BEFORE THE MINNESOTA PUBLIC UTILITIES COMMISSION

Nancy Lange	Chair
Dan Lipschultz	Commissioner
Matthew Schuerger	Commissioner
Katie J. Sieben	Commissioner
John A. Tuma	Commissioner

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

ISSUE DATE: January 3, 2018

DOCKET NO. E-999/CI-14-643

ORDER UPDATING ENVIRONMENTAL COST VALUES

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ORDER UPDATING ENVIRONMENTAL COST VALUES

PROCEDURAL HISTORY

I. Introduction

In 1993, the Minnesota Legislature passed a law requiring the Commission to "quantify and establish a range of environmental costs associated with each method of electricity generation" and requiring utilities to use these costs "when evaluating and selecting resource options in all proceedings before the commission, including resource plan and certificate of need proceedings."[1]

A. Previous Commission Action

In 1994, the Commission established interim cost values,[2] and in 1997, after a contested-case proceeding, it established final values.[3] The Commission adopted values for the environmental costs of several major byproducts of electricity generation: carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide, lead, and particulate matter.

The Commission's decision was affirmed by the Minnesota Court of Appeals.[4]

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[1] 1993 Minn. Laws, ch. 356, § 3 (codified at Minn. Stat. § 216B.2422, subd. 3) [hereinafter "Minn. Stat. § 216B.2422" or "Environmental Cost Statute"].

[2] *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3*, Docket No. E-999/CI-93-583, Order Establishing Interim Environmental Cost Values (March 1, 1994).

[3] Docket No. E-999/CI-93-583, Order Establishing Environmental Cost Values (January 3, 1997) [hereinafter "January 1997 order"]; Order Affirming in Part and Modifying in Part Order Establishing Environmental Cost Values (July 2, 1997) [hereinafter "July 1997 order"].

[4] *See In re Quantification of Envtl. Costs*, 578 N.W.2d 794 (Minn. App. 1998).

B. Motion to Update Cost Values

On October 9, 2013, several environmental advocacy organizations filed a motion requesting that the Commission update the cost values for emissions of CO_2, NO_x, and SO_2 and establish a cost value for emissions of fine particulate matter ($PM_{2.5}$), for which the Commission had not previously set a value.[5] They recommended that the Commission adopt the federal government's Social Cost of Carbon as the cost value for CO_2 and retain an independent expert to analyze the costs of the other three pollutants.[6]

The Commission determined that the scientific evidentiary support for the existing values had been reasonably called into question. On February 10, 2014, it reopened its investigation into the appropriate range of environmental cost values for CO_2, $PM_{2.5}$, SO_2, and NO_x.[7] The Commission asked the Minnesota Department of Commerce and the Minnesota Pollution Control Agency (the Agencies) to convene a stakeholder group to provide recommendations on the scope of the investigation.[8]

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

On October 15, 2014, the Commission issued a *Notice and Order for Hearing* in this docket referring the investigation to the Office of Administrative Hearings (OAH) for a contested case. The Commission specifically directed parties to address the following issues:

- Whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of carbon dioxide under Minn. Stat. § 216B.2422 and, if not, what measure is better supported by the evidence; and
- The appropriate values for $PM_{2.5}$, SO_2, and NO_x under Minn. Stat. § 216B.2422.

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[5] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3*, Docket No. E-999/CI-00-1636, Memorandum in Support of Clean Energy Organizations' Motion to Update Externality Values for Use in Resource Decisions, at 1–2.

[6] *Id.* at 18–19.

[7] Docket No. E-999/CI-00-1636, Order Reopening Investigation and Convening Stakeholder Group to Provide Recommendations for Contested Case Proceeding, at 3 (February 10, 2014).

[8] *Id.*

[9] Docket No. E-999/CI-00-1636, Comments by the Minnesota Department of Commerce and the Minnesota Pollution Control Agency, at 9–10 (June 10, 2014).

[10] *Id.* at 16–17.

II. The Parties and Their Representatives

The following parties appeared in this case:

- Minnesota Department of Commerce, Division of Energy Resources, and Minnesota Pollution Control Agency (collectively, the Agencies), represented by Linda Jensen, Assistant Attorney General.
- Minnesota Center for Environmental Advocacy (MCEA), Fresh Energy, and the Sierra Club (collectively, the Clean Energy Organizations or CEOs), represented by Kevin Reuther, Leigh Currie, and Hudson Kingston, attorneys with MCEA.
- Peabody Energy Corporation (Peabody), represented by Tristan L. Duncan, Shook, Hardy & Bacon L.L.P., and Jonathan Massey, Attorney at Law.
- Lignite Energy Council (Lignite), represented by Eric F. Swanson, Winthrop & Weinstine P.A.
- Great River Energy, Minnesota Power Company, and Otter Tail Power Company (collectively the Utilities), represented by B. Andrew Brown, Dorsey & Whitney L.L.P.
- Minnesota Power Company (MP), represented by David Moeller, Senior Attorney.
- Northern States Power Company, d/b/a Xcel Energy (Xcel), represented by James R. Denniston, Assistant General Counsel.
- Minnesota Large Industrial Group (MLIG), represented by Marc Al and Andrew P. Moratzka, Stoel Rives L.L.P.
- Minnesota Chamber of Commerce (MCC), represented by Benjamin L. Gerber, Attorney at Law.
- Doctors for a Healthy Environment (DHE), represented by Kevin P. Lee, Attorney at Law.
- Clean Energy Business Coalition (CEBC), represented by Bradley Klein and Jessica Dexter, attorneys with the Environmental Law & Policy Center.

III. Proceedings Before the Administrative Law Judge

The Office of Administrative Hearings assigned Administrative Law Judge (ALJ) LauraSue Schlatter to hear the case.

Between November 2014 and December 2015, the ALJ held several prehearing conferences and issued 17 orders addressing various evidentiary and procedural matters.

The parties filed direct, rebuttal, and surrebuttal testimony prior to the opening of evidentiary hearings. The ALJ held evidentiary hearings in Saint Paul on September 24–30, 2015, and January 12–14, 2016. After the hearings, the parties filed initial briefs, reply briefs, and proposed findings of fact and conclusions of law.

IV. Public Comments

On August 26, 2015, the Administrative Law Judge held a public hearing at the Commission's offices in Saint Paul. Representatives of the Clean Energy Organizations, MLIG, the Utilities, MCC, and DHE attended.

Approximately 100 members of the public attended the hearing, 34 of whom spoke on the record. Several organizations and members of the public also submitted written comments. The ALJ summarized the public comments in a six-page attachment to her reports.

Nearly all commenting members of the public urged the Commission to update the environmental costs to reflect the latest information on the human-health and environmental effects of air pollution from power plants, citing both the effect of carbon-dioxide emissions on the global climate and the health problems caused by particle pollution, such as asthma and pulmonary diseases.

A number of commenters, including 2,000 signatories to a Sierra Club petition, urged the Commission to adopt the Federal Social Cost of Carbon. However, others, including the Minnesota Rural Electric Association, opposed adopting this measure of cost, arguing that it would increase energy prices without any benefit to Minnesota.

V. The Administrative Law Judge's Reports

The Administrative Law Judge filed her *Findings of Fact, Conclusions, and Recommendations* on carbon-dioxide values on April 15, 2016, and her *Findings of Fact, Conclusions, and Recommendations* on the other three pollutants on June 15, 2016.

With respect to carbon dioxide, the ALJ found that the Federal Social Cost of Carbon generally provided a practicable basis for quantifying a range of environmental costs associated with the emission of CO_2. But the ALJ concluded that, for purposes of this docket, the record did not justify calculating these costs beyond the year 2200, or taking special efforts to reflect the cost of low-probability/high-cost outcomes (the "95^{th} percentile" scenario). Consequently the ALJ recommended that the Commission adopt a the Federal Social Cost of Carbon calculated over a range of discount rates, but modified to reflect the two changes noted above.

With respect to $PM_{2.5}$, SO_2, and NO_x, the ALJ did not recommend immediate adoption of any values, due to flaws that she identified in the parties' modeling. Instead, she recommended that the Commission direct Xcel or the Agencies to rerun their model using corrected data and assumptions and, ultimately, establish values based on the updated results.

VI. Proceedings Before the Commission

The following parties filed exceptions to one or both ALJ reports under Minn. Stat. § 14.61 and Minn. R. 7829.2700: MLIG, the Clean Energy Organizations, Xcel, the Agencies, and the Utilities.

On July 21, 25, and 27, 2017, the Commission heard oral argument from and asked questions of the parties. On July 27, 2017, the record closed under Minn. Stat. § 14.61, subd. 2.

Having examined the entire record in this case, and having heard the arguments of the parties, the Commission makes the following findings, conclusions, and order.

FINDINGS AND CONCLUSIONS

I. Summary of Commission Action

The Commission has examined the record, considered the Administrative Law Judge's reports, considered the exceptions to those reports, and heard oral argument from the parties. The Commission concurs in many of the ALJ's findings and conclusions. However, the Commission's view of the evidence leads it to different conclusions on certain issues, as explained in detail in the relevant sections of this order.

In particular, while the Commission finds that the overall framework of the Federal Social Cost of Carbon is reasonable and the best available measure to determine a range of costs associated with the emission of carbon dioxide from power plants, to better reflect the uncertainty inherent in estimating long-term damage costs of carbon emissions, the Commission adjusts certain economic assumptions, resulting in a range of $9.05–$42.46 per ton in 2020.[11]

In addition, with respect to NO_x, SO_2, and $PM_{2.5}$, the Commission finds that the values recommended by Xcel are the values best supported by the record as a whole. Accordingly, the Commission adopts the following ranges for NO_x, SO_2, and $PM_{2.5}$:

Table 1: Updated Environmental Cost Values for NO_x, SO_2, and $PM_{2.5}$
(2014 dollars/ton)

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

The Commission accepts, adopts, and incorporates the Administrative Law Judge's findings, conclusions, and recommendations to the extent that they are consistent with the Commission's decisions.

II. Background

A. Quantifying Environmental Costs

When an economic activity imposes a cost or benefit on an unrelated third party, the cost or benefit is known as an economic external cost or "externality." In particular, generating electricity by burning fossil fuels imposes costs on society by releasing pollutants—the byproducts of combustion—into the atmosphere.

[11] Utilities' Compliance Filing (August 3, 2017). Throughout this order, the word *ton* will refer to 2,000 pounds, or a "short ton."

The Environmental Cost Statute requires that the Commission, "to the extent practicable, quantify and establish a range of environmental costs associated with each method of electricity generation." This, in essence, is a requirement to determine the costs imposed on the public by pollution from power plants.

The statute then directs utilities to use those costs "in conjunction with other external factors . . . when evaluating and selecting resource options in all proceedings before the commission." In other words, the purpose of quantifying environmental externalities is to allow them to be weighed, along with other considerations, when the Commission makes decisions about what new generation sources should be built or acquired—and what existing facilities should be repowered or retired—by Minnesota utilities.

B. The Damage-Cost Valuation Method

The statute requires the Commission to quantify the costs associated with electricity generation, but it is silent on the method of quantification, leaving that decision to the Commission's discretion.

In its January 1997 order, the Commission considered several methods for estimating environmental cost values:

- The *damage-cost* method, which attempts to place an economic value on the net damage to the environment caused by power-plant emissions;
- The *willingness-to-pay* method, which measures the amount that society would be willing to pay for reduced emissions;
- The *cost-of-control* method, which uses the costs of avoiding or reducing an environmental effect at the source to estimate the value of the externality;
- The *mitigation-cost* method, which uses the costs of eliminating the harm or impact of an externality; and
- The *risk-of-regulation* method, which estimates future taxes or costs that a utility might incur due to increased regulation of emissions.[12]

The Commission deemed the damage-cost method the best approach to quantifying environmental costs, finding it superior because it appropriately focuses on actual damages from uncontrolled emissions. The Commission has required the parties to continue using a damage-cost approach in these most recent proceedings.[13]

C. The Current Environmental Cost Values

Quantifying environmental damages involves the consideration of scientific evidence that generally does not provide definitive answers. In its January 1997 order, the Commission found that using a range of values for each pollutant would appropriately acknowledge the uncertainty inherent in the quantification of environmental costs. The Commission also found that

[12] January 1997 order, at 14.

[13] *See* October 15, 2014 Notice and Order for Hearing, at 4.

establishing ranges would permit the testing of resource plans for sensitivity to changes in environmental values.

In addition, the Commission concluded that those ranges—with the exception of carbon dioxide's—should be *geographically* sensitive. That is, they should reflect that the damage done by conventional air pollutants depends largely on site-specific factors, including the number of people exposed to the pollution.

For these reasons, the Commission adopted ranges of values for the each pollutant that varied depending on the location of the proposed generation site: urban, metropolitan fringe, and rural. The Commission also established values for out-of-state power plants within 200 miles of Minnesota; those values were set equal to the values that had been calculated for rural Minnesota sources:

Table 2: Original Environmental Cost Values
(1995 dollars/ton)

	Urban	Metropolitan Fringe	Rural	Within 200 Miles of Minnesota
SO_2	112 – 189	46 – 110	10 – 25	10 – 25
PM_{10}	4,462 – 6,423	1,987 – 2,886	562 – 855	562 – 855
CO	1.06 – 2.27	0.76 – 1.34	0.21 – 0.41	0.21 – 0.41
NO_x	371 – 978	140 – 266	18 – 102	18 – 102
Pb	3,131 – 3,875	1,652 – 1,995	402 – 448	402 – 448
CO_2	0.30 – 3.10	0.30 – 3.10	0.30 – 3.10	0.30 – 3.10

In May 2001, the Commission updated the values to account for inflation, and it continued adjusting the values for inflation on a yearly basis. As of June 2017, the values stood as follows:

Table 3: Inflation-Adjusted Environmental Cost Values
(2016 dollars/ton)

	Urban	Metropolitan Fringe	Rural	Within 200 Miles of Minnesota
SO_2	0[14]	0	0	0
PM_{10}	6,666 – 9,595	2,968 – 4,311	840 – 1,277	840 – 1,277
CO	1.59 – 3.38	1.13 – 2.00	0.30 – 0.61	0.30 – 0.61
NO_x	554 – 1,461	209 – 397	27 – 152	27 – 152
Pb	4,677 – 5,789	2,468 – 2,980	601 – 669	601 – 669
CO_2	0.44 – 4.64	0.44 – 4.64	0.44 – 4.64	0.44 – 4.64

D. Standard of Proof

The Legislature has directed the Commission to quantify a range of environmental costs associated with electricity generation. Having found that the environmental costs that the Commission established in 1997 warrant reevaluation, the Commission relies on the new record developed in this docket to provide the most appropriate basis for determining the revised values. In this order the Commission establishes the cost ranges supported by a preponderance of the evidence in the record, viewed as a whole.

E. Uncertainty

Any attempt to quantify environmental costs of these pollutants is inherently uncertain because of the complexity and forward-looking nature of the exercise. Parties disputed how, or even whether, revised environmental costs could be reasonably calculated in light of this uncertainty. But lack of consensus about proper methods or calculations does not support a conclusion that the record supports no practicable cost range.

The Commission regularly encounters uncertainty—especially in the context of evaluating resource plans, which are unavoidably grounded in a utility's estimates about the future. The statute itself implicitly acknowledges that a degree of uncertainty is inherent in environmental cost valuation, directing the Commission to quantify costs "to the extent practicable."

The Commission confronted the challenge of uncertainty when first establishing externality costs in 1997, and when it established estimates of the cost of complying with future CO_2 regulations in 2007.[15] In the latter case, the Commission concluded:

[14] The Commission's January 1997 order provided that after the year 2000—when a nationwide cap on SO_2 emissions was to take effect—no externality value should be applied to SO_2 emissions.

[15] *In the Matter of Establishing an Estimate of the Cost of Future Carbon Dioxide Regulation on Electric Generation Under Minnesota Statutes § 216H.06*, Docket No. E-999/CI-07-1199.

