Minnesota Public Utilities Commission

Staff Briefing Papers

Meeting Dates: **July 21 and 27, 2017**..Agenda Item #1.a.**

Company: All Electric Utilities

Docket No.   E999/CI-14-643

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

Issue: Whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of carbon dioxide (CO_2) under Minn. Stat. § 216B.2422 and, if not, what measure is better supported by the evidence.

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Previous Case File Documents (Docket Nos. CI-93-583 and CI-00-1636)
Commission Order Establishing Environmental Cost Values...January 3, 1997
Court of Appeals Opinion from 1997 Order Establishing Values... May 19, 1998
Commission Order Reopening Investigation (Docket No. 00-1636)................................. February 10, 2014
Notice of Updated Environmental Externality Values ....June 16, 2017

Commission/ALJ Orders and ALJ Report
Commission Notice and Order for Hearing.. October 15, 2014
ALJ Order Regarding Burdens of Proof .... May 17, 2015
ALJ Report, CO_2 ....April 15, 2016

Relevant Documents
Master Exhibit List, Phase 1, CO_2 .... November 12, 2015
Issues Matrix, filed by Xcel Energy on behalf of all parties... November 12, 2015

Briefs
Agencies (Department of Commerce and MPCA), Initial Brief..........................November 24, 2015
Clean Energy Business Coalition, Initial Brief..November 24, 2015
Clean Energy Organizations, Initial Brief..November 24, 2015
Doctors for a Healthy Environment, Initial Brief ....November 24, 2015
Great River Energy/Minnesota Power/Otter Tail Power, Initial Brief ....November 24, 2015
Minnesota Large Industrial Group, Initial Brief ....November 24, 2015
Peabody Energy, Initial Brief..November 24, 2015

Xcel Energy, Initial Brief ....November 24, 2015

Agencies (Department of Commerce and MPCA), Reply Brief ....December 15, 2015
Clean Energy Business Coalition, Reply Brief..December 15, 2015
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Minnesota Large Industrial Group, Reply Brief..December 15, 2015
Xcel Energy, Reply Brief ....December 15, 2015
Peabody Energy, Corrected Reply Brief...December 18, 2015

Exceptions
Agencies (Department of Commerce and MPCA), Exceptions ....May 5, 2016
Clean Energy Organizations, Exceptions..May 5, 2016
Great River Energy/Minnesota Power/Otter Tail Power, Exceptions ....May 5, 2016
Minnesota Large Industrial Group, Exceptions...May 5, 2016
Xcel Energy, Exceptions ....May 5, 2016

Agencies (Department of Commerce and MPCA), Reply Exceptions .... May 16, 2016
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Great River Energy/Minnesota Power/Otter Tail Power, Reply Exceptions........................... May 16, 2016
Minnesota Large Industrial Group, Reply Exceptions.. May 16, 2016
Xcel Energy, Reply Exceptions... May 16, 2016

Other
MLIG, Motion to Take Notice..July 3, 2017
GRE/MP/OTP, Response to the Motion...July 6, 2017

The attached materials are workpapers of the Commission Staff. They are intended for use by the Public Utilities Commission and are based upon information already in the record unless noted otherwise.

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Part 1: Introduction

A. Procedural History

Orders and Filings

On February 10, 2014, the Commission issued an order in Docket No. E-999/CI-00-1636 reopening its investigation into the environmental costs of different methods of generating electricity under Minn. Stat. § 216B.2422, subd. 3. Before referring the matter to the Office of Administrative Hearings (OAH), the Commission sought input on the scope of the investigation, whether to retain an expert, and the possible role of an expert, from a stakeholder group led by the Minnesota Department of Commerce, Division of Energy Resources and the Minnesota Pollution Control Agency (the Agencies).

On June 10, 2014, the Agencies filed a report stating that there was little consensus arising out of the stakeholder meeting or in subsequent written comments. The Agencies therefore offered their own recommendations concerning the scope and process of the investigation, and the retention of an expert.

