 (discussion under Issue 2). However, Dr. Muller questioned the modeling choices made by Dr. Desvousges in his use of CAMx, and observed that these choices resulted in inaccurate damage cost values. These modeling choices can be classified into four areas: geographic scope of damages, location specificity of emission sources, concentration-response parameters, and value of a statistical life. First and foremost, the choice of geographical scope of damages (Issue 4 above and Muller Rebuttal pp. 26-32 and Muller Surrebuttal pp. 12-15) plays the largest role in the determination of damage values. Dr. Muller repeatedly contended that Dr. Desvousges' choice to limit the scope of damages to a "grid box" encompassing Minnesota and small distances beyond the state's borders meant that a substantial proportion of damages that occur outside of this "grid box" were not included. Multiple lines of evidence, including Dr. Desvousges' own testimony, indicate that emissions of these pollutants in Minnesota travel considerable distances and have impacts beyond the "grid box." Second, the location specificity in the model of emission sources factored into the accuracy of the damage value estimates (Issue 3 and Muller Rebuttal pp. 34-38 and Muller Surrebuttal pp. 25-26). Dr. Desvousges' decision to model only three hypothetical plants to represent all "urban," "metro-fringe" and "rural" areas of the state ignored the considerable heterogeneity in damages from different sources within any one of these three land-use designations. Furthermore, Dr. Desvousges' initial choice to combine two of those three sources into one model run made it impossible to separate the effects of each plant's emissions and further compromised the accuracy of the estimates (Muller Rebuttal p. 33). Third, the choice of the concentration-response parameter to characterize the premature mortality risk associated with $PM_{2.5}$ pollution influenced the accuracy of the damage value results (Issue 6 and Muller Rebuttal p. 18 and Muller Surrebuttal pp. 18-19). Dr. Muller largely agreed with Dr. Desvousges' choice to base this concentration-response parameter mostly on the two landmark long-term studies on the relationship between $PM_{2.5}$ concentration and premature mortality risk. Dr. Muller also did not object to Dr. Desvousges' decision to use a third meta-analysis to develop his concentration-response parameter. However, Dr. Muller did raise minor objections to Dr. Desvousges' choice to use a Monte Carlo analysis that truncated the distribution of values at the 25th and 75th percentiles and to arbitrarily assign weights to the different concentration-response functions. These choices led to inaccuracy in this important model parameter. Finally, the choice of value of a statistical life (VSL) had significant bearing on the damage estimates (Issue 7 above and Muller Rebuttal pp. 17-18 and Muller Surrebuttal pp. 15-19). Again, this was largely an area of agreement between Dr. Muller and Dr. Desvousges; Dr. Muller raised no objection to Dr. Desvousges' choice of VSL, indicating that it fell within his own VSL estimate range. However, Dr. Muller did raise a methodological concern regarding Dr. Desvousges' decision to use one central VSL and stated that his own use of a reasonable low and high value to frame the range of damage values better characterized the uncertainty in this important model parameter.

<u>*CEO*</u>: Dr. Marshall testified that Dr. Desvousges's damage values fail to account for geographic variability and are distorted by specific assumptions made by the modelers. Dr. Marshall testified that the reliability of Dr. Desvousges's results should not be judged solely on the reliability of the CAMx model, but also on the reliability of the modeling approach and decisions about inputs. Dr. Marshall testified that CAMx can produce reliable results, but was the wrong tool for this job because its use leads to an unnecessary loss of information (variability of results based on emission source). While CAMx presents a realistic representation of pollution transport, model realism is not the only factor to consider when selecting a model. Because annual average concentrations of $PM_{2.5}$

are the main drivers of air-pollution-related damage from power plants, seasonal and daily variations represented by CAMx are only important to the extent that they impact annual average concentrations. Dr. Marshall recommended InMAP over CAMx because InMAP's less-complex representation chemistry and meteorology allows InMAP to be used to account for the impact of plant location.

Dr. Marshall testified that Dr. Desvousges's CAMx results greatly underestimate the damage caused by annual average $PM_{2.5}$ exposure by excluding damages beyond an approximately 100-mile (or less) boundary around Minnesota and by making inappropriate assumptions about the VSL and concentration response function values that should be used to estimate damages (*see also* Issues 4, 6, & 7 above).