> [A]ll forecasts entail a degree of doubt. This fact, however, is only tangentially relevant to the Commission's decision. The future is uncertain. The need to plan for the future is not. The degree of uncertainty regarding future CO_2 regulation and future technology makes the task of estimating regulatory costs more difficult; it does not make the task any less necessary. And it certainly does not lead the Commission to conclude that the most likely estimate of CO_2 costs is effectively $0.[16]

To summarize, it is clear that CO_2, $PM_{2.5}$, SO_2, and NO_x emissions impose environmental costs. It is less clear how to quantify those costs. But uncertainty about quantification does not relieve the Commission of its statutory responsibility to quantify these externalities "to the extent practicable." The Commission is adopting cost ranges based on an extensive record, relying on modeling assumptions and statistical methods that most appropriately account for these costs and best account for the inherent uncertainty.

The Commission will address CO_2 costs first and will then address the costs associated with $PM_{2.5}$, SO_2, and NO_x.

COST OF CARBON

I. Introduction

A. Carbon Dioxide

Carbon dioxide (CO_2 or carbon) is a *greenhouse gas*—that is, CO_2 emissions absorb and retain heat much like a greenhouse does. Since the start of the Industrial Revolution, humans have emitted increasing quantities of CO_2, thereby increasing the amount of heat-trapping gases in the atmosphere. This dynamic arguably imposes environmental costs by changing the climate. Acknowledging this problem, the Legislature has declared a goal to reduce greenhouse gas emissions throughout the state to 20% of 2005 levels by 2050.[17]

As previously noted, the Environmental Cost Statute directs the Commission to "quantify . . . a range of environmental costs associated with each method of electricity generation" and requires utilities to use these costs "when evaluating and selecting resource options in all proceedings before the commission."[18]

[16] Docket No. E-999/CI-07-1199, Order Establishing Estimate of Future Carbone Dioxide Regulation Costs, at 5 (December 21, 2007) [hereinafter "December 2007 order"].

[17] Minn. Stat. § 216H.02, subd. 1.

[18] Minn. Stat. § 216B.2422, subd. 3(a).

B. Summary of the Issues

In its *Notice and Order for Hearing*, the Commission declared its objective to resolve "[w]hether the [Federal Social Cost of Carbon] is reasonable and the best available measure to determine the environmental cost of CO_2 and, if not, what measure is better supported by the evidence." To accomplish this objective, the Commission must address several key issues that arise from the parties' differing approaches to estimating CO_2-related costs:

- ***The Federal Social Cost of Carbon***—Are the Federal Social Cost of Carbon values (damage estimates) developed by the federal Interagency Working Group the best available measure of the environmental cost of CO_2 for purposes of Minnesota's Environmental Cost Statute? If not, does the methodology underlying those values provide a reasonable framework for establishing CO_2 costs under the statute?

- ***Time Horizon***—When calculating the economic cost of an additional ton of CO_2 for purposes of the statute, how far into the future should climate-related damages from CO_2 emissions be considered?

- ***Discount Rates***—When calculating the economic cost of an additional ton of CO_2 for purposes of the statute, what discount rates should apply to convert future damages to a present discounted value?

- ***Leakage***—Should the Commission modify its CO_2 cost estimates to anticipate how Commission policies reflecting the cost of CO_2 might be evaded?

II. The Federal Social Cost of Carbon

A. Introduction

The Federal Social Cost of Carbon (FSCC) is an estimate, in dollars, of the discounted present value of damages caused by an additional ton of CO_2 emitted into the atmosphere in a given year.

Because CO_2 emissions remain in the atmosphere for hundreds or thousands of years, it is not possible to calculate the resulting harms based solely on summing the harms that have already accrued. Many modeling assumptions about the future—such as population, income, gross domestic product, emissions, the relationship between CO_2 concentration and temperature, the relationship between temperature change and harm, technological change, adaptation, and mitigation—rely on projections based on current experience and evidence.[19]

To develop the FSCC, the Council of Economic Advisers and the Office of Management and Budget (OMB) convened a working group with the participation of the National Economic Council, the Office of Energy and Climate Change, the Office of Science and Technology Policy, the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and the Treasury. This group was dubbed the U.S. Government Interagency Working Group on the Social Cost of Carbon (IWG).

[19] ALJ's April 15, 2016 Report [hereinafter "CO_2 Report"], at Finding 7.

The IWG calculated the FSCC by incorporating the results of a variety of mathematical models designed for specific tasks. The FSCC considered five different scenarios to forecast population and economic growth, and the emissions resulting from that growth. And it incorporated three different integrated assessment models[20] to forecast the effect of those emissions on temperature change, and the economic damages (in dollars) that may result from a given change in temperature. Projected economic damages were measured as the impacts of climate change on the global gross domestic product (GDP).[21]

The output of these scenarios and models reflects a vast amount of information. To combine all the data and estimates, the IWG adopted multiple strategies. The IWG calculated the social cost of carbon 150,000 times for each year evaluated (2010, 2020, 2030, 2040, and 2050) using varying assumptions, and then calculated the average of the results to generate an estimate of future CO_2 costs. The IWG then calculated the present value of these future costs based on three discount rates (2.5%, 3.0%, and 5.0%), resulting in three estimates of the FSCC per year. Finally, the IWG calculated a fourth FSCC value reflecting the far upper end (the 95th percentile) of the range of likely CO_2 costs, to illustrate the extent to which CO_2 costs under extreme circumstances might exceed CO_2 costs under expected circumstances.

The IWG has revised the FSCC values from time to time "to reflect increasing knowledge of the science and economics of climate impacts."[22] The IWG's most recent FSCC values are as follows:[23]

Table 4: Federal Social Cost of Carbon Values
(2015 dollars/ton)

	5.0% discount rate	3.0% discount rate	2.5% discount rate	95th Percentile 3% discount rate
2020	$ 12.30	$ 43.06	$ 63.56	$ 126.10
2030	$ 16.40	$ 51.26	$ 74.84	$ 155.83
2040	$ 21.53	$ 61.51	$ 86.12	$ 187.61
2050	$ 26.65	$ 70.74	$ 97.39	$ 217.34

Parties disagreed about whether the FSCC is a reasonable measure of the environmental cost of carbon, whether it is the best measure in the record, and if not, what the best measure of the social cost of carbon (SCC) would be.

[20] Integrated assessment models use techniques from multiple disciplines—chemistry, statistics, economics, and others—to simulate the relationship between emissions and their impacts.

[21] Hanemann Direct, at 26–27; Polasky Direct, Schedule 2 (IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, 2010), at 5, 8–10.

[22] Polasky Direct, Schedule 2, at 1.

[23] CEOs' Comments, Exhibit A (July 7, 2017) (converting IWG's data into 2015 dollars per short ton).

B. Positions of the Parties

1. Proponents

The CEBC, the CEOs, and DHE recommended that the Commission use the FSCC cost estimates adopted by the IWG as the range of environmental costs associated with utilities' CO_2 emissions. The Agencies also recommended using those estimates, except that the Agencies did not take a position regarding the 95th percentile scenario. All these parties argued that no other cost estimates in the record were developed using more rigorous methods and data.

In support of adopting the IWG's FSCC estimates, the proponents argued that these estimates were based on the latest peer-reviewed science, using open, transparent decision-making incorporating the views of a dozen federal agencies. The proponents noted that, consistent with statutory directive, the FSCC generates a range of values and, consistent with the Commission's directive from 1997, the FSCC reflects the cost of carbon on a global scale.[24] The proponents argued that the FSCC can be readily revised to incorporate the latest scientific advances. And they argued that utilities could readily incorporate the FSCC into their resource-planning filings.

Both the CEOs and DHE argued that the FSCC systematically understated the cost of carbon—DHE emphasized the model's failure to address non-lethal health consequences—yet they still regarded it as the best-supported cost proposal in the record.

2. Peabody

Peabody argued that proponents failed to prove by a preponderance of the evidence that the FSCC is a reasonable or practicable measure of the cost of carbon. Given the uncertainties inherent in estimating a cost over centuries, Peabody argued that no one cost method could be deemed demonstrated by a preponderance of the evidence.

Peabody criticized both the climate and economic modeling underlying the FSCC. According to Peabody, over the last 20 years the climate models have consistently overstated the amount of warming that would occur. Peabody alleged that the IWG misused and inappropriately manipulated the economic models. Moreover, Peabody claimed that the FSCC's choice of discount rates violated the guidelines of the Office of Management and Budget.

More narrowly, Peabody argued that the economic models were not suited to estimating Minnesota-specific impacts of CO_2 emissions because moderate warming in Minnesota would actually have net beneficial effects for the state.

For these reasons, Peabody recommended that the Commission set the cost of CO_2 at zero. Alternatively, Peabody recommended finding that increasing CO_2 generates net benefits such as increased crop production.

[24] *See* January 1997 order, at 15 ("CO_2 . . . causes damages globally rather than regionally or locally . . . . [T]his means assessing damage globally . . . .")

3. MLIG and the Utilities

MLIG and the Utilities (Great River Energy, Minnesota Power Company, and Otter Tail Power Company) echoed Peabody's concerns about the credibility of any model that attempts to forecast results centuries into the future. They argued that the FSCC was designed to aid analysis of federal policies, but that it lacks the precision needed to aid resource-planning or similar decisions. MLIG noted that the White House had recently disbanded the IWG, thereby eliminating the source of updates to the FSCC.[25] Moreover, the parties claimed that many of the initial assumptions used in the FSCC contradicted the assumptions that provided the basis for the Commission's 1997 order establishing the social cost of carbon.

Consequently MLIG and the Utilities opposed the proposal to use the FSCC as a foundation for establishing a new cost of carbon under the Environmental Cost Statute. Instead, they recommended that the Commission reaffirm its 1997 decision.

But if the Commission were to adopt the FSCC framework, these parties would recommend modifying the FSCC framework to generate results more appropriate to the purposes of the Environmental Cost Statute. Specifically, they proposed the following changes:

- Reducing the time over which environmental damages would be calculated (the time horizon) from 2300 to 2100.
- Calculating damages that would accrue in Minnesota only, rather than damages that would accrue throughout the world.
- Calculating the FSCC based on the damage caused by the average ton of CO_2 emitted, rather than the last ton emitted (the marginal ton).
- Calculating the FSCC using discount rates of 3.0% and 5.0%, but not 2.5%.

4. Xcel Energy

Like MLIG and the Utilities, Xcel argued that the FSCC was neither reasonable nor the best alternative in the record. Among other things, Xcel argued that the FSCC formula failed to adequately account for uncertainty, use statistically sound methods, limit risk, or minimize the consequences of subjective judgments. Because many of the assumptions that underlie the FSCC values reflect policy judgments, Xcel cautioned the Commission against delegating the task of establishing Minnesota's SCC to the IWG—an entity that might fall under political influence (or different political influences) in the future.

That said, given the practical challenge of developing a new climate model from scratch—and periodically updating this model—Xcel concluded that the FSCC represents the best starting point in the record for quantifying the social cost of carbon. But Xcel proposed its own method for modifying the FSCC estimates.

[25] Executive Order 13,783 (March 28, 2017).

Xcel's proposal incorporated the same climate science and economics used in calculating the FSCC, retained all the IWG's core assumptions, and generated the same number of estimates of carbon costs, but then applied a statistical methodology that excluded consideration of damage data at the higher and lower ends of the probability distribution. Specifically, Xcel used the IWG's five socioeconomic scenarios for each of the three integrated assessment models, calculating the 25th and 75th percentile values of each distribution separately for each of three discount rates (2.5%, 3.0%, and 5.0%). Finally Xcel averaged all the 25th percentile values together to create a single, composite 25th percentile value, and did the same with the 75th percentile values. These numbers established the lower and upper bounds of Xcel's carbon cost estimates.

Xcel defended its choice to disregard results below the 25th percentile, and above the 75th percentile, as an effort to generate a practicable carbon cost estimate—that is, an estimate that could be put into practice. Xcel acknowledged that the high and low values were supported in the record, but concluded that applying these values in a Commission docket would yield predictable, and not very useful, results: The extreme high end would justify eliminating all carbon-emitting resources (and perhaps extending the life of nuclear plants), while the extreme low end would justify maintaining the status quo, or perhaps adding more fossil fuel plants.

Xcel defended its choice to average together values, regardless of discount rate, rather than (1) reporting an upper- and lower-bound value for each discount rate, or (2) picking a single discount rate. Xcel argued that reporting a separate lower and upper value for each discount rate would simply increase the burden of applying the standard without adding meaningfully to the information available to the Commission. And because the choice of discount rate is purely a matter of judgment, Xcel argued, taking an average of the values generated by each discount rate would minimize the influence of arbitrary judgments.

C. The Recommendation of the Administrative Law Judge

The ALJ concluded that the preponderance of the evidence supported the conclusion that the FSCC both provided a reasonable foundation for determining the environmental cost of CO_2 and was the best available foundation in the record.[26] In particular, the ALJ found that the preponderance of the evidence supported the following conclusions:

- The FSCC—by identifying a distribution showing the likelihood and magnitude of potential CO_2 costs, calculating the weighted average of the distribution, and then reporting that average using various discount rates—establishes "a range of environmental costs" as that phrase is used in the Environmental Cost Statute.
- The IWG was justified in the manner in which it chose to calculate changes in global mean temperatures at equilibrium (equilibrium climate sensitivity).
- Given that the costs associated with CO_2 emissions increase as the amount of emissions increase, for purposes of the Environmental Cost Statute, the most appropriate cost of CO_2 reflects the cost of the last (marginal) ton emitted.

[26] CO_2 Report, Conclusion 56.

- For purposes of the Environmental Cost Statute, the cost of CO_2 emitted in Minnesota includes costs that occur anywhere in the world, not merely costs that occur in Minnesota or the United States.

Nevertheless, the ALJ found shortcomings with this measure of CO_2 cost. For example:

- The ALJ concluded that the integrated assessment models underlying the FSCC do not account for a significant number of important environmental consequences that will occur as a result of climate change, and that the FSCC underestimates the negative effects that global warming would have on human health. Consequently the ALJ concluded that the FSCC understates the full environmental cost of CO_2, likely understates damages, and inadequately represents the risk that the growth of CO_2 emissions could reach a "tipping point" triggering irreversible, catastrophic damage. But the ALJ did not recommend any specific changes to the calculation of CO_2 costs on this basis.
- The ALJ recommended that the Commission decline to require utilities to report CO_2 cost values calculated at the 95th percentile—that is, roughly, a worst-case scenario. The ALJ acknowledged that the risk of extreme events is not well represented in the other FSCC values. Nevertheless, the ALJ found insufficient support for the idea that cost values with a 1/20 chance of arising would provide a meaningful reflection of that risk.
- The ALJ recommended that the Commission decline to consider CO_2 costs accruing after the year 2200 when calculating the cost of CO_2 for purposes of the Environmental Cost Statute.

The ALJ found insufficient support for making any other adjustments to the FSCC formula for purposes of measuring the cost of CO_2 under the statute. In particular, the ALJ rejected Xcel's proposal. The ALJ concluded that the practice of ignoring potential CO_2 costs below the 25th percentile and above the 75th percentile would inappropriately exclude consideration of half of the possible outcomes, including the more extreme outcomes which are the sources of greatest concern. And the ALJ found insufficient theoretical or practical support for Xcel's proposal to average CO_2 cost estimates generated using different discount rates.

D. Commission Action

The Commission concurs with the ALJ, the Agencies, the CEBC, the CEOs, and DHE that the FSCC provides the best framework in the record from which to establish a range of environmental costs associated with CO_2 emissions for purposes of Minnesota's Environmental Cost Statute.

The degree of rigor employed in the development of these cost values, and the timeliness of the underlying data and analyses, far exceeds any other framework in the record—including the Commission's 1997 order establishing the cost of CO_2. The modeling inputs and parameters relied on the most credible and widely used sources of information in the scientific literature.

For example, the IWG employed the three most widely used integrated assessment models. The range of climate sensitivity values was derived from the most credible source of peer-reviewed scientific information available at the time: the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), an intergovernmental body established by

the United Nations Environment Program and the World Meteorological Organization. And the socioeconomic-emissions scenarios were based on scenarios from the Energy Modeling Forum (EMF-22), which have been used and described in peer-reviewed literature.