On June 16, 2014, the Commission requested comments on the Agencies' report and recommendations. The Commission received comments from:
- Fresh Energy, Sierra Club, Izaak Walton League of America – Midwest Office, Will Steger Foundation, Center for Energy and the Environment, and the Minnesota Center for Environmental Advocacy (the Clean Energy Organizations);
- Great River Energy, Minnesota Power, and Otter Tail Power Company (filing jointly);
- The Lignite Energy Council;
- Peabody Energy Corporation;
- The Minnesota Chamber of Commerce;
- The Minnesota Large Industrial Group;
- The State of North Dakota; and
- Xcel Energy

On October 15, 2014, the Commission referred the matter of the investigation into environmental and socioeconomic costs to OAH for contested case proceedings. The Commission stated that the purpose of the proceedings would be to determine:[1]

1. Whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of carbon dioxide (CO_2) under Minn. Stat. § 216B.2422 and, if not, what measure is better supported by the evidence; and

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[1] Commission Order, Docket 14-643, October 15, 2014.

2. The appropriate values for $PM_{2.5}$, SO_2, and NOx [the criteria pollutants] under Minn. Stat. § 216B.2422, subd. 3.

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

On November 12, 2015, the issues matrix for the CO_2 portion of this matter was filed.[2] On November 24, 2015, parties filed initial briefs. On December 15, 2015, parties filed reply briefs and proposed findings.

On April 15, 2016, the Administrative Law Judge issued her Report in the CO_2 portion of this matter.

Public Hearing

On August 26, 2015, a public hearing was held at the Commission's office in Saint Paul. Members of the public spoke about air pollution and climate change, shared personal stories, and many made the comment that the price utilities charge to consume electricity is not equivalent to the price people pay for health-related conditions. Therefore, many members of the public who spoke at the public hearing recommended that the Commission update the cost of pollution to reflect impacts to public health and the planet more broadly.

Others cautioned that this proceeding should be cognizant of the possible rate impacts, especially to those most vulnerable. Appreciating the ambition to be mindful of the environment, some public comments emphasized the need for affordable utility bills as well.

Parties and Witnesses to this Proceeding

The parties and their respective witnesses to this proceeding were (in alphabetical order):

Clean Energy Business Coalition (CEBC)
- Mr. Shawn Rumery
- Mr. Christopher Kunkle

Clean Energy Organizations (CEO):
- Dr. Stephen Polasky
- Dr. John Abraham
- Dr. Andrew Dessler
- Dr. Peter Reich

Department of Commerce and Minnesota Pollution Control Agency (Agencies)
- Dr. Michael Hanemann

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[2] CO_2 Issues Matrix (Nov. 12, 2015) (eDocket No. 201511-115671-01).

- Dr. Kevin Gurney

Doctors for a Healthy Environment (DHE)
- Dr. William N. Rom

Great River Energy, Minnesota Power, Otter Tail Power (GRE/MP/OTP, or "the Utilities")
- Dr. Anne E. Smith

Minnesota Large Industrial Group (MLIG)
- Dr. Ted Gayer

Peabody Energy Corporation (Peabody):
- Dr. William Happer
- Dr. Richard Lindzen
- Dr. Robert Mendelsohn
- Dr. Roy Spencer
- Dr. Roger H. Bezdek
- Dr. Richard S.J. Tol
- Dr. William Wecker

Xcel Energy (Xcel)
- Mr. Nicholas Martin

B. The ALJ Report and Disputed Issues

Typically a contested case, such as a rate case, develops a clearly defined set of disputed and resolved issues over time, which is generally outlined in an Issues Matrix. While there is an Issues Matrix with a number of key issues identified, essentially none of them are resolved.