Dr. Marshall testified that Dr. Desvousges's CAMx results would more than double if a realistic geographic scope of damages had been used. Dr. Marshall based this conclusion on CAMx results for changes in air pollution concentrations at a national scale that Dr. Desvousges did not use to calculate resultant damages. Dr. Marshall considered Dr. Desvousges's argument that these national results are less accurate because they were calculated using a lower-resolution grid (36 km as opposed to 12 km). But Dr. Marshall concluded that damages based on low-resolution results are more accurate than damages based on an assumption that there are no damages outside of Minnesota.

MLIG: Subject to Dr. McClellan's testimony as set forth above regarding the invalidity of the primary (health) damages calculations, the MLIG has not offered affirmative testimony as to this issue. The MLIG has specifically not offered testimony regarding secondary (public welfare) damages from exposure to the Criteria Pollutants at issue.

Xcel Energy: Dr. Desvousges testified that his 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 reducing 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 county. In addition, Dr. Desvousges noted that his externality values are consistently the lowest for the rural scenario, then higher for the metropolitan fringe scenario, and the 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.

Issue 11: Criteria for Reviewing the Models and Proposals

Record Citations:
Muller Direct 8- 10, 11-14, 22, 31, 37, 39, 40-48, 50, 70-71.
ALJ Order Regarding Burdens of Proof, March 27, 2015.
Marshall Surrebuttal (Ex. 119) at 2:9 – 3:19.
Desvousges Direct at 4
Desvousges Rebuttal at 15-16
Desvousges Surrebuttal at 64-65

Agencies: Dr. Muller did not in pre-filed testimony set out a specific list that the ALJ or Commission might use for evaluating the models and proposals. As he later summarized in his opening statement Dr. Muller identified at numerous places in his testimony reliability, transparency, and public availability, as well as a use of a reduced-form model as required by the Commission as criteria by which one can evaluate various models and proposals. Dr. Muller noted the advantage of a model with a relatively simple structure, which means a variety of different modeling assumptions can be made, and one can see how damages change when those modeling assumptions are changed. To balance simplicity and accuracy in the prediction of ambient pollution concentration, he recommended use of an integrated assessment model (IAM) that includes an air quality model that connects emissions to concentration estimates. He identified the benefit of accuracy and practicability when the model accounts for diverse emissions sources.

Dr. Muller agreed with Dr. Marshall that the most important factors (other than model choice) in selecting a proposal are the choice of VSL, concentration-response function, geographic scope, and how spatial variability is treated. He indicated that while the values he recommends are provided for specific sources and source locations, they have the advantage that they may be applied by the Commission in a variety of possible ways.

CEO: The ALJ determined that "[a] party or parties proposing that the Commission adopt a new environmental cost value for one or more of the criteria pollutants . . . bears the burden of showing, by a preponderance of the evidence, that the cost value being proposed is reasonable, practicable, and the best available measure of the criteria pollutant's cost."

Dr. Marshall has emphasized that four key decisions impact damage values more than other decisions. The Value of a Statistical Life, the concentration-response function, deciding how to account for spatial variability, and the geographic scope of damages have the greatest impact on overall damages. These key decisions should guide the Commission's overall assessment of and choice between the models and values proposed in these proceedings.

MLIG: Subject to Dr. McClellan's testimony as set forth above regarding the invalidity of the primary (health) damages calculations, the MLIG has not offered affirmative testimony as to this issue. The MLIG has specifically not offered testimony regarding secondary (public welfare) damages from exposure to the Criteria Pollutants at issue. The MLIG has, however, asked in its opening statement that the Commission and the Administrative Law Judge proceed in this proceeding in a statistically sound, evidence-based approach, and that the outcome of this proceeding should be based on empirical evidence, sound analysis, that it should avoid undue speculation, and that it should be respectful of Minnesota and Minnesota commerce and industry.

Xcel Energy: Dr. Desvousges recommended that the proposals for updated externality values for $PM_{2.5}$, SO_2, and NO_x should be based on a balanced consideration of the following criteria: use a damage cost approach; develop the most accurate and credible estimates; address the inherent uncertainty in estimating human health and other damages in a systematic and reasonable way; use sound science and economics; minimize subjective judgments; yield a practicable range; and be transparent, replicable, and updatable. Dr. Desvousges believes his proposal meets these criteria better than Dr. Muller's or Dr. Marshall's proposals.

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

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Docket No. E999/CI-14-643

Dated this 1st day of March 2016

/s/

____

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