Nevertheless, the Commission also concurs with the ALJ, MLIG, the Utilities, and Xcel that the appropriate measure of CO_2 costs for purposes of Minnesota's Environmental Cost Statute will differ from the FSCC values. As Xcel stated,

> estimating the FSCC is only partly a matter of using the most up-to-date climate science and economics. It is at least as dependent on public policy decisions that have no one correct answer—decisions such as the geographic scope of damages, the modeling horizon, the discount rate choice, and how to model damages from a marginal ton of emissions. Because the Commission will unavoidably be considering public policy questions with no single answer, it has a reasonable basis to apply its discretion and consider the practical implications of those decisions.[27]

Because aspects of this calculation are inextricably tied to policy judgments, the Commission, like the ALJ, concludes that the FSCC is the best available measure for determining the environmental cost of CO_2, but warrants certain amendments to better suit the Minnesota resource-planning context.

Having reviewed the arguments of the parties and the report of the ALJ regarding CO_2 costs, the Commission finds that the ALJ's findings are generally well supported in the record and that her conclusions and recommendations flow from her findings; consequently the Commission will accept and adopt most of them. But the Commission will decline to adopt the ALJ's recommendations with respect to two FSCC issues:

- First, regarding the appropriate discount rates to reflect intergenerational payment for future damages, the Commission declines to use the 2.5% discount rate employed by the IWG.

- Second, regarding the appropriate time horizon for reflecting future economic damages well into the future, the Commission declines to adopt a range of values based on damage estimates calculated through the year 2200 as recommended by the ALJ. Instead, the Commission adopts a range of costs that includes one estimate calculated through the year 2100, and another calculated through the year 2300.

The Commission provides further analysis below regarding the appropriate *time horizons* and *discount rates* to use when calculating CO_2 costs. The Commission also addresses the challenge posed by *leakage*—that is, the potential that the Environmental Cost Statute, rather than encouraging reduction of CO_2-emitting activities, would simply encourage those activities to occur out-of-state.

[27] Xcel's Exceptions, at 6 (May 5, 2016).

III. Time Horizon

A. Introduction

According to the IPCC, emissions of CO_2 remain in the atmosphere for centuries, and 15% to 40% of emitted CO_2 remains in the atmosphere for 1,000 years or longer. People who analyze the consequences of CO_2 emissions generally select only a portion of this period for analysis. For example, each of the integrated assessment models used to calculate the FSCC had a different default end date, ranging from the year 2200 to 3000.

In short, any practical calculation of the cost of carbon must reflect a finite period—a time horizon—for which the harms are evaluated. But parties disagree about the appropriate time horizon for calculating CO_2 costs for purposes of the Environmental Cost Statute.

The 22nd study by the Stanford Energy Modeling Forum (EMF-22), discussed above, developed ten computer models for exploring how potential policy changes might influence global climate change in the year 2100. The models are designed to reflect the relationships between variables such as population growth, economic growth, CO_2 emissions, and the amount of energy absorbed by atmospheric compounds other than CO_2. The EMF-22 scenarios have been published and are available for public scrutiny.

The IWG incorporated the EMF-22 scenarios for the year 2100 into its calculation of the FSCC. In addition, the IWG reasoned that knowledge of CO_2 concentration in the atmosphere in 2100 would provide a basis for predicting CO_2 concentration in the atmosphere for the next 200 years, out to the year 2300.

B. The Recommendation of the Administrative Law Judge

The ALJ found that the record demonstrates that CO_2 released into the atmosphere will not be fully absorbed into the land or oceans for a minimum of two hundred years, and that the CO_2 will affect the climate as long as it remains in the atmosphere. And the ALJ found no fault with the IWG's reliance on the peer-reviewed EMF-22 emissions scenarios, which forecasted results in the year 2100.

But the ALJ concluded that the IWG's choice to extrapolate the EMF-22 results through the year 2300 was based on limited data and lacked the benefit of peer review. The ALJ concluded that the record could not support conclusions drawn on the basis of two centuries of extrapolation.

That said, the ALJ could not deny that if the record provided an adequate basis for quantifying CO_2 levels in the year 2100, it provided a basis for quantifying those levels for some period thereafter. Balancing this logic against the uncertainties involved in forecasting, the ALJ found it reasonable to calculate damages based on forecasts out to the year 2200.

C. Positions of the Parties

1. The Agencies and the CEOs

The Agencies and the CEOs defended the IWG's choice to calculate the environmental costs of CO_2 emissions through the year 2300. They argued that the EMF-22 studies established a firm

foundation for estimating the concentration of greenhouse gases in the year 2100. And, citing evidence that CO_2 emissions tend to remain in the atmosphere for 200 years or more, they argued that it was reasonable to take account of the foreseeable harm that would continue to accrue over the following two centuries.

While the Agencies and the CEOs acknowledged the challenges of making forecasts out to the year 2300, they reasoned that the principles that apply to forecasts in general continue to apply to these forecasts. Indeed, the CEOs argued that the IWG's time horizon for calculating damages was conservative:

> The IWG Technical Supporting Documents (TSD) demonstrate that damages attributable to an emitted ton [of CO_2] continue on even after that ton has left the atmosphere. As one example, the 2013 TSD explained why [one integrated assessment] model would continue to demonstrate increasing damages even after modeled CO_2 had left the atmosphere and the temperature increase started to decline from its peak: "The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease." Ignoring these impacts in a final Commission decision would run counter to the evidence in the record.[28]

Finally, the CEOs raised a practical concern with the ALJ's recommendation: The record makes it feasible to calculate CO_2 damages through the year 2100 or 2300, but calculating damages through any other time horizon—and revising those calculations—would be substantially more burdensome. It would require someone to acquire each of the integrated assessment models used to calculate the FSCC, adjust the code to exclude consideration of costs after the year 2200 but not otherwise alter the model's operations, rerun each of the models, and then recalculate the results using each of the Commission-approved discount rates.

Moreover, because damage formulas discount the value of damages accruing in later years, the CEOs reasoned that the effort required to implement the ALJ's recommendation may ultimately produce little change in the final measure of CO_2 costs. For these reasons, among others, the Agencies and the CEOs opposed the ALJ's recommended time horizon of 2200.

2. Peabody, MLIG, the Utilities, and Xcel Energy

Among their other objections to the FSCC, Peabody, MLIG, the Utilities, and Xcel argued that the record does not justify relying on extrapolations out to 2300 based on forecasts of 2100. In particular, they emphasized people's inability to anticipate technological change, including changes that would enable people to better adapt to future conditions—thereby reducing the effective cost of those conditions.

[28] CEOs' Exceptions, at 7–8.

Moreover, MLIG and the Utilities noted that calculating damages over such a long period has the effect of giving inordinate weight to speculative future events. They emphasized the risks of making large extrapolations, especially using models that incorporate nonlinear (e.g., quadratic) damage functions. MLIG and the Utilities acknowledged that there is some limited empirical evidence about how temperature increases of up to three degrees centigrade would affect the economy. But forecasting almost three centuries into the future will inevitably result in more scenarios in which temperatures rise more than four degrees centigrade, MLIG and the Utilities argued, where estimates of the resulting damage are more speculative. Finally, when damages are calculated using a discount rate of 3.0% or lower, more than half of the resulting costs derive from damages forecasted to accrue after the year 2100—a result which MLIG and the Utilities find unreasonable.

For these reasons, Peabody, MLIG, and the Utilities asked the Commission to calculate CO_2 environmental costs based on a time horizon of 2100, the end point of the EMF-22 scenarios. But Xcel's witness did not recommend a specific time horizon, concluding that this issue was ultimately a judgment call.

Finally, Xcel echoed the CEOs' concern about the feasibility of implementing the ALJ's recommendation to calculate CO_2 damages through the year 2200. Xcel argued that the record does not currently contain cost data calculated to that date, and obtaining that data—and periodically updating it—could prove to be unduly burdensome.

D. Commission Action

1. Rejecting the 2200 Time Horizon

Reasonable parties may differ in their choice of time horizon. But because CO_2 emissions remain in the atmosphere for such a long time, and cause harm throughout and beyond that time, the consequences of this choice can be substantial.

This issue requires the Commission to balance the known physical properties of CO_2 in the atmosphere against the uncertainties inherent in any form of long-range forecast. The ALJ acknowledged these competing considerations when she adopted her "compromise position" of calculating damages through the year 2200.[29] The choice of a midpoint between 2100 and 2300 reflects the compelling arguments on both sides of the issue.

However, no party favors using 2200 as the time horizon for calculating CO_2 costs. As the CEOs noted, the consequence of removing these sums from the calculation may be less than anticipated, because the contemporary value of costs incurred after 2200 will be reduced by the application of the discount rate. And in any event, the Commission concludes that the challenges of calculating—and perpetually updating—CO_2 costs forecast to the year 2200 renders this option impracticable. Consequently the Commission will decline to adopt this aspect of the ALJ's recommendations.

[29] CO_2 Report, at 130 (Memorandum).

2. Selection of the 2100 and 2300 Time Horizons

While the Commission finds the ALJ's recommendation impracticable, the Commission appreciates the tension in the choice between the two time horizons set forth in the record. It is uncontested that the EMF-22 emissions scenarios provide a more reliable foundation for making judgments about 2100 than the extrapolations provide for 2300. Reliance on the extrapolations certainly entails a greater risk of error. That includes the risk of overestimating CO_2-related costs, as well as the risk of underestimating those costs.

But ignoring the extrapolations also runs the risk of error. MLIG and the Utilities warn that nonlinear models might produce large, unreliable results when forecasting events centuries away, but these models might also predict large, reliable results. The magnitude of harm from CO_2 emissions is not necessarily proportionate to the magnitude of the emissions; the ALJ found that the risk that some tipping point could trigger an environmental catastrophe justifies erring on the side of adopting higher CO_2 cost estimates.[30]

The Commission is persuaded that the EMF-22 scenarios provide a serviceable description of the likely state of the population, the economy, and especially the level of CO_2 in the atmosphere in 2100—and therefore, that they provide a serviceable description of the atmospheric levels of CO_2 for *some* period thereafter. Even if conclusions derived from the IWG's extrapolations are not as reliable as the conclusions based on the EMF-22 studies, it is not clear that they are less reliable than an assumption that CO_2 costs after 2100 drop to zero.

Moreover, the Commission finds the IWG's extrapolations to be based on well-reasoned, plausible, and even conservative assumptions. For example, the IWG assumed the following:

- The rate of population growth would decline linearly, leveling off in the year 2200.
- The growth of GDP per capita would also decline linearly, leveling off in the year 2300.
- The decline in the amount of CO_2 emitted per dollar of output (CO_2/GDP) would continue through 2300.
- Carbon released as a result of land uses such as agriculture and forestry would decline linearly and, by 2200, would match the amount of carbon absorbed by land uses.
- There would be no growth in greenhouse gases other than CO_2.[31]

Finally, the Commission observes that the IWG's choice to calculate damages out to 2300 already reflected a truncated time horizon for two of the three integrated assessment models.

While the Utilities and Xcel claim that the FSCC failed to account for the possibility that people would respond to climate change through adaptation and mitigation, the ALJ rejected these

[30] *Id.*, Conclusion 43.

[31] Polasky Direct, Schedule 2 (IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, 2010), at 43.

allegations.[32] Indeed, far from predicting that CO_2 emissions would spiral out of control, the IWG's extrapolations forecast that the rate of CO_2 emissions would level off and, by 2200, start to decline.[33] This pattern would seem to be consistent with technological improvement, innovation, and increasing energy efficiency.[34]

In sum, the Commission has good reason to restrict itself to considering the most reliable evidence in the record, and also good reason to consider reasonable extrapolations from that evidence. With the benefit of this record, the Commission will do both. That is, the Commission will direct utilities to calculate the cost of CO_2 using both a 2100 time horizon and a 2300 time horizon. This decision is consistent with the Commission's strategy of addressing uncertainty by considering a broader rather than a narrower range of estimates.[35]

IV. Discount Rate

A. Introduction

The social discount rate reflects an assumption about a society's willingness to bear a current cost (or forgo a current benefit) to avoid a greater cost (or derive a greater benefit) in the future. In practice, to calculate the *current* dollar value of a *future* event, the nominal value of that future event must be discounted to become comparable to today's dollars. This calculation is performed by applying the appropriate discount rate.

The choice of a discount rate to be used over very long periods raises scientific, economic, philosophical, and legal issues.[36] Because the consequence of emitting carbon accrues for centuries, the choice of discount rate substantially affects the value assigned to emitting, or avoiding emitting, CO_2. For example, a $1 million harm in 100 years could be valued today at $85,000 (using a discount rate of 2.5%), $52,000 (using a discount rate of 3.0%), or $7,600 (using a discount rate of 5.0%).[37]

The IWG chose to report the FSCC calculated with those three discount rates: 2.5%, 3.0%, and 5.0%. The IWG explained this choice of discount rates as follows:

> [W]e first estimate the future damages to agriculture, human health, and other market and non-market sectors from an additional unit of carbon dioxide emitted in a particular year in terms of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three [integrated assessment models]. Then we discount the stream of future damages

[32] CO_2 Report, Conclusion 44.

[33] Polasky Direct, Schedule 2, at 46; Hanemann Rebuttal, at 23.

[34] Polasky Direct, Schedule 2, at 44.

[35] *See* December 2007 order, at 9.

[36] Hanemann Direct, Attachment 4 (Michael Greenstone, et al., *Developing a Social Cost of Carbon for US Regulatory Analysis: A Methodology and Interpretation*, 7 REV. ENVTL. ECON. & POL'Y 23 (2013)), at 31.

[37] Polasky Direct, at 11.

> to its present value in the year when the additional unit of emissions was released using the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.
>
> . . .
>
> In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review [of theories and data], the [IWG] determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.[38]

B. Positions of the Parties

1. Xcel Energy

While Xcel recommended that the Commission make a number of changes to the IWG's FSCC formula, it did not propose changes to the three discount-rate levels. But given the subjective nature of identifying an appropriate discount rate, Xcel argued for calculating the final range of carbon costs by combining data generated using each of the three discount rates. Xcel reasoned that reporting separate cost figures for each discount rate would add needless complexity to utility filings, provide little additional information, and simply postpone the question of how to analyze a resource option when the Commission receives competing cost estimates calculated using different discount rates.

2. MLIG and the Utilities

MLIG and the Utilities supported the IWG's reliance on the 3.0% and 5.0% discount rates as reflective of the consumption rate of interest (also known as the social rate of time preference). But MLIG and the Utilities opposed the use of the 2.5% discount rate as lacking a meaningful connection to empirical evidence. They argued that the 2.5% rate, rather than reflecting support in the record, reflected an idealized notion about people's willingness to sacrifice for future generations. Moreover, when calculating damages extending beyond the year 2100, MLIG and the Utilities argued that this discount rate produced values that were excessive, and excessively speculative.

Instead, MLIG and the Utilities argued for including a discount rate of 7.0. They reasoned that this rate better reflects the opportunity costs a utility faces when making capital investments—a factor that may not have been relevant to the IWG, but which should be relevant for purposes of Minnesota's Environmental Cost Statute. In support of this potion, MLIG and the Utilities allege that Circular A-4 from the federal Office of Management and Budget requires the use of a 7.0% discount rate for federal purposes.

In addition, MLIG urged the Commission to adopt one of two options on discount rates. Under one option, the Commission would use discount rates of 3.0%, 5.0%, and 7.0%. MLIG raised

[38] Polasky Direct, Schedule 2 (IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, 2010), at 17, 23.

doubts about the merits of using a 3.0% discount rate, but concluded that it would be appropriate to offer that perspective provided the Commission offered the 5.0% and 7.0% perspectives as well. MLIG also proposed an alternative option, whereby the Commission would rely on a weighted average of these discount rates.