For this reason, and due to the sheer volume of the record, staff's outline for this briefing paper and the decision options uses the Conclusions section of the ALJ Report as an organizational template to outline the scope of the issues. The Conclusions section of the ALJ Report include the following issues:

1. Use of Integrated Assessment Models, or IAMS, as Damage Cost Models
2. Discount Rates
3. The 95th Percentile Value at 3 Percent Discount Rate (a "tipping point")
4. Equilibrium Climate Sensitivity
5. Marginal Ton
6. Modeling Time Horizon
7. Geographic Scope
8. Leakage
9. Uncertainty

10. Adaptation and Mitigation
11. Use of FSCC (Federal Social Cost of Carbon) Outside of Federal Regulatory Setting
12. Scientific Process
13. Xcel Proposal
14. Reasonable and the Best Available Measure of CO_2

For the most part, staff has organized this briefing paper according to the issues identified in the ALJ's Conclusions, although not in the same sequence. Additionally, staff chose to divide the briefing paper—i.e. the issues list—into sections based on whether the disputed issues most appropriately fit into the physical sciences, economics, or procedural aspects of the Commission's ultimate decision-making process.

The Decision Options section of this briefing paper is a list of all ALJ Conclusions with redlined Exceptions filed by the parties. Staff acknowledges this may not be the best, most efficient way to present the Commission options, but the only other alternatives staff identified, if basing the decision options on the ALJ Report, would be to either to present the Commission with the entire ALJ Report (with 433 Findings of Fact) and/or her 3 recommendations (Recommendation 1 has two parts).

The Commission could alternatively use the November 12, 2015 Issues Matrix, developed by Xcel Energy, which has 31 issues listed. In the Issues Matrix, each witness proposal is identified as a standalone issue, as is the validity of each individual integrated assessment model used to calculate the social cost of carbon. Staff believes the 14 sections of ALJ Conclusions appropriately captures the list included in the Issues Matrix.

In the end, because the Commission might need to make several policy decisions to ultimately establish the final values, staff chose to include the ALJ Conclusions, with party exceptions, as a list of options that would logically flow to the Commission's determination of the most reasonable CO_2 cost value. For parties who did not submit redline exceptions, staff briefly presented their positions. To incorporate the Issues Matrix to some extent, staff also included witness proposals as an option, but did not give detail beyond stating their existence.

Notably, not all sections of the ALJ's Conclusions, listed as decision options, necessarily represent a standalone issue and therefore may not require a Commission action. For example, uncertainty is an issue to which the ALJ devoted a separate section in her Conclusions, yet uncertainty is an issue inherently subsumed by all other issues in this case. Thus, the Commission may skip through some sections of the Decision Options and decide on others, to the extent that is the most efficient manner to conduct deliberations.

C. Terminology, Acronyms, and Introduction to Concepts

Because this case involves several concepts which may not be familiar to Commission proceedings, this section will introduce commonly used (but esoteric) terminology, acronyms, organizational entities, scientific concepts, and possible approaches to the record evidence.

What is the federal social cost of carbon?

The federal social cost of carbon (FSCC or SCC) is an estimate, in dollars, of the discounted present value of damages caused by a unit of carbon dioxide (CO_2) emitted into the atmosphere. The acronyms, FSCC and SCC, are sometimes used interchangeably throughout the record; for this briefing paper, staff generally uses FSCC when referring to its development or use by the federal government. Staff uses SCC when discussing a broader usage of the term and its application by any entity, including, possibly, the Commission.

What is the IWG?

The FSCC was developed by the U.S. Government Interagency Working Group on the Social Cost of Carbon (IWG), a working group of federal regulatory agencies tasked with developing a single set of standardized SCC estimates. The IWG was convened by the Council of Economic Advisers and the Office of Management and Budget (OMB), with participation by the Council on Environmental Quality, 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.

The IWG's stated objective was to "develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of IWG's SCC estimates used in the rulemaking process."[3] Since the publication of the interim estimates in 2009, the IWG's SCC estimates have been used in 34 proposed rulemakings.[4] Notably, the FSCC was updated in 2013.

What is the IPCC?

The IPCC, or Intergovernmental Panel on Climate Change, is an intergovernmental body jointly established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). Beginning in 1990, IPCC has released a series of Assessment Reports (AR), Special Reports, Technical Papers, Methodology Reports, and other products that "have become standard works of reference" constituting "the most authoritative and objective scientific and technical assessments" on climate science.[5]

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[3] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 3.
[4] Exhibit 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, p. 4.
[5] Ex. 405, IPCC Fifth Assessment, Foreword, at v.

The ALJ found in her Report, "The Commission and the Minnesota Court of Appeals recognize the IPCC as a source of expertise on climate change."[6,7]

What are AR4 and AR5?

The IPCC has published five "Assessment Reports" thus far. The First Assessment Report was published in 1990, the Second in 1995, the Third in 2001, the Fourth in 2007, and the Fifth in 2014.[8]

For this proceeding, the IPCC Fourth and Fifth Assessment Reports (AR4 and AR5) were cited extensively for two main reasons. First, AR4 and AR5 reflect some of the most recent data and research in the field of climate science. Second, IPCC's AR4 is the Assessment Report upon which the IWG based its estimates for the *likely*[9] values for "equilibrium climate sensitivity," which measures the change in global mean temperatures, at equilibrium, as a result of changes in radiative forcings. According to IWG, "At the time the 2013 SCC update was released, the most authoritative statement about [equilibrium climate sensitivity] appeared in IPCC's AR4."[10]

Parties and staff occasionally refer to the IPCC Fourth Assessment as AR4 and the Fifth Assessment as AR5. In this briefing paper, staff uses IPCC Fourth Assessment and AR4 interchangeably, and the same is the case for IPCC Fifth Assessment and AR5.

What are CMIP3 and CMIP5?

According to IPCC:

> Climate models are the primary tools available for investigating the response of the climate system to various forcings, for making climate predictions on seasonal to decadal time scales and for making projections of future climate over the coming century and beyond.[11]

The Coupled Model Intercomparison Projects (CMIP) were created under the World Climate Research Programme. CMIP3 and CMIP5 refer to the ensemble of models that made projections about future climate impacts for IPCC's Fourth and Fifth Assessments,

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[6] ALJ Report, Finding of Fact 12, Footnote 49, at 12.

[7] See *In the Matter of the Quantification of Envtl Costs Pursuant to Laws of Minn. 1993, Chap. 356, Sec. 3*, PUC Docket No. E-999/CI-93-583, ORDER ESTABLISHING ENVIRONMENTAL COST VALUES at 24 (Jan. 3, 1997); *In re Quantification of Envtl Costs*, 578 N.W.2d 794, 800-01 (Minn. Ct. App. 1998), *review denied* (Minn. Aug. 18, 1998).

[8] Ex. 800, Hanemann Direct, at 34.

[9] Staff notes that IPCC italicizes the typeset of assessed likelihood and levels of confidence. Thus, when referring to IPCC's values, staff likewise uses italics.

[10] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG 2015 Response to Comments, at 12.

[11] Ex. 405. IPCC Fifth Assessment, at 746.

respectively.[12] In short, CMIP3 and CMIP5 are, in IPCC's words, "a set of coordinated and thus consistent and increasingly well-documented climate model experiments."[13]

What is equilibrium climate sensitivity?