3. Peabody

Peabody argued that the discount rates used in calculating the FSCC values are arbitrary. Instead, Peabody recommended that discount rates reflect the principles articulated by Frank Ramsey in the 1920s for optimizing the trade-off between current consumption and savings/investment for future consumption (the Ramsey Rule). This model is complex, but generally argues that the relevant discount rate should vary with economic growth: The more a person can earn (and potentially leave to future generations) by emitting an extra ton of CO_2 today, the more willing that person should be to emit that CO_2—that is, the higher the discount rate. One practical effect of using the Ramsey Rule is to require modeling of discount rates that change from time to time, and from place to place.

Peabody also spoke in support of the 7.0% discount rate. Peabody cited a White House guide to Circular A-4 issued by the Office of Management and Budget, instructing agencies to use the 7.0% discount rate in addition to lower rates where important intergenerational costs or benefits are at stake.

In contrast, Peabody argued that a 2.5% discount rate would differ from the rates applicable to every other public investment, and lacked theoretical support, evidentiary support, or even a reasonable explanation. Peabody characterized the 2.5% discount rate as the IWG "choosing whatever discount rate pleases them."

4. The Agencies

The Agencies supported the discount rates used by the IWG. They argued that these three rates reflected reasonable judgments under both descriptive and prescriptive approaches to determining an appropriate rate of discount, and were consistent with the values used in the existing literature on the economics of climate change and greenhouse gas mitigation.

The Agencies opposed the 7.0% discount rate as reflecting inappropriate criteria for this docket. The Agencies argued that this rate wrongfully conflated monetized CO_2 damage values with the potential rate impact due to the use of the damage values. According to the Agencies, a discount rate on par with an investor–owned utilities' overall rate of return could be justified only if the nation's gross domestic product were derived primarily from utility consumption—which it is not. After reviewing the economic literature on climate change, the Agencies could not identify an economist who had used a discount rate higher than 5.5%.

Finally, the Agencies opposed placing any reliance on the Ramsey Rule, arguing that it is based on implausible assumptions such as the following:

- That climate policy can be viewed through the metaphor of a single, infinitely lived individual arranging his consumption over the course of his (infinite) lifetime.

- That this individual has constant preferences and constant expectations regarding what gives him well-being throughout the course of this lifetime.
- That everything the individual cares about can be measured in financial terms.

C. The Recommendation of the Administrative Law Judge

The ALJ recommended using discount rates of 2.5%, 3.0%, and 5.0%. The ALJ found that the preponderance of the evidence demonstrated that the 3.0% and 5.0% discount rates are recognized as consumption rates of discount, an appropriate discount rate for purposes of establishing the long-run cost of environmental damage. And while the ALJ acknowledged that the 2.5% discount rate did not have the same amount of support in the record, the ALJ concluded that

> the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that the IWG's choice of a 2.5 percent rate of discount is within the existing bounds of rates used in other climate change models. The 2.5 percent rate of discount is a reasonable approach to account for the multigenerational scope of the FSCC and to address the concern that interest rates are uncertain over time.[39]

The ALJ found that the proposal to calculate the SCC using a 7.0% discount rate was not sufficiently supported in the record. The ALJ reasoned that a 7.0% discount rate reflects a utility's long-run capital cost for investments designed to reduce CO_2 emissions or otherwise comply with environmental regulations. Whatever the merits of this calculation for other purposes, the ALJ found, it is inconsistent with the goal of measuring the long-run cost of environmental harms.

Finally, the ALJ rejected the use of the Ramsey Rule for identifying the relevant discount rate for this docket. The ALJ found the rule's simplifying assumptions—for example, that climate policy can be viewed through the metaphor of a single, infinitely-lived individual—renders it unpersuasive. Noting that the Ramsey Rule would generate a relatively high discount rate that would decline over time, the ALJ doubted that this policy would promote intergenerational equity or address the challenge that a society's priorities and preferences may change over the course of centuries. Given the ALJ's conclusion that the FSCC fails to account for various kinds of harms arising from CO_2, and that future CO_2 emissions could trigger a "tipping point" event with catastrophic consequences, the ALJ concluded that a Ramsey Rule discount rate would not be reasonable and was not the best alternative in the record.

D. Commission Action

1. Combining Data Generated Using Different Discount Rates

As previously noted, Xcel recommended calculating CO_2 costs by, among other things, combining data generated by calculations using three different discount rates. And Xcel defends this practice, in part, on the theory that providing the Commission with separate CO_2 cost values based on each Commission-approved discount rate would be burdensome.

[39] CO_2 Report, Conclusion 18.

The Agencies, the CEOs, Peabody, and the Utilities all argued that combining data in this manner could not be justified if the three discount rates were not selected as representative of some proportionate distribution, and that the record does not show that they were.

Whatever the merits of this objection, the Commission notes that the choice of discount rate (a) reflects a policy judgment and (b) heavily influences the resulting CO_2 cost values. For these reasons, the Commission prefers seeing CO_2 cost values disaggregated based on discount rates, similar to the manner provided by the FSCC. Consequently the Commission declines to adopt Xcel's proposal, and will instead establish a range of CO_2 costs based on applying each Commission-approved discount rate separately.

2. The 3.0% and 5.0% Discount Rates

The Commission concurs with the ALJ, the Agencies, the Utilities, and Xcel that discount rates of 3.0% and 5.0% are consistent with the economic literature and otherwise well supported in the record for use in evaluating multigenerational environmental costs. Consequently the Commission is basing its range of CO_2 values on these discount rates.

MLIG also supported adoption of these discount rates, albeit subject to the condition that the Commission also adopt the 7.0% discount rate. Neither the ALJ nor any other party argued that the merits of the 3.0% and 5.0% discount rates bear any relationship to the merits of the 7.0% discount rate. Because the Commission likewise finds little relationship between these issues, the Commission will address the merits of the 7.0% discount rate separately.

3. The 2.5% Discount Rate

While the Commission finds that the record amply demonstrates the merits of using the 3.0% and 5.0% discount rates, the Commission is not persuaded that the record provides the same degree of support for the 2.5% rate.[40]

While the Commission is mindful of the harms associated with greenhouse gases, the purpose of this docket is not merely to acknowledge the harms, but to meaningfully quantify them to aid in establishing a range of CO_2 costs to use in evaluating utility resources. The 3.0% and 5.0% discount rates provide a more certain and reliable basis for that purpose. Moreover, using the 3.0% and 5.0% discount rates would be consistent with the Commission's previous decision setting environmental externality values.[41] Consequently the Commission will decline to use the 2.5% discount rate in establishing its range of environmental costs for CO_2.

4. The 7.0% Discount Rate

The Commission also declines to use a 7.0% discount rate for establishing the range of CO_2 costs. MLIG and the Utilities argued that the 7.0% rate better reflects a discount rate associated with long-run utility investments in regulatory compliance, as mandated by the Office of

[40] Smith Direct, at 24.

[41] January 1997 order, at 27.

Management and Budget, and that it reflects a conservative approach that is justified in the face of uncertainty. The Commission finds neither argument compelling.

In this docket the Commission seeks to quantify the environmental cost associated with various emissions, where cost is understood as the long-term damage from the emissions. Whether 7.0% reflects a utility's long-run discount rate for regulatory compliance or the rate impact of these cost values, these are not relevant considerations for purposes of this docket.

As previously noted, the Agencies were unaware of any studies of environmental costs using a discount rate exceeding 5.5%. More noteworthy, perhaps, Peabody's own witness reported that when he analyzed 39 studies on the social cost of carbon, he found that only two used a discount rate above 5.0%.[42]

In addition, the Commission is not persuaded that the Office of Management and Budget requires, or even encourages, the use of a 7.0% discount rate for calculating the cost of CO_2 over centuries. The IWG addressed the OMB's Circular A-4 in 2010:

> The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. . . . [T]he consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.[43]

The IWG provided further elaboration in 2015:

> OMB was fully involved in the development of the SCC estimates as a working group co-chair and supports the working group's recommendations regarding the discount rate and the focus on global damages. The departure from the standard discount rate recommendations in Circular A-4 is explained in detail in [technical support documents, but b]riefly, the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself.[44]

[42] Polasky Rebuttal, at 22 (citing a 2008 meta-analysis of studies conducted by Dr. Richard Tol).

[43] Polasky Direct, Schedule 2, at 23.

[44] Polasky Rebuttal, Schedule 1 (IWG Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis), at 36.

The Commission's objective is to find the best available measure for determining the environmental cost of CO_2 for use in evaluating and selecting resources. Consequently the Commission will not use a 7% discount rate in establishing a range of CO_2 costs.

5. Composite Discount Rate

Because the Commission is not persuaded that a 7.0% discount rate is appropriate for purposes of this docket, it will also decline to adopt MLIG's proposed composite discount rate that incorporated the 7.0% rate.

6. Ramsey Rule

Like the ALJ, the Commission is not persuaded that the Ramsey Rule provides a useful basis for calculating a discount rate for purposes of this docket.

The Ramsey Rule seeks to maximize the sum of anticipated benefits accruing over time. To achieve that end, it calculates a consumption discount rate from (a) the elasticity of the marginal utility of consumption, (b) the growth rate of per capita consumption, and (c) the pure rate of time preference. MLIG argued that the discount rates should change over time, and from place to place, as the economic growth rates at any given time and place change.

While the Ramsey Rule may have some merit, the Commission ultimately concurs with the IWG that there is no consensus about the nature of the formula's components. As the IWG remarked:

> The IWG agrees that a Ramsey framework can be useful in informing the selection of an appropriate range of discount rates for estimating the SCC. As noted above, this was one of the approaches considered by the IWG in the selection of the 2.5, 3, and 5 percent range. . . .
>
> However, after reviewing several approaches to estimating specific parameters, the IWG noted that there is no consensus in the literature on the appropriate approach for selecting specific values for the components of the Ramsey equation. For this reason, the IWG used this analysis to inform its choice of a range of discount rates, but concluded that the Ramsey equation alone should not determine a specific choice of discount rate.
>
> The IWG agrees that the Ramsey framework could, in theory, support a formulation where discount rates change over time. In a paper summarizing the aforementioned workshop on discounting, thirteen prominent economists indicated that the Ramsey framework "provides a useful framework for thinking about intergenerational discounting" but also pointed out that there is disagreement in the literature about what individual parameters in the Ramsey framework represent . . . , which makes it difficult to select defensible values. As noted above, the IWG believes it is premature

> to use the Ramsey framework as the sole basis for deriving discount rates, either fixed or variable . . . .[45]

Likewise, given the state of the academic literature on this matter, this Commission also concludes that it would be inappropriate to use the Ramsey Rule to derive the discount rate for this docket.

In conclusion, the Commission finds that the discount rates best supported in the record are 3.0% and 5.0%. This finding coincides with the Commission's previous finding setting environmental externality values.[46]

V. Leakage

A. Introduction

Leakage refers to the idea that a policy that prompts beneficial behavior in one jurisdiction might prompt offsetting behavior in another jurisdiction. Thus, when viewed from a broad perspective, the policy's benefits in the first jurisdiction "leak out," reducing or eliminating the policy's net benefits.

In this docket, parties disagree about the amount of leakage that might arise from Minnesota establishing a range of costs related to CO_2 emissions, and the relevance of this question to the current docket.

B. Positions of the Parties

1. MLIG and the Utilities

MLIG and the Utilities speculated that consideration of carbon costs may cause utilities to curtail building or running generators in Minnesota that emit CO_2, and that this outcome might have unforeseen consequences. For example, it might prompt a utility to buy replacement electricity from generators in neighboring states—including electricity generated by CO_2-emitting generators.

In these scenarios, the parties argued, Minnesota's efforts to discourage CO_2 emissions within the state would be offset—perhaps 100% offset, or less, or more—by added CO_2 emissions in other states. Given this possibility, MLIG and the Utilities recommended that the Commission take this dynamic into account when quantifying the range of environmental costs associated with CO_2 emissions. Specifically, MLIG and the Utilities recommended that the Commission quantify the environmental cost of CO_2 emissions offset by the amount of leakage. And they recommended that the Commission conduct a study addressing the application of the CO_2 environmental cost values, given the existence of leakage.

[45] *Id.* at 24 (citation omitted).

[46] January 1997 order, at 27.

2. The Agencies and the CEOs

The Agencies and the CEOs opposed these proposals. The Agencies argued that the issue of leakage exceeds the scope of the current docket. They argued that the Commission has a duty to fulfill the mandate of the Environmental Cost Statute to the fullest extent of its jurisdiction; the behavior of actors outside the Commission's jurisdiction is outside the Commission's concern. And the CEOs argued that leakage is a matter to be addressed, as necessary, in other dockets.

3. Xcel Energy

Xcel agreed with MILG and the Utilities that the Commission should consider leakage when considering the environmental costs of various sources of electricity. But Xcel agreed with the Agencies and the CEOs that the Commission should not attempt to address that matter here. Rather, Xcel argued, leakage should be addressed on a case-by-case basis as utilities incorporate environmental costs into their analyses of resource options.

C. The Recommendation of the Administrative Law Judge

The ALJ concluded that the Commission did not need to address leakage in order to fulfill its statutory mandate to establish a range of environmental costs for CO_2 emissions. But the ALJ recommended that the Commission open an investigation into the questions of how to best measure leakage, and whether and how to take leakage into account in other proceedings.

D. Commission Action

The Commission concurs with the ALJ that the task of calculating leakage of increased CO_2 emissions is not properly a part of this proceeding. The Legislature has charged the Commission with the task of quantifying environmental costs associated with electricity generation, which includes costs associated with CO_2 emissions. The issue of leakage does not pertain to the quantification of these costs, but to their application.

That said, at this time the Commission will decline to initiate an investigation to explore how to apply the concept of leakage in general. The Commission concludes that leakage cannot be meaningfully addressed except within the context of a utility's specific circumstances. The Commission reaches this conclusion because externality values are merely one factor it considers when approving a new source of electricity, and because the manner in which the Commission considers externality values limits the potential for leakage.

1. Leakage is only one factor for consideration.

First, externality values are merely one factor the Commission considers when approving a new source of electricity. The Environmental Cost Statute directs utilities to "use the [environmental cost] values established by the commission in conjunction with other external factors, including socioeconomic costs, when evaluating and selecting resource options in all proceedings before the commission, including resource plan and certificate of need proceedings."

Thus, the statute itself identifies factors beyond environmental costs—"other external factors, including socioeconomic costs"—for the Commission's consideration.

Moreover, the statute specifies that the externality values would be used for evaluating and selecting resource options in the context of, for example, resource-planning and certificate-of-need proceedings. When evaluating resource plans, the Commission seeks a plan that will minimize environmental harms—as well as promote service adequacy and reliability, keep bills and rates low, minimize socioeconomic harms, enhance the utility's operating flexibility, and reduce the utility's risks.[47] Similarly, when evaluating a certificate of need, the Commission considers the need to protect the natural environment—as well as considerations of the future adequacy, reliability, or efficiency of the energy supply; the consequences for the natural and socioeconomic environments, including human health; the applicable laws and policies of local, state, and federal authorities; and the potential alternatives to the proposed facility.[48] Thus, any presumption that environmental costs are the sole—or even dominant—factor driving the selection of a new generator is unsupported.

2. Context can limit the harms of leakage.

Second, the consequences of leakage are limited by the manner in which the Commission considers environmental costs. Specifically, while environmental costs may influence a utility's selection of generators, they would not thereafter alter the operating cost of those generators. The Environmental Cost Statute specifies that the Commission's environmental cost values would apply for purposes of selecting resource options, not for setting incremental energy prices.

Moreover, the problem of leakage cannot be evaluated on a generic basis. Context is necessary to determine how strongly environmental costs influence a resource plan, and how significantly leakage would undermine the goal of reducing environmental costs.

To aid this kind of analysis, the Commission long ago required resource plans to analyze various scenarios using various assumptions—and to include at least one option that excluded consideration of all externality values.[49] The Commission will direct utilities to continue this practice. By comparing a scenario that excludes environmental costs to other scenarios that consider such costs, all parties can gain some perspective about the size of environmental costs relative to other considerations.