Equilibrium climate sensitivity, or ECS, is often defined as the global average surface warming following a doubling of CO_2 concentration.[14] A doubling of atmospheric CO_2 from pre-industrial levels means that the concentration of atmospheric CO_2 will increase from a pre-industrial level of about 280 parts per million (ppm) to twice that, approximately 560 ppm.[15] According to AR5, as of 2011, the atmospheric concentration of CO_2 was 391 ppm, an approximately 40% increase from pre-industrial levels.[16]

Measuring and modeling the climate system's response to sustained radiative forcing—that is, the net change in the energy balance of the Earth system in response to some external perturbation[17]—can provide a relationship between CO_2 emissions and temperature change. Equilibrium climate sensitivity is a standard measurement of translating atmospheric CO_2 levels to warming. Peabody Energy (Peabody) referred to the ECS as "the most important variable" to predict the level of warming in response to CO_2 emissions.[18]

Indeed, the complexities of, for example, the relationship of CO_2 emissions, ocean heat uptake, and global mean surface temperature make it difficult to exactly predict the level of emissions that may result in a doubling of atmospheric CO_2, especially since reaching "equilibrium" can take hundreds if not thousands of years. Thus, other, shorter-term measures, like transient climate response (TCR), are also used to predict temperature change, but these measures have their own limitations, namely that they do not model the climate in equilibrium. (This will be discussed further in later sections.)

How did the IWG apply equilibrium climate sensitivity for the social cost of carbon?

Equilibrium climate sensitivity is a key input parameter in the economic integrated assessment models (IAMs) and, in turn, the IWG's calculation of the FSCC. The IWG based its climate sensitivity assumptions on the IPCC AR4 *likely* ECS range, and it retained this range when it updated the SCC in 2013. Some parties objected to this choice, arguing the social cost of carbon should be updated to use the AR5 data.

According to the IWG, "After consulting with several lead authors of … the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to

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[12] Ex. 405. IPCC Fifth Assessment, at 817.
[13] Ex. 405. IPCC Fifth Assessment, at 746.
[14] Ex. 268, IPCC Fourth Assessment, Climate Change Summary.
[15] Ex. 103, Dessler Rebuttal, at 2.
[16] Ex. 405. IPCC Fifth Assessment, at 11.
[17] Ex. 405. IPCC Fifth Assessment, at 53.
[18] Ex. 221 at 7 (Spencer Direct).

be consistent with a [likely range of 2°C to 4.5°C of warming]."[19] The IWG ultimately chose a "Roe & Baker" distribution because (1) "it is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations," and (2) it "better reflects the IPCC judgment that 'values substantially higher than 4.5°C still cannot be excluded.'"[20] The table below gives summary statistics for the calibrated Roe & Baker distribution.

	Roe & Baker
Pr(ECS < 1.5°C)	0.013
Pr(2°C < ECS < 4.5°C)	0.667
5th percentile	1.72
10th percentile	1.91
Mode	2.34
Median (50th percentile)	3.00
Mean	3.50
90th percentile	5.86
95th percentile	7.14

The ECS distribution was calibrated by applying three constraints from the IPCC:
1. median equal to 3°C, to reflect the judgment of "a most likely value of about 3°C";
2. two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5°C; and
3. zero probability that it is less than 0°C or greater than 10°C.

What are some important unit conversions?

In the table above, and throughout the record and this briefing paper, parties and staff discuss warming in terms of degrees Celsius (°C), not degrees Fahrenheit (°F). A temperature difference of 1°C is the equivalent of a temperature difference of 1.8°F. To consider some frequently referenced values for temperature increase in this record, staff provides some equivalent values for °C (Celsius) would translate to the following in °F (Fahrenheit):
- 1°C = 1.8°F
- 2°C = 3.6°F
- 3°C = 5.4°F
- 4.5°C = 8.1°F
- 6°C = 10.8°F

In addition, the Commission's current environmental externality values are stated in $/short ton, whereas the FSCC and the summary estimates for each emission year are represented in $/metric ton. Xcel presents its proposed range consistent with the Commission's current

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[19] Ex. 100, Schedule 2 of Polasky Direct, IWG Technical Support Document, at 12-13.
[20] Ex. 100, Schedule 2 of Polasky Direct, IWG Technical Support Document, at 14.

values, or $/short ton. GRE/MP/OTP presents its range in terms of $/tonne, which is referring to a metric ton.

What are IAMs?

Estimating a SCC requires linking together climate data and economic models. Whereas the IPCC's CMIP phases were undertakings to develop a multi-model approach to make climate impact projections, the IWG employed economic integrated assessment models, or IAMs, to translate these impacts into monetary terms.

Stated more elaborately, Agencies' witness, Dr. Hanemann, described IAMs as "mathematical computer models that are based upon explicit assumptions about the behavior of a modeled system. They attempt to incorporate information from physical and social sciences that consider economic, political, and demographic variables in addition to the climate system to provide a coherent synthesis of different information that is available for use by decision makers."[21]

To produce the FSCC, the IWG used three of the most recognized IAMs in climate science literature:[22]
- the Dynamic Integrated Climate and Economy (DICE) model developed by Dr. William Nordhaus;
- the Policy Analysis of the Greenhouse Effect (PAGE) model developed by Dr. Chris Hope; and
- the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model developed by Dr. Richard Tol.

Dr. Richard Tol, developer of the FUND model, submitted testimony on behalf of Peabody Energy. Dr. Tol was also a Principal Lead Author of the IPCC Second Assessment Report of Working Group III.[23]

The IWG explained its reasons for choosing these three particular IAMs in its 2015 *Response to Comments*:

> The IWG agrees with those commenters who believe the choice of the three IAMs—DICE, FUND, and PAGE—was the most appropriate for the purpose of estimating the SCC. The IWG made this determination when it began developing the SCC estimates in 2009-2010. DICE, FUND, and PAGE are the most widely used and widely cited models in the economic literature that link physical impacts to economic damages for the purposes of estimating the SCC.
> …

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[21] Ex. 800, Hanemann Direct, at 23.
[22] ALJ Report, finding 83 and 84.
[23] Ex. 236, Tol Rebuttal at 2.

In addition, the National Academies of Science (NAS) identified these three models as "the most widely used impact assessment models" in a 2010 report (NAS, 2010). Furthermore, in a comprehensive literature review and meta-analysis conducted in 2008, the vast majority of the independent impact estimates that appeared in the peer-reviewed literature were derived from FUND, DICE, or PAGE (Tol, 2008).[24]

How were the SCC estimates developed?

In setting the SCC estimates, the IWG took several steps to link together the climate science with the economic models. These steps included:
1. Standardizing the three IAMs to make a multi-model approach more workable and to generate comparable damages estimates;
2. Creating five socioeconomic-emissions scenarios adopted from "EMF-22," which will be discussed further below;
3. Selecting a ECS (equilibrium climate sensitivity) distribution;
4. Using three discount rates (2.5%, 3%, 5%) to determine the present value of future damages; and
5. Synthesizing the results to arrive at a single FSCC range.[25]

A detailed discussion of these steps is included as "Section E. Implementation of the IAMs," on pages 33-44 of the ALJ Report.

The IWG chose to produce estimates using more than one IAM, and to do so while maintaining some consistency across the three IAMs. This "standardization" required "making the model alterations necessary so that each model could be run with the same socioeconomic emissions assumptions, equilibrium climate sensitivity and discount rate assumptions."[26] The standardization process is important because some parties claimed the IWG's modifications were unreasonable, and on this basis, these parties recommend either rejecting the IAMs' estimates or modifying them using more reasonable assumptions.

What is EMF-22?

Temperature change is partially dependent upon the amount of CO_2 emitted, and the amount of CO_2 emitted is partially dependent upon socioeconomic factors like population growth and the health of the economy. Thus, the SCC incorporated a set of socioeconomic and emissions trajectories, which IWG considered separately and later incorporated into PAGE, DICE, and FUND. Socioeconomic-emissions trajectories included assumptions for factors such as GDP, population, CO_2 emissions, and non-CO_2 radiative forcing.