In summary, because externality values are merely one factor the Commission considers when approving a new source of electricity, and because the manner in which the Commission considers externality values limits the potential for leakage, the Commission will not attempt to quantify the effects of leakage on a generic basis. Rather, the Commission will leave it to parties to address this matter in resource plans and certificate-of-need proceedings, as appropriate.

VI. Conclusion – Cost of Carbon

Twenty years after the Commission first established externality values for CO_2 under the Environmental Cost Statute, the Commission finds that it is necessary to update those values to reflect developments in climate science and scientific literature and practice. The Commission is mindful that its decisions here do not, and cannot, reflect every nuance of that evolving field.

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[47] Minn. R. 7843.0500, subp. 3.

[48] Minn. R. 7849.0120.

[49] *See* January 1997 order, at 33.

Rather the Commission's decision is grounded in the goal of producing usable results that will aid the Commission and the parties in the evaluation and selection of future utility resources.

For the foregoing reasons, the Commission will adopt a range of environmental cost for CO_2 emissions associated with electricity generation as follows:

- The low end of the range shall reflect the global damage of the last (marginal) short ton emitted, calculated through the year 2100, with a 5.0% discount rate.

- The high end of the range shall reflect the global damage of the last (marginal) short ton emitted, calculated through the year 2300, with a 3.0% discount rate.

This formula generates the following ranges of CO_2 cost values through the year 2050:

Table 5: Environmental Cost Values for CO_2 (2017–2050)[50]
(2015 dollars per net short ton)

	Low	High		Low	High
2017	$8.44	$39.76	2034	$11.92	$55.07
2018	$8.64	$40.66	2035	$12.12	$55.97
2019	$8.85	$41.56	2036	$12.33	$56.87
2020	$9.05	$42.46	2037	$12.53	$57.77
2021	$9.25	$43.36	2038	$12.74	$58.67
2022	$9.46	$44.26	2039	$12.94	$59.58
2023	$9.66	$45.16	2040	$13.15	$60.48
2024	$9.87	$46.06	2041	$13.35	$61.38
2025	$10.07	$46.96	2042	$13.56	$62.28
2026	$10.28	$47.86	2043	$13.76	$63.18
2027	$10.48	$48.77	2044	$13.97	$64.08
2028	$10.69	$49.67	2045	$14.17	$64.98
2029	$10.89	$50.57	2046	$14.38	$65.88
2030	$11.10	$51.47	2047	$14.58	$66.78
2031	$11.30	$52.37	2048	$14.79	$67.68
2032	$11.51	$53.27	2049	$14.99	$68.58
2033	$11.71	$54.17	2050	$15.20	$69.48

[50] Utilities' Compliance Filing, Table 2 (August 3, 2017). Values for 2020 and 2050 were derived from conducting runs of the full suite of integrated assessment models consistent with the July 2015 IWG Technical Support Document; other values were derived from a linear interpolation/extrapolation from the model-based values.

Combining the higher discount rate with the shorter time horizon generates the lowest practicable estimate of CO_2 costs. Combining the lower discount rate with the longer time horizon generates the highest practicable estimate. By considering resource plans prepared with these costs—along with a scenario that excludes consideration of externality costs—the Commission will gain insight into the magnitude of the CO_2-related stakes in any resource choice.

CRITERIA POLLUTANTS

I. Introduction

A. The Criteria Pollutants

In addition to carbon dioxide, the CEOs asked the Commission to revisit the values it established in 1997 for nitrogen oxides (NO_x) and sulfur dioxide (SO_2) and to establish, for the first time, a value for fine particulate matter ($PM_{2.5}$).[51]

The parties and the ALJ refer to NO_x, SO_2, and $PM_{2.5}$ as "criteria pollutants" because they are among the pollutants for which the federal Clean Air Act requires the U.S. Environmental Protection Agency to establish national standards for permissible air-concentration levels. While those standards have no bearing on what values should be set under the Environmental Cost Statute, the phrase "criteria pollutants" remains a convenient shorthand for air pollutants that—in contrast to carbon dioxide—do not have global climatological impacts.

1. Fine Particulate Matter ($PM_{2.5}$)

$PM_{2.5}$ is composed of microscopic solids or liquid droplets that are so small that they can be inhaled by people and cause premature death (mortality) and disease (morbidity), including nonfatal heart attacks; irregular heartbeat; aggravated asthma; decreased lung function; increased respiratory symptoms, such as irritation of the airways; and coughing or difficulty breathing.

Beyond human health impacts, $PM_{2.5}$ can, depending on its chemical composition, contribute to acid deposition, which can harm the natural environment, damage sensitive agricultural crops, and stain or corrode manmade structures. $PM_{2.5}$ is also the main cause of reduced visibility (haze) in parts of the United States.

$PM_{2.5}$ is emitted directly from power plants as "primary" $PM_{2.5}$ and can also form as "secondary" $PM_{2.5}$ through reactions among other pollutants, called "precursors." Generally, primary $PM_{2.5}$ will have a larger impact on air quality closer to the emissions source, while secondary $PM_{2.5}$ will have impacts farther from the source.

2. Sulfur Dioxide (SO_2)

Through chemical reactions in the atmosphere, emissions of sulfur dioxide result in acid deposition. SO_2 can also act as a $PM_{2.5}$ precursor through the formation of sulfates.

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[51] *In the Matter of the Investigation into Environmental and Socioeconomic Costs Under Minn. Stat. § 216B.2422, Subd. 3*, Docket No. E-999/CI-00-1636, Memorandum in Support of Clean Energy Organizations' Motion to Update Externality Values for Use in Resource Decisions, at 1–2.

3. Nitrogen Oxides (NO_x)

Nitrogen oxides contribute to acid deposition as well as the formation of $PM_{2.5}$ and ozone. The health effects of ozone exposure include lung irritation and lower resistance to respiratory infections.

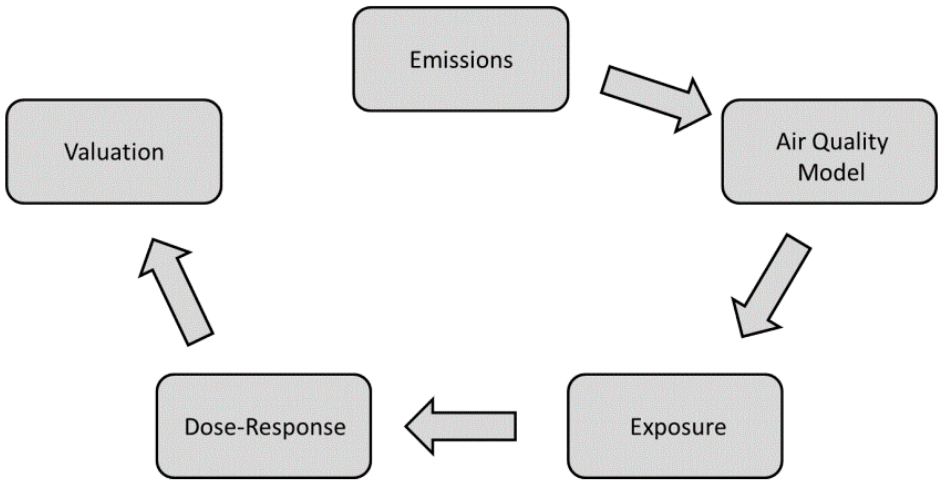
B. Estimating Criteria-Pollutant Damages: Integrated Assessment Modeling

Three parties—the Agencies, the CEOs, and Xcel—used integrated assessment models to calculate the damages caused by emissions of criteria pollutants. Their approaches differed in various respects, but the basic structures of their models were similar.

To begin, each party selected a geographic study area—either the contiguous United States or a smaller region around Minnesota—within which the damages from criteria pollutants would be measured. The study areas were subdivided into counties or grid cells. Parties then estimated the existing concentrations of criteria pollutants in each county or cell, typically using data drawn from national pollution databases.

Next, parties took emissions data from existing power plants, or hypothetical plants that might be built in the future, and fed the data into an air-quality model to predict how much these sources would increase the ambient concentrations across the study area. This step corresponds to the first two boxes in Figure 1, below.

Figure 1: Structure of an Integrated Assessment Model[52]



Each party's model also included demographic data about the location and size of the human populations in the study area ("Exposure," Figure 1). To this population data, the parties applied a "dose–response function" drawn from the epidemiological literature and intended to represent the relationship between exposure to a pollutant and human mortality ("Dose-Response," Figure 1).[53]

[52] Muller Direct, at 5.

[53] Parties also referred to this formula as a "concentration-response function."

Using dose–response functions and the results of their air-quality modeling, the parties estimated how much death rates would increase at a given location due to increased emissions. In addition to mortality, some of the models also considered human morbidity, agricultural damage, visibility impacts, staining, and corrosion, but in general the lion's share of damages was attributable to human mortality.

Finally, the parties assigned a dollar value to these impacts by (in the case of human mortality impacts) multiplying the deaths projected to result from criteria-pollutant emissions by a dollar amount intended to represent the economic value of one human life (Figure 1, "Valuation"). The result was a value expressed in dollars per ton of criteria pollutant emitted.

C. Summary of Recommended Cost Values

The Agencies, the CEOs, and Xcel recommended that the Commission adopt a range of costs for each pollutant to reflect the uncertainty involved in each step of integrated assessment modeling.

In general, the low end of a range reflected a party's view of the most optimistic combination of assumptions—emissions, dose–response function, value of statistical life, etc.—reasonably likely to occur. In contrast, the high end reflected a pessimistic yet, in the party's view, still reasonable, set of assumptions.

The parties' cost values were based on different years (the Agencies, for example, presented their values in 2011 dollars), but translating the values into equivalent inflation-adjusted figures does not significantly affect their relative magnitude.

1. The Agencies' Values

The Agencies calculated damage costs ranging from $12,835 to $553,638 per ton of $PM_{2.5}$ emitted by Minnesota sources. For SO_2, the range was $4,310 to $127,410 per ton, and for NO_x, $65 to $28,069 per ton. The Agencies separately calculated values for 87 Minnesota counties and 6 individual power plants. As a summary, they presented the following statewide averages:

Table 6: Agencies' Average Cost Values for Minnesota Sources
(2011 dollars per ton)

	Low Damage Assumptions			High Damage Assumptions		
	Average (std. dev.)	Min. value	Max. value	Average (std. dev.)	Min. value	Max. value
Primary $PM_{2.5}$	26,012 (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 Agencies also calculated cost values for some 400 emissions sources located outside of Minnesota but within 200 miles of the state's border, excluding Canada:

Table 7: Agencies' Average Cost Values for Out-of-State Sources
(2011 dollars per ton)

	Low Damage Assumptions			High Damage Assumptions		
	Average (std. dev.)	Min. value	Max. value	Average (std. dev.)	Min. value	Max. value
Primary $PM_{2.5}$	24,122 (17,393)	10,804	217,919	130,485 (89,806)	59,303	1,100,000
SO_2	8,656 (4,157)	3,221	20,863	47,158 (22,515)	17,631	110,679
NO_x	939 (437)	55	2,559	4,967 (2,398)	227	13,757

2. The CEOs' Values

Like the Agencies, the CEOs calculated cost values for power plants in Minnesota and within 200 miles of the state's border, excluding Canada. For each county in this geographic area, the CEOs proposed cost ranges for each criteria pollutant at three different smokestack heights, for a total of nine cost ranges per county.

The CEOs presented a sampling of their recommended values for different counties for illustrative purposes. The full set of values for a power plant in Ramsey County, one of the most populous counties in Minnesota, is set forth in Table 6, below:

Table 8: CEOs' Cost Values for Ramsey County, Minnesota
(2015 dollars per ton)

	Low stack height	Medium stack height	High stack height
$PM_{2.5}$	339,328 – 591,975	99,675 – 173,887	31,486 – 54,929
SO_2	15,914 – 27,762	16,430 – 28,663	17,472 – 30,480
NO_x	30,657 – 53,482	12,816 – 22,358	5,701 – 9,945

The CEOs also calculated a set of "generic" damages values, to be used in situations where the location of a potential plant is unknown:

Table 9: CEOs' Generic Cost Values
(2015 dollars per ton)

	Min. value	Max. value
$PM_{2.5}$	$125,000	$218,000
SO_2	$16,000	$28,000
NO_x	$14,000	$24,000

3. Xcel's Values

Xcel recommended three sets of cost values, corresponding to three possible power-plant locations: rural, metropolitan fringe, and urban. As shown in the following table, the cost values ranged from $3,437 to $25,137 per ton of $PM_{2.5}$ emitted, $1,985 to $7,893 for NO_x, and $3,427 to $14,382 for SO_2.

Table 10: Xcel's Recommended Cost Values
(2014 dollars per ton)

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

D. Summary of the Issues

The Commission's primary objective is to determine what set of criteria-pollutant externality values is best supported by the record and most appropriate for use in making decisions about the electric generating facilities that will be built in Minnesota in the future. To accomplish this objective, the Commission must address several key issues that arise from the parties' differing approaches to estimating those values:

- ***Air-Quality Modeling*—**Which of the air-quality models employed in this proceeding is soundest and most reliable from a technical perspective?
- ***Source Locations*—**What emissions sources, at what locations, should be considered in setting externality values?
- ***Geographic Scope of Damages*—**Should pollution costs be determined on a national scale or be limited to damages occurring in and near Minnesota?

- ***Dose–Response Function*—**What relationship between $PM_{2.5}$ concentration and all-cause mortality is best supported by the record?
- ***Value of a Statistical Life*—**What value of a statistical life is best supported by the record?

II. Air-Quality Modeling

A. Introduction

The behavior of pollutants in the atmosphere is governed by complex physical and chemical processes, which the parties endeavored to simulate using air-quality models that took emissions data from real or hypothetical power plants and predicted how those emissions would impact pollution in downwind areas.

The parties' overall approaches to modeling fell into two categories: reduced-form modeling and photochemical-grid modeling. Reduced-form models use simplified mathematical functions to predict pollutants' transport, transformation, and removal from the atmosphere. For example, a reduced-form model might represent chemical reactions among pollutants using constant conversion rates defined as a function of wind speed.

Photochemical-grid models, by contrast, are designed to simulate environmental conditions in a high degree of detail. For example, such a model might calculate reactions among pollutants on a minute-by-minute basis. Photochemical-grid models generally provide the most realistic predictions of air-pollutant behavior but, due to their complexity, require significant computational resources and time to execute.

Parties criticized each other's choice of model—reduced-form or photochemical-grid—and also took issue with the methods and assumptions that other parties employed in their modeling. Below, the parties' modeling approaches and criticisms are described, and the ALJ's findings on each model summarized.

B. The Agencies' Model (AP2)

1. Summary of Model

The Agencies used AP2, a reduced-form model, to create their damage estimates.

The Agencies modeled six existing Minnesota power plants, a hypothetical source in each of Minnesota's 87 counties, and 400 additional sources located within 200 miles of the state. One source at a time, the Agencies increased the emissions of a single pollutant by a single ton, holding other variables constant, and calculated the impact on ambient concentrations of $PM_{2.5}$ and ground-level ozone.

The Agencies' model considered damages from exposure to ambient $PM_{2.5}$ and ground-level ozone, which the Agencies believed would account for the major effects of the three criteria pollutants. Moreover, the Agencies limited their model to human health impacts—mortality and morbidity—and impacts on economically important crops. They excluded impacts on visibility, timber yields, and acidification, maintaining that these contribute a very small share of total damages.

2. Criticism

Xcel contended that AP2, as a reduced-form model, could not be relied on to accurately simulate the transport and dispersion of criteria pollutants. It argued that the model used data that was outdated and from different time periods and that it failed to account for hourly, daily, and seasonal variations in pollutant concentrations, rendering its estimates of ozone and secondary $PM_{2.5}$ unreliable.

Xcel also criticized the Agencies' decision to model each pollutant in isolation from the others, arguing that this would lead the model to overstate particulate nitrate formation. And it argued that the Agencies' decision to model the emission of one incremental ton of each pollutant, rather than the emissions of a whole plant, resulted in ambient concentrations that were too small to be viewed as reliable.

The Agencies disagreed with Xcel's assertion that photochemical-grid models are more accurate than reduced-form models. They emphasized that AP2 achieved satisfactory scores under common model-performance-evaluation tests (referred to as "Boylan and Russel standards").

The CEOs argued that AP2 was not as refined as their model (a reduced-form model called InMAP) because AP2 models the transport, transformation, and deposition of pollution using constant wind speeds, conversion rates, and deposition rates, and uses a less detailed spatial resolution.

The Agencies, however, responded that a comparison of the models' results demonstrated that AP2 is at least as reliable as the CEOs' model.

C. The CEOs' Model (InMAP)

1. Summary of Model

The CEOs used a new reduced-form model called InMAP to generate their damage estimates. InMAP's predictions are constructed on baseline air quality information taken from a complex air quality model called WRF-Chem.[54]

Like the Agencies, the CEOs modeled increased emissions at hypothetical sources in each Minnesota county and at counties within 200 miles of the state. Each hypothetical source was modeled with a low, medium, and high stack height. The CEOs also calculated a set of "generic" values using data from Minnesota's existing fleet of power plants.

The CEOs' model only considered damages from exposure to primary and secondary $PM_{2.5}$; damages from SO_2 and NOx emissions were counted to the extent that they contributed to the formation of secondary $PM_{2.5}$. Further, the CEOs considered only the human-mortality impacts of $PM_{2.5}$; non-mortality impacts and environmental impacts were not included in InMAP's predictions.

2. Criticism

The Agencies expressed some concern that the CEOs incorporated only $PM_{2.5}$'s effects on adult mortality rates into their damages estimates. However, the Agencies acknowledged that the

[54] Weather Research and Forecasting with Chemistry

effect of excluding non-mortality impacts was likely small, noting that in the Agencies' analysis, morbidity effects contributed less than five percent of the total damages.

Xcel criticized InMAP for being a new, relatively untested model that does not fall into any of the EPA's recommended model categories. Xcel asserted that InMAP had not demonstrated the ability to reproduce either the observed ambient air concentrations or marginal changes, both of which are expected of an air-quality model.

Xcel argued that because InMAP relies on average annual wind speed, direction, and turbulence data, it cannot account for seasonal and daily variations in ozone and $PM_{2.5}$ formation, resulting in overestimates of ambient concentrations to the east, and underestimates to the west. Xcel also criticized the CEOs' use of area sources rather than point sources in their modeling of county-by-county emissions, arguing that modeling area sources would overstate ozone and $PM_{2.5}$ impacts.

Finally, Xcel criticized the CEOs' model performance evaluation on several bases—in particular, their use of WRF-Chem control scenarios. Xcel contended that these scenarios were developed for measuring emissions from mobile sources (i.e., vehicles), which have very different characteristics than power plants.

D. Xcel's Model (CAMx)

1. Summary of Model

Xcel used CAMx, a photochemical-grid model, to estimate the changes in ambient pollution concentrations from three hypothetical plants, each one located in a different area of the state and intended to represent unique resource-planning scenarios: an urban power plant, a plant at the metropolitan fringe, and a rural plant.[55]

After modeling baseline concentrations, Xcel calculated the incremental changes in air quality caused by each plant. CAMx produced hourly concentrations for 92 chemical species for 25 vertical layers in each of the study area's 4,615 cells for 24 hours a day, each day of the year. This resulted in approximately 93 trillion hourly concentrations for each plant.

Xcel included primary and secondary $PM_{2.5}$ in its study, attributing the effects of secondary $PM_{2.5}$ to SO_2 and NO_x. It also modeled ozone, attributing its effects to NO_x emissions. Xcel estimated damages in the following categories: human health (both mortality and morbidity), agriculture (crop production), materials (corrosion and soiling), and visibility.

Xcel compared its CAMx results with actual ambient-concentration data and found that the results corresponded well with the actual ambient conditions. To the extent that there were differences in a few instances, CAMx was more likely to overstate baseline ambient concentrations, especially for ozone and $PM_{2.5}$. Xcel also tested its CAMx model using EPA's model-evaluation criteria, and found that it performed as well as or better than many other recent photochemical-grid applications.

[55] The hypothetical plants were located in three Minnesota cities: Burnsville, the site of Xcel's Black Dog plant (urban); Becker, the site of Xcel's Sherco plant (metro fringe); and Marshall (rural).

2. Criticism

The Agencies and the CEOs argued that photochemical-grid models like CAMx may not be the best tool in every case because they require significant amounts of time and computational resources to run, making it prohibitive to model a large number of plants or scenarios. They argued that reduced-form models, by including only essential atmospheric processes, are more practical and generate comparable results.

The Agencies and the CEOs also criticized Xcel's decision to model its rural and metro-fringe plants simultaneously, arguing that doing so could cause distorted results and made it impossible to determine the separate impact of each plant because their emissions were commingled.

Xcel acknowledged that emissions from one generator could change the background chemistry of the other, although it believed that outcome unlikely in this case. Xcel subsequently conducted separate modeling runs for each plant and confirmed that the two plants did not significantly impact each other's results.

Finally, the Agencies argued that Xcel's inadvertent use $PM_{2.5}$ emissions data from the wrong power plant in modeling one of its hypothetical plants rendered the CAMx results invalid.[56] Xcel, however, argued that the error did not affect its ultimate externality values because the relationship of $PM_{2.5}$ emissions to ambient concentrations is linear.

E. The Recommendation of the Administrative Law Judge

The ALJ concluded that CAMx was the most reliable model and would be appropriate to use in this matter if the Commission were to limit the sources and source locations under consideration. However, the ALJ recommended that the Commission use the AP2 model if it decides adopt an approach similar to the Agencies, which would require modeling a large number of sources.

1. AP2

ALJ found that the Agencies failed to demonstrate by a preponderance of the evidence that modeling individual pollutants separately is an approach commonly used in this field. But she also found that, when compared to Xcel's CAMx results, AP2 did not appear to overstate nitrate formation.

The ALJ concluded that the Agencies had failed to demonstrate that the AP2 model, when evaluated according to the Boylan and Russell performance standards, generally performs at the highest standards of the performance goals when compared to CAMx, or that it performs at adequate standards when compared to real ambient monitor data from the EPA.

The ALJ found that the Agencies' performance evaluations were not reliable, and that the Agencies had failed to respond substantively to many of Xcel's concerns about the way in which the Agencies conducted the performance evaluations.

[56] Specifically, Xcel used an emissions rate of 9.4 tons of $PM_{2.5}$ per year (based on its Riverside plant's emissions) rather than 341 to 359 tons of $PM_{2.5}$ per year (based on the actual emissions of its coal-fired Sherco plant). The company provided corrected data in a letter filed on October 13, 2015.

Despite these deficiencies, the ALJ found that AP2 and its predecessor have a substantial history of being used for purposes similar to AP2's use in this proceeding, and recommended that the Commission use the AP2 model if it decides adopt an approach similar to the Agencies, involving the modeling of a large number of sources.

2. InMAP

The ALJ concluded that the CEOs failed to demonstrate that the InMAP model is reasonable, practicable, and the best model to measure criteria-pollutant externalities.

The ALJ found that InMAP represented a departure from typical reduced-form models, and that the complexities that the CEOs claim make it more accurate and realistic also make it much less transparent than a typical reduced-form model. She found that the CEOs had made no demonstration that InMAP has been accepted for publication following peer review or that it has a history of being relied upon in other settings for similar purposes.

The ALJ also identified issues with the CEOs' implementation of InMAP that cast doubt on their modeling results. She found that they did not demonstrate that modeling counties as area sources was reasonable. Moreover, she found that the CEOs did not address Xcel's criticism that comparing the results to WRF-Chem control scenarios was not valid.

3. CAMx

The ALJ concluded that CAMx was the most reliable model and would be appropriate to use in this matter if the Commission were to limit the sources and source locations under consideration. But given its computational demands, she found that CAMx would not be practicable under an approach like that of the Agencies or the CEOs.

The ALJ concluded that Xcel's decision to model rural and metro-fringe plants simultaneously did not have significant impacts on their damage costs. However, she concluded that Xcel failed to demonstrate the reliability of its urban plant's damage costs because it failed to recalculate those costs following the discovery of its accidental use of $PM_{2.5}$ emissions data from the wrong facility.

The ALJ did not credit Xcel's explanation—that the error had no impact on its final externality values because of the linear relationship between ambient $PM_{2.5}$ concentrations and $PM_{2.5}$ emissions. Specifically, she found that Xcel had failed to demonstrate why the simultaneous discharge of SO_2 and NO_x, reported in the correct quantities, with an artificially low amount of $PM_{2.5}$ would not have distorted the modeling results.

F. Commission Action

The Commission concurs in most of the Administrative Law Judge's findings on this issue. For the reasons explained below, the Commission concludes that the CAMx air-quality model is the most reliable of the air-quality models employed by the parties and should be used for setting externality values in this case.

CAMx was the most technically complete of the three models used in this case. It incorporated hourly, variable, three-dimensional wind speeds and direction, as well as detailed chemistry algorithms to model ambient air-quality changes. It was the only model that could accurately

determine the dispersion of emissions throughout the year; incorporated flue-gas chemistry; and accurately accounted for chemical reactions in the atmosphere.

Xcel compared its CAMx results with data on ambient concentrations and found that they corresponded well with actual conditions. Xcel also conducted extensive testing using EPA's model-evaluation criteria, and found that its CAMx model performed as well as or better than many other recent photochemical-grid-model applications.

None of the parties criticized CAMx as a model, other than to state that it is too cumbersome to simulate the number and geographical variety of sources that the Agencies and CEOs claim are appropriate. However, as explained in the next section, the Commission does not require such fine geographic detail for resource-planning purposes.

The only major criticism of CAMx that the ALJ found persuasive was Xcel's use of the wrong $PM_{2.5}$ emissions data in modeling its metro-fringe plant. Xcel inadvertently used the $PM_{2.5}$ emissions rate for its Riverside natural-gas-powered plant instead of the $PM_{2.5}$ emissions rate for Unit 1 of its Sherco coal-fired plant. The ALJ concluded that Xcel failed to demonstrate why this error would not have skewed the modeling results.[57]

The Commission declines to adopt the ALJ's conclusion. The evidence shows that primary $PM_{2.5}$—which is emitted directly from the smokestack of a power plant—does not react with other chemicals or emissions in the plume. Thus, the relationship between the amount of primary $PM_{2.5}$ emitted and the resulting ambient concentrations of $PM_{2.5}$ is linear, and using the wrong emissions rate (tons per year) does not affect the damages per ton of pollutant emitted.

The ALJ found various problems with the other parties' models. In the case of AP2, she found that the Agencies failed to show that modeling pollutants separately is an accepted approach (although particulate concentrations did not appear to be overstated in the results), and that there were a number of issues with the Agencies' model performance evaluations that rendered them invalid. And she found InMAP to be a nonstandard, untested model and identified issues with CEOs' implementation of InMAP that cast doubt on their modeling results.

The Commission concurs. For all the foregoing reasons, the Commission finds that CAMx is the most reliable model in the record.

III. Source Locations

A. Introduction

As described earlier, each party selected a different group of sources for which to calculate damages.

To some extent, parties' choice of sources was dependent on the capabilities of their individual models—for example, the Agencies and the CEOs chose to model numerous source locations, a task for which their reduced-form models were ideally suited. But the choice also reflected a

[57] *See* ALJ's Findings of Fact, Conclusions, and Recommendations: Criteria Pollutants, Conclusion of Fact 27 (June 15, 2016).

party's view of the level of externality-cost detail that would be most useful to the Commission in resource-planning proceedings.

B. Positions of the Parties

1. The Agencies and the CEOs

The Agencies and the CEOs took similar approaches, calculating damages for a hypothetical power plant in each county in Minnesota. They both also calculated damages for sources outside Minnesota but within 200 miles of the state's border—which, in the Department's modeling, amounted to nearly 400 source locations.

The Agencies and CEOs contended that modeling emissions from every county in Minnesota was important because it captures variations in the effects of emissions from sources across the state.

With regard to modeling sources outside Minnesota, the Agencies noted that in the last proceeding, the Commission adopted cost values for out-of-state sources within 200 miles of the border. They maintained that, to be consistent with that prior decision, and because power plants within 200 miles of Minnesota could have an impact on the state's air quality and supply electricity demand in Minnesota, their externality costs should be estimated.

The Agencies criticized Xcel's use of only three source locations in its modeling, arguing that three source categories could not adequately represent the variety of sources of criteria-pollutant emissions in Minnesota. The Agencies speculated that the main reason Xcel chose only three source locations was the time and expense needed to run the CAMx model, which requires approximately three weeks of computing time for each modeling run.

2. Xcel

Xcel modeled three hypothetical sources intended to represent three broad categories of generating-facility locations the Commission might encounter in resource-planning proceedings: urban, rural, and metropolitan fringe.

Xcel maintained that its three-category approach was consistent with the Commission's approach in the last proceeding, where the Commission concluded that rural, metro-fringe, and urban categories were practicable and appropriate for resource-planning purposes. Xcel argued that the cities where it located the hypothetical plants (1) are realistic locations for a power plant—Xcel operates power plants at two of the chosen locations—and (2) represent a cautious approach because they are located in, or upwind of, significant population centers.

Xcel disagreed with the Agencies' and CEOs' decision to model sources for every county in Minnesota and within 200 miles of the border. It reasoned that creating cost estimates for this many source locations would require thousands of modeling runs and a low level of detail. Given a low level of detail, the company argued, modeling emissions damages from each county gives a false illusion of precision.

C. The Recommendation of the Administrative Law Judge

The Administrative Law Judge concluded that the Commission is best positioned to determine the number and location of sources that will serve its purposes. She found nothing in the law that directed the Commission how to make this determination, other than the requirement that the decision should be practicable and lead to numbers that carry some indicia of reliability in what is an uncertain area.

The ALJ suggested that it would be reasonable for the Commission to consider some other structure than the geographical categories adopted in the last case, since modeling capabilities have matured significantly since that time. But she also found that the computational intensiveness of CAMx would make it impracticable to use if the Commission were to adopt an approach that examines more than a handful of sources.

The ALJ found that the Agencies and the CEOs did not demonstrate that their approach to Minnesota sources was reasonable, finding nothing in the record to indicate that the Commission requires county-by-county detail in resource-planning, certificate-of-need, or related proceedings.

Similarly, with respect to out-of-state sources, the ALJ reasoned that accounting for the impact of sources outside Minnesota does not require the Commission to adopt externalities values for nearly 400 sources and source locations. She found that the sheer number of sources proposed by the Agencies and CEOs made including them cumbersome and potentially confusing.

D. Commission Action

The Commission concurs with the Administrative Law Judge that the statute affords the Commission broad discretion to establish externality values suitable for evaluating and selecting resource options in resource-plan and certificate-of-need proceedings before the Commission. Accordingly, as further explained below, the Commission will maintain the same three source categories established in the January 1997 order: urban, rural, and metro-fringe.

The Commission favors the urban/rural/metro-fringe structure because it recognizes that the cost of criteria-pollutant emissions depend to a great degree on the source's proximity to population centers. The purpose of this proceeding is to quantify the costs associated with power-plant pollution; human health impacts are the main driver of these costs, and human health impacts depend on two main factors: the concentration, or dose, of pollution and the number of people exposed to it.

The three source locations chosen by Xcel broadly represent the main population-proximity scenarios that the Commission is likely to encounter in resource-planning proceedings. Xcel chose the locations conservatively, so that each set of geographic values—urban, rural, and metro-fringe—would fully reflect the environmental costs of siting a plant in that type of location. And since these are the same categories that the Commission currently uses, stakeholders should readily be able to apply them with minimal risk of confusion.

The Agencies and the CEOs took a "more information is better" approach to selecting emissions sources to model. While more information may be desirable in general, the Commission must also consider the quality of the information. As discussed in the previous section, the modeling results that these parties would have the Commission rely on are not the best information in the

record. And the Commission agrees with the ALJ and Xcel that the Commission does not need to understand the potential impact of hundreds of hypothetical sources in order to make informed resource-planning decisions.

For the foregoing reasons, the Commission finds that the three source categories modeled by Xcel sufficiently capture the information it is likely to need for resource-planning purposes.

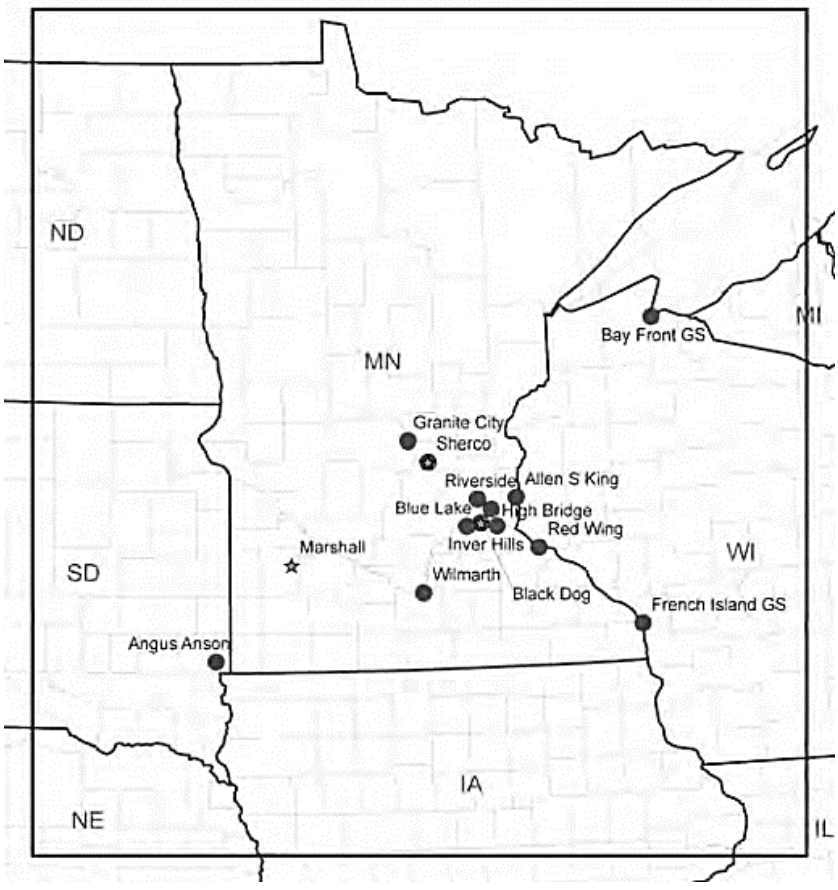
IV. Geographic Scope of Damages

A. Introduction

In addition to choosing what emissions sources to model, each party selected the area in which to determine the damages from those sources' emissions.

Parties took one of two approaches to select a geographic scope of damages: The Agencies and the CEOs both modeled damages occurring across the entire contiguous United States. Xcel, on the other hand, calculated damages occurring in Minnesota and portions of neighboring states within approximately 100 miles of Minnesota's borders:

Figure 2: Xcel's Geographic Study Area



B. Positions of the Parties

1. The Agencies and the CEOs

The Agencies acknowledged that the most significant effects on ambient concentration of $PM_{2.5}$ generally occur within about 200 miles of a plant; however, they asserted that emissions from a plant in Minnesota affect $PM_{2.5}$ levels throughout the United States.

The Agencies disagreed with Xcel's decision to calculate damages values based on a geographic area that included just Minnesota and a band extending approximately 100 miles from the state's borders. The Agencies argued that this approach rendered Xcel's estimates artificially low and that there was no scientific or practical reason for limiting damages to this domain.

The Agencies noted that part of Xcel's justification for limiting its damages calculation geographically was to be consistent with the Commission's approach in the earlier proceeding; however, the Agencies argued that Xcel's approach in this proceeding has not always been consistent with that case.

The CEOs, similarly, challenged Xcel's decision to limit the geographic scope of its estimated damages to Minnesota and an approximately 100-mile band around Minnesota's borders. They asserted that much of the $PM_{2.5}$ and NO_x damages, and a majority of the SO_2 damages, from a generic power plant would occur outside Xcel's geographic modeling domain.

The CEOs stated that, a week before surrebuttal testimony was filed, Xcel provided them with modeling results for a larger modeling domain, although at a lower resolution than what Xcel used for its other modeling. After analyzing this data, the CEOs concluded that less than half of Xcel's CAMx damages occur in Minnesota and the surrounding 100-mile strip.

2. Xcel

Xcel stated that it limited its study area to be consistent with the first externalities case, in which the Commission quantified the costs of criteria pollutants based only on those damages occurring within Minnesota.[58]

Xcel argued that a limited study area makes sense because, unlike carbon dioxide, the impact of criteria pollutants is mostly local and regional. It maintained that primary emissions of $PM_{2.5}$, SO_2, and NO_x will generally be greatest near the source, and that concentrations are typically small at a distance of 50 kilometers. Secondary $PM_{2.5}$ formed from SO_2 and NO_x emissions travel further, but Xcel argued that the majority of concentration changes will still take place within 100 miles of the source.

Xcel argued that determining damages on a national scale hinges on the ability of models to accurately predict changes in ambient air concentrations throughout the contiguous United States. Based on the limitations of reduced-form models, Xcel doubted whether AP2 and InMAP could be relied on to produce accurate results on a national scale. Xcel also stated that EPA

[58] *See* January 1997 order, at 15.

guidance recommends that reduced-form models only be used to model impacts on receptors located up to 50 km away from an emissions source.

Finally, Xcel argued that there was no need to estimate impacts from criteria pollutants far beyond Minnesota because federal regulations—specifically the Cross-State Air Pollution Rule, or CSAPR—ensure that Minnesota sources do not have a significant impact on downwind states.

C. The Recommendation of the Administrative Law Judge

The Administrative Law Judge observed that Minn. Stat. § 216B.2422 is silent as to whether the Commission must include damages outside of Minnesota and concluded that whether the geographic scope of damages should extend beyond Minnesota's borders is a policy question for the Commission.

The ALJ acknowledged that emissions from Minnesota generators travel beyond the state's boundaries. However, she found that primary $PM_{2.5}$ causes damages which are mostly local and regional and that, although SO_2 and NO_x can form secondary $PM_{2.5}$ at significant distances, the record did not contain reliable evidence of the percentage of SO_2 and NO_x emitted in Minnesota that causes impacts and damages outside the state.

The ALJ concluded that neither the CEOs nor the Agencies had proven that their respective models could reliably predict criteria-pollutant externality values across the contiguous United States. And even though she found that CAMx is capable of predicting impacts from criteria-pollutant emissions on ambient $PM_{2.5}$ in states as distant from Minnesota as Florida, the ALJ was not able to draw a conclusion as to the model's *reliability* in predicting the impact of emissions over such distances.

Finally, with respect to Xcel's argument that the federal Cross-State Air Pollution Rule prevents Minnesota's criteria-pollutant emissions from causing significant impacts in other states, the ALJ found that, while the CSAPR does not reduce out-of-state damages to zero, it does provide safeguards to alert federal and state officials if damaging amounts of pollutants cross Minnesota's borders.

D. Commission Action

The Commission concurs with the Administrative Law Judge that the Environmental Cost Statute leaves the decision about the geographic scale at which to calculate damages to the Commission's discretion. For the reasons explained below, the Commission finds that Xcel's study area—comprising Minnesota and an approximately 100-mile strip of surrounding territory—is the most appropriate scope of damages on this record.

In the first externalities case, the Commission limited the geographic scope of damages for criteria pollutants to Minnesota, citing the need to focus on the effects of generation byproducts that cause the most significant cost.[59] The Commission finds that that rationale still applies today. The changes in ambient concentrations caused by criteria-pollutant emissions decline with

[59] January 1997 order, at 15.

distance from the source; in the case of Minnesota sources, the majority of those changes and their impacts are confined to Minnesota and an area within 100 miles of its borders.

Moreover, modeling the dispersion of air pollutants involves substantial uncertainty. This uncertainty increases with distance and is further compounded by the small concentration changes predicted at great distances.

Even if the Commission were to look beyond a 100-mile range, the record in this case does not contain reliable evidence of criteria-pollutant damages beyond this distance. The Agencies and CEOs attempted to model emissions on a national scale, but for the reasons previously discussed, the results of their modeling are not credible.

There was some evidence that CAMx is capable of predicting impacts as far away as Florida. Specifically, the CEOs stated that, late in the contested-case proceeding, Xcel provided them with modeling results for a larger geographic scope. However, these results were at a lower resolution and were not subjected to any model-performance tests to ensure their reliability. Moreover, Xcel's expert witness credibly testified that CAMx could not predict damages throughout the contiguous United States with sufficient reliability to be used in this proceeding.

Finally, the Commission agrees with the ALJ that the federal Cross-State Air Pollution Rule, while it does not eliminate out-of-state damages, does provide safeguards to alert federal and state officials if damaging amounts of pollutants cross Minnesota's borders. The rule places emissions limits on sources that have been determined to have significant impacts on downwind states. The fact that Minnesota sources must comply with the CSAPR lends further support to the conclusion that quantifying criteria-pollutant damages beyond 100 miles is neither practicable nor necessary.

V. Dose–Response Function

A. Introduction

Not every person who comes into contact with air pollution suffers adverse effects; rather, changes in air pollution tend to affect the most vulnerable members of a population, such as the sick, the elderly, and the very young. Integrated assessment models account for this fact by employing dose–response functions, which use the increase in the concentration of a pollutant to calculate an expected change in death or disease rates.

Dose–response relationships are drawn from peer-reviewed research in the relevant scientific fields. In the case of human mortality, they are derived from epidemiological studies.

In this case, the parties placed particular emphasis on the mortality risk associated with $PM_{2.5}$ exposure, which had the greatest effect on overall damages.

B. The Agencies' and CEOs' Dose–Response Functions

1. Summary

The Agencies' model assumed a 6% to 14% increase in mortality risk for a 10 $\mu g/m^3$ increase in ambient $PM_{2.5}$.

The Agencies relied on two studies that are frequently cited in air-pollution-damage analyses: Lepeule's 2012 update of the Harvard Six Cities Study (Lepeule study),[60] and Krewski's 2009 update of the American Cancer Society Study (Krewski study).[61]

According to the Agencies, the Lepeule study found that a 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentration was associated with a 14% increase in adult mortality rates, while the Krewski study found that a one-unit increase in $PM_{2.5}$ was associated with a 6% increase in adult mortality rates. Because the choice between these two figures significantly affects the final damage amount, the Agencies used both values to calculate a range of damages associated with $PM_{2.5}$ emissions.

The CEOs assumed a dose–response relationship range of 7.8% to 14% in modeling $PM_{2.5}$ damages.

The CEOs relied on the same two epidemiological studies as the Agencies to derive their dose–response range. However, the CEOs derived a different figure—7.8%—from the Krewski study than the Agencies did.

The CEOs attributed this difference primarily to their effort to account for "ecologic covariates": factors other than pollution known or suspected to influence mortality in the relevant populations. Examples of ecologic covariates include the percentage of homes with air conditioning, percentage of adults with less than a grade 12 education, and percentage of self-reported white or non-white persons.

While each party considered its own dose–response range to be the most correct, neither considered the other's unreasonable, acknowledging that the choice was largely a matter of professional judgment.

2. Criticism

Xcel criticized the Agencies' and CEOs' approach for failing to use standard statistical methods to minimize uncertainty. According to Xcel, such methods include assigning weights to individual studies, creating a distribution from the weighted pool of studies, and developing a mean estimate and confidence interval. Moreover, Xcel argued that the Agencies and CEOs failed to provide an adequate explanation of why they included certain studies in their analysis and excluded others.

Xcel maintained that it is critical to conduct comprehensive literature reviews of relevant studies, to rely on several different studies, and to use meta-analysis techniques, especially when evaluating human-health damages.

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[60] Johanna Lepeule et al., *Chronic Exposure to Fine Particles and Mortality: An Extended Follow-up of the Harvard Six Cities Study from 1974 to 2009*, 120 ENVTL. HEALTH PERSP. 965 (2012).

[61] DANIEL KREWSKI ET AL., HEI RESEARCH REPORT 140: EXTENDED FOLLOW-UP AND SPATIAL ANALYSIS OF THE AMERICAN CANCER SOCIETY STUDY LINKING PARTICULATE AIR POLLUTION AND MORTALITY (2009).

C. Xcel's Dose–Response Function

1. Summary

Xcel used a dose–response range of 5.3% to 7.3%, with a mean of 6.8%.

It relied on a 2013 meta-analysis by Hoek and others (the Hoek study) that incorporates the results of 13 major cohort studies, including the Lepeule and Krewski studies.[62] Eleven of these studies estimated the additional risk of all-cause mortality associated with a 10 $\mu g/m^3$ increase in ambient concentrations of $PM_{2.5}$. To reflect the uncertainty in the literature, Xcel created a statistical distribution of dose–response values. It included values from the Lepeule study and a follow-up to the Krewski study,[63] but gave the most weight to the Hoek study, viewing it as the best synthesis of the available data.

To further address the uncertainty involved in estimating mortality damages, Xcel employed a "Monte Carlo" analysis, making thousands of random draws from its distribution of dose–response values and multiplying each value by another one randomly drawn from its value-of-statistical-life distribution[64] to derive a damages-value distribution.

2. Criticism

The Agencies agreed with the methodology Xcel used in developing its dose–response function. The CEOs, however, criticized Xcel's use of the 25th and 75th percentiles of its Monte Carlo distribution as the high and low ends of its damages range, arguing that doing so effectively excluded the values from the Lepeule study and Krewski follow-up study.

Xcel disagreed with the CEOs, arguing that the values from all three studies affected the Monte Carlo distribution—including both the 25th and 75th percentiles and the mean—even if a particular study's values did not fall within this "interquartile" range.

D. MLIG's Critique of the Dose–Response Evidence

1. Summary

The Minnesota Large Industrial Group asserted that the epidemiological literature did not demonstrate a relationship between $PM_{2.5}$ exposure and premature mortality at concentrations below 12 $\mu g/m^3$. It argued that the other parties erred by assuming that health effects would increase as $PM_{2.5}$ concentrations increased regardless of the ambient concentration level at a given locality.

MLIG presented evidence that the ambient air concentration of $PM_{2.5}$ in Minnesota has generally been below the National Ambient Air Quality Standard (NAAQS) of 12 $\mu g/m^3$. According to

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[62] *See* Gerard Hoek et al., *Long-term Air Pollution Exposure and Cardio-respiratory Mortality: a Review*, ENVTL. HEALTH 12:43 (2013).

[63] Michael Jerrett et al., *Spatial Analysis of Air Pollution and Mortality in California*, 188 AM. J. RESPIRATORY & CRITICAL CARE MED. 593 (2013).

[64] Xcel's value-of-statistical-life analysis is described in the next section.

MLIG, the EPA sets the NAAQS for $PM_{2.5}$ at a level that will protect public health with an adequate margin of safety. MLIG therefore argued that the ambient levels of $PM_{2.5}$ in Minnesota cannot be expected to cause increased health risks.

Specifically addressing the studies relied on by the Agencies and the CEOs, MLIG argued that "the Lepeule and Krewski reports do not address the question whether the concentration-response functions are valid in areas where the 3-year average mean ambient-air concentrations for $PM_{2.5}$ are below 12 $\mu g/m^3$." Rather, MLIG contended, the data underlying the Krewski study only show a statistically significant relationship at 13.2–13.8 $\mu g/m^3$ and above.

MLIG concluded, with a "reasonable degree of medical certainty," that the current and projected levels of $PM_{2.5}$ in Minnesota would not cause additional mortality over and above that occurring naturally and from other causes.

2. Responses

The Agencies and the CEOs disagreed that the Environmental Cost Statute requires causation to "a reasonable degree of medical certainty." They maintained that the epidemiological literature shows a linear relationship between $PM_{2.5}$ and mortality at all observed concentrations, and that there is no threshold below which $PM_{2.5}$ exposure is considered safe.

They also questioned the relevance of the EPA's national standard for $PM_{2.5}$, arguing that the EPA sets NAAQS based on policy judgments about the acceptable levels of risk and that the standard does not limit what scientific data the Commission may consider in determining environmental costs under section 216B.2422.

E. The Recommendation of the Administrative Law Judge

The ALJ noted that, although the Agencies, the CEOs, and Xcel criticized each other's approaches to establishing dose–response functions, their ranges of acceptable values overlapped. Based on the parties' recommendations, the ALJ suggested a 6.8% dose–response figure, or, if the Commission preferred to adopt a dose–response range to reflect uncertainty, a range of 6% to 7.3%.

Addressing MLIG's arguments, the ALJ found that the relationship between chronic exposure to $PM_{2.5}$ and all-cause cardiovascular and lung-cancer mortality was linear without a threshold. She reasoned that Minnesota's compliance with the $PM_{2.5}$ NAAQS did not reduce human-mortality damages to zero, and she concluded that the CEOs, the Agencies, and Xcel had demonstrated that it was appropriate to calculate mortality and morbidity damages for emissions of $PM_{2.5}$ in Minnesota even if the ambient air concentration of $PM_{2.5}$ was below 12 $\mu g/m^3$.

F. Commission Action

The Commission concurs with the Administrative Law Judge that the Agencies, the CEOs, and Xcel demonstrated a sufficient relationship between $PM_{2.5}$ exposure and health effects to justify quantifying the human-health damages associated with $PM_{2.5}$ emissions from power plants. However, the Commission declines to adopt the ALJ's recommended dose–response values. For the reasons explained below, the Commission finds that Xcel's dose–response function is the one best supported by this record.

Xcel's testimony outlined in detail the approach it took to developing its dose–response function. Xcel used the techniques of meta-analysis to select epidemiological studies, choosing studies based on their scientific soundness, level of detail, and relevance to the purposes of this proceeding. For each pollutant and damage category, the utility used several studies to estimate the amount of potential costs, weighting the studies to reflect their relative robustness.

In determining mortality risks from $PM_{2.5}$, Xcel relied primarily on a recent survey of 13 major cohort studies. To reflect the uncertainty in the literature, it considered that survey together with two other recent studies with more extreme findings (the Lepeule study and a Krewski study follow-up). Finally, Xcel used the results of its weighted analysis to create a Monte Carlo distribution reflecting how thousands of randomly drawn dose–response values affected the overall amount of damages.

Neither the Agencies' analysis nor the CEOs' analysis was as rigorous as Xcel's. The Agencies, moreover, agreed with Xcel's approach to generating a dose-response range. And while the CEOs criticized Xcel's decision to use the interquartile range of its Monte Carlo distribution, Xcel persuasively argued that the interquartile range reflected values from all studies considered, regardless of whether a study's values fell within that range.

MLIG argued that the other parties had not demonstrated a relationship between $PM_{2.5}$ exposure and premature mortality at the concentrations that exist in Minnesota. The crux of MLIG's argument was that the epidemiological literature does not address sustained exposure to $PM_{2.5}$ at concentrations below 12 $\mu g/m^3$. Given this, MLIG contended that the record did not establish the causal link between $PM_{2.5}$ emissions and health damages required under Minn. Stat. § 216B.2422.

The Commission disagrees. Although the key studies focused on cities whose long-term ambient concentrations were generally above 12 $\mu g/m^3$, the studies did not rule out a relationship at levels below 12 $\mu g/m^3$. At all concentrations studied, the relationship between all-cause cardiovascular and lung-cancer mortality was shown to be linear; any uncertainty about $PM_{2.5}$ impacts at concentrations below 12 $\mu g/m^3$ does not prevent the Commission from inferring a relationship at those levels based on a proven relationship at higher concentrations.

For all these reasons, the Commission finds that a dose–response range of 5.3% to 7.3% is best supported by the record.

VI. Value of a Statistical Life

A. Introduction

In calculating human-health damages, each party relied on a different estimate of the value of a statistical life.

The value of a statistical life, or VSL, is a measure of the monetary value to a person of reducing his or her mortality risk. There is no generally accepted, "correct" VSL. Rather, the VSL is estimated using one of two methods: stated-preference or revealed-preference analysis.

Stated-preference studies use surveys to determine how much people are willing to pay for a reduction in the likelihood of dying. Revealed-preference studies, by contrast, rely on evidence of real-world transactions that affect mortality risk. For example, when consumers purchase safety devices like bicycle helmets, smoke detectors, or fire extinguishers, these transactions reveal a willingness to pay a certain amount for a corresponding reduction in mortality risk.

The labor market is an important source of data for revealed-preference analyses. "Hedonic wage studies," a category of revealed-preference studies, use information about participants' household wages and on-the-job risks to infer the value associated with those risks.

B. The Agencies' VSL

1. Summary

The Agencies recommended a VSL range of $3.7 to $9.5 million (2011 dollars).

For the high end of their range, the Agencies used the VSL that the EPA uses in economic analyses of air pollution: approximately $9.5 million. The EPA's VSL was produced from a collection of 21 revealed-preference studies and 5 stated-preference studies. The Agencies argued that the fact that the EPA's VSL had been used in many air-pollution-related policy analyses bolstered its credibility.

For the low end of their range, the Agencies relied on a 2006 survey of a number of stated-preference and hedonic-wage studies, from which they drew a VSL of approximately $3.7 million (the Kochi survey[65]).

2. Criticism

The CEOs criticized the Agencies' VSL range, arguing that pairing the EPA figure (derived from both stated- and revealed-preference studies) with the $3.7 million figure (derived only from stated-preference studies in the Kochi survey) amounted to comparing apples and oranges.

Xcel criticized the Agencies' choice of VSL range for several reasons. It argued that the EPA value was based on outdated studies—the most recent of which was conducted in 1991—and that the Agencies' low-end value was based on only a subset of the studies surveyed in the Kochi survey. Moreover, Xcel argued that the Agencies failed to consider another study, the Mrozek and Taylor study,[66] which had lower VSL estimates than many other studies.

Finally, Xcel argued that the Agencies' analysis did not capture the full uncertainty in the underlying data. Although the EPA and the Kochi survey both relied on multiple studies, Xcel criticized the Agencies for failing to account for dispersion around the studies' means, or to use a Monte Carlo analysis to create a distribution of VSL estimates.

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[65] Ikuho Kochi et al., *An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for Environmental Policy Analysis*, 34 ENVTL. & RESOURCE ECON. 385 (2006).

[66] Janusz R. Mrozek and Laura O. Taylor, *What Determines the Value of Life? A Meta-Analysis*, 21 J. POL'Y ANALYSIS & MGMT. 253 (2002).

C. The CEOs' VSL

1. Summary

The CEOs recommended a VSL of $9.8 million (2015 dollars).

Like the Agencies, the CEOs relied on the EPA's VSL. However, unlike the Agencies, they did not recommend using it as part of a range. The CEOs maintained that the EPA's VSL is appropriate for use as a single value because the EPA derived it by taking the central tendency of many studies, including both hedonic-wage and stated-preference studies.

However, recognizing that the Commission may prefer a range, the CEOs stated that it would be appropriate to use the Kochi hedonic-wage value—$13.6 million—as the high end and the Kochi stated-preference value—$ 4.0 million—as the low end.

2. Criticism

The Agencies approved of the CEOs' choice of a VSL of $9.8 million, which was within the Agencies' recommended range. However, the Agencies asserted that using a single VSL figure instead of a range fails to recognize the uncertainty inherent in estimating the VSL.

Xcel criticized the CEOs' VSL approach for relying on a single, outdated study, with a relatively high result compared to other studies. Xcel maintained that there were several newer meta-analyses of VSLs that have larger sample sizes, use better statistical techniques, and provide a more thorough investigation of alternative model specifications.

D. Xcel's VSL

1. Summary

Xcel recommended a VSL range of $4.1 to $7.9 million (2014 dollars), with a mean of $5.9 million.

Xcel conducted a meta-analysis of recent studies, relying primarily on the Kochi survey. It used the Mrozek and Taylor study for an alternative low VSL estimate, and a 2003 study by Viscusi and Aldy[67] for an alternative high VSL estimate. Finally, Xcel included a fourth study from 2012 that was too recent for its results to have been incorporated in any of the other studies.[68]

Xcel assigned a weight of 55% to the Kochi survey, while the other three studies received a combined weight of 45% (15% each). Using this weighting, Xcel conducted a Monte Carlo analysis, drawing thousands of times from the studies' combined distribution and multiplying each value by another one randomly drawn from Xcel's dose–response distribution to derive a damages distribution. Xcel based its VSL range on the 25th and 75th percentiles of this distribution.

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[67] W. Kip Viscusi & Joseph E. Aldy, *The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World*, 27 J. RISK & UNCERTAINTY 5 (2003).

[68] Thomas J. Kniesner et al., *The Value of a Statistical Life: Evidence from Panel Data*, 94 REV. ECON. & STAT. 74 (2012).

2. Criticism

The Agencies agreed that Xcel's mean VSL of $5.9 million was reasonable, noting that it fell nearly directly in the center of the Agencies' range.

The CEOs argued that Xcel's VSL calculation was flawed because it was based on a distribution that included negative values. They contended that, because a negative VSL is highly implausible, Xcel should have excluded negative values in calculating a final VSL range.

Xcel responded that, while ultimately the VSL can be expected to be positive, eliminating negative values from a Monte Carlo distribution, without also removing too-high values, would tend to skew the distribution's curve, whose center is positive and represents the "true" VSL.

E. The Recommendation of the Administrative Law Judge

The Administrative Law Judge observed that, although the parties criticized each other's approaches to establishing a VSL, their ranges of acceptable values overlapped. She concluded that $7.70 million was a reasonable VSL value within the ranges recommended by Xcel, the Agencies, and the CEOs.

F. Commission Action

For the reasons explained below, the Commission finds that Xcel's recommended VSL range is the one best supported by the record. The Commission therefore declines to adopt the ALJ's recommendation on this issue.

The Commission finds Xcel's analysis of the value of a statistical life to be the most rigorous analysis in this record. The company accounted for uncertainty by doing a meta-analysis of several recent studies surveying both stated-preference and revealed-preference studies. Both types of studies have advantages and disadvantages; it is therefore reasonable to include both when determining the appropriate value of a statistical life for modeling purposes.

Finally, Xcel assigned weights to each of the studies in its meta-analysis, giving the most weight to the Kochi survey because it was recent (2006); analyzed the most complete set of individual studies; and used the most appropriate statistical methods. To further address uncertainty in the modeling, Xcel used the distribution resulting from its meta-analysis to create a Monte Carlo distribution, from which it derived its final VSL range.

The other VSL recommendations in this record—the Agencies' and the CEOs'—both incorporate the EPA's VSL figure, which is based on data that is nearly 25 years old. Moreover, neither party relied on meta-analysis techniques (other than those used in the underlying studies) or employed Monte Carlo analyses in developing their recommendations. The Commission therefore finds their recommendations less reliable than Xcel's.

Finally, the Commission finds unpersuasive the CEOs' contention that Xcel's VSL calculation was flawed because it was based on a distribution that included negative values. It would indeed be highly surprising if Xcel's final recommendation was to adopt a negative VSL. However, the company persuasively argued that it appropriately retained negative values in its VSL distribution so as not to skew the analysis.

For all these reasons, the Commission declines to adopt the ALJ's recommendation on the value of a statistical life.

VII. Conclusion – Criteria Pollutants

A. The Recommendation of the Administrative Law Judge

In light of the flaws she found in the parties' models, the Administrative Law Judge did not recommend that the Commission adopt any of their recommended externality cost ranges. Instead, the ALJ recommended that the Commission take one of two approaches in determining final externality values:

- The Commission could adopt a model configuration that provides a five- or six-tiered version of Xcel's three-tiered source groupings, with the additional tiers reflecting factors such as nearby topography, vegetation, and buildings. If the Commission chooses this option, the ALJ recommended that the CAMx model be rerun to calculate costs for the additional tiers.
- Alternatively, the Commission could adopt a model configuration that includes all 87 counties in Minnesota, but excludes out-of-state locations in eastern Wisconsin, Michigan, and Illinois, as well any out-of-state locations that do not have active power plants. If the Commission chooses this option or one similar in scope and size, the ALJ recommended that AP2 be used because it is the most reliable reduced-form model in the record.

B. Commission Action

Based on its analysis of all the foregoing issues, the Commission finds that Xcel's proposed externality values are the values that best quantify the environmental costs associated with emissions of criteria pollutants from power plants.[69]

Xcel modeled the dispersion of criteria pollutants using CAMx, a comprehensive, accurate, and reliable photochemical-grid model, using a geographic scope appropriate for criteria-pollutant emissions. It calculated costs for a manageable set of sources that were representative of the types of resource-planning scenarios the Commission is likely to encounter. Finally, Xcel's dose–response and VSL ranges reflect the most up-to-date epidemiological and economic literature, as well the most rigorous statistical methods.

The Agencies and the CEOs proposed values much higher than Xcel's, and they contended that Xcel's estimates omitted significant costs. However, Xcel maintained that, if anything, its values overstate criteria-pollutant damages. The company cited, among other factors that it argued made its estimates conservative:

- Basing its urban values on the impact of siting a coal-fired plant in the middle of a city;

[69] Because it finds Xcel's values appropriate as calculated, the Commission declines to adopt the ALJ's recommendation to rerun CAMx or AP2.

- Using the CAMx air-quality model, which, though it modeled emissions reliably, tended to overstate actual $PM_{2.5}$ and ozone concentrations;
- Using estimates for morbidity risks and VSL that likely overstate those values;
- Not adjusting mortality risks or VSL based on age; and
- Using cost-of-illness estimates for morbidity damages and replacement-cost estimates for materials damages, both of which tend to overstate damages compared to a willingness-to-pay valuation method.[70]

The Commission concludes that Xcel's modeling assumptions are reasonable and appropriately account for the uncertainty inherent in any effort to quantify damages from criteria pollutants. And comparing Xcel's proposed values to the other parties' values to assess the reasonableness of the former is not useful or appropriate given the flaws in the other parties' modeling.

For all these reasons, the Commission finds that Xcel's proposed externality values quantify, to the extent practicable, the environmental costs associated with electricity generation. It will therefore adopt them under Minn. Stat. § 216B.2422, subd. 3.

ORDER

1. The Commission hereby quantifies and establishes the range of environmental cost of carbon dioxide emissions associated with electricity generation as follows:

    - The low end of the range shall reflect the global damage of the last (marginal) short ton emitted, calculated through the year 2100, with a 5.0% discount rate.
    - The high end of the range shall reflect the global damage of the last (marginal) short ton emitted, calculated through the year 2300, with a 3.0% discount rate.

2. The Commission adopts the following environmental cost values for criteria pollutants (2014 dollars per ton):

[70] Xcel also noted that its recommended values were substantially larger than the values established in the first externalities case. For example, the costs per ton established for NO_x in the first proceeding ranged from $18 to $102 for rural sources and from $371 to $978 for urban sources. Xcel's recommended updated values for NO_x range from $1,985 to $6,370 per ton for rural sources and from $2,760 to $7,893 per ton for urban sources. Xcel attributed much of the increase to significant advances in the scientific understanding of the effects of pollution on human health, as well as the availability of enhanced computer systems and software for modeling pollutant dispersion.

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

3. In resource-selection proceedings, utilities shall continue to analyze potential resources under a range of assumptions about environmental values—including at least one scenario that excludes consideration of environmental externalities.

4. The Commission accepts, adopts, and incorporates the Administrative Law Judge's findings, conclusions, and recommendations to the extent they are consistent with the decisions made herein.

5. This order shall become effective immediately.

BY ORDER OF THE COMMISSION

Daniel P. Wolf
Executive Secretary

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