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[24] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 7-8.
[25] ALJ Report, Finding of Fact 100.
[26] ALJ Report, Finding of Fact 102.

The IWG adopted socioeconomic-emissions scenarios from the Stanford Energy Modeling Forum (EMF) exercise, or EMF-22. The EMF-22 modeling exercise consisted of ten well-recognized scenarios that used several different models to evaluate global actions necessary to meet specified global stabilization targets. The EMF-22 scenarios have been peer-reviewed, published, and are publically available.[27] According to Dr. Hanemann, "EMF-22 is a highly authoritative source for the required inputs."[28]

For the FSCC, IWG considered five socioeconomic and emissions trajectories from EMF-22, four of which represented various degrees of growth in population, wealth, and emissions, and another which represented an emissions pathway that would stabilize atmospheric CO_2 concentration at 550 ppm.[29]

Table 2 from IWG's February 2010 *Technical Support Document*, below, shows the socioeconomic and emission trajectories used in the five trajectories selected from EMF-22. (Staff presents Table 2 below for illustrative purposes, not to comment on the merits or likelihood of any one scenario.) Importantly, the IWG treated all five scenarios as equally likely.

Table 2: Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios -

Reference Fossil and Industrial CO_2 Emissions (GtCO$_2$/yr) -

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	26.6	31.9	36.9	40.0	45.3	60.1
MERGE Optimistic	24.6	31.5	37.6	45.1	66.5	117.9
MESSAGE	26.8	29.2	37.6	42.1	43.5	42.7
MiniCAM	26.5	31.8	38.0	45.1	57.8	80.5
550 ppm average	26.2	31.1	33.2	32.4	20.0	12.8

Reference GDP (using market exchange rates in trillion 2005$)[14]

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	38.6	53.0	73.5	97.2	156.3	396.6
MERGE Optimistic	36.3	45.9	59.7	76.8	122.7	268.0
MESSAGE	38.1	52.3	69.4	91.4	153.7	334.9
MiniCAM	36.1	47.4	60.8	78.9	125.7	369.5
550 ppm average	37.1	49.6	65.6	85.5	137.4	337.9

Global Population (billions)

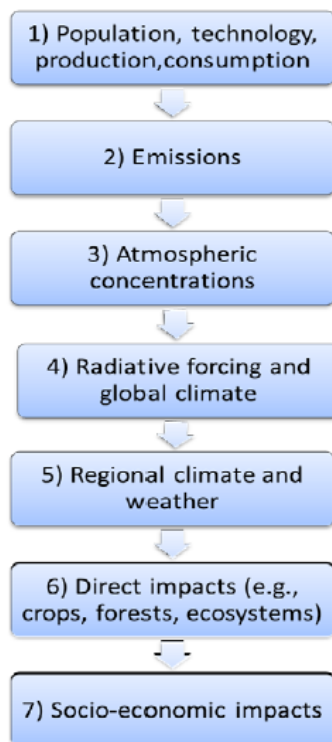| EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	6.1	6.9	7.6	8.2	9.0	9.1
MERGE Optimistic	6.0	6.8	7.5	8.2	9.0	9.7
MESSAGE	6.1	6.9	7.7	8.4	9.4	10.4
MiniCAM	6.0	6.8	7.5	8.1	8.8	8.7
550 ppm average	6.1	6.8	7.6	8.2	8.7	9.1

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[27] ALJ Report, Finding of Fact 107.
[28] Ex. 800, Hanemann Direct, at 50.
[29] Ex. 100, Schedule 2 of Polasky Direct, at 15.

Due to the sheer number of models already discussed by this point, it may be helpful to step back and discuss some general elements of an IAM. In doing so, staff refers the Commission to "Figure 1: Elements of an IAM," shown in Dr. Hanemann's Direct testimony, where he included a schematic depiction of how an IAM functions:[30]

Figure 1. Elements of an IAM

1) Population, technology, production, consumption

2) Emissions

3) Atmospheric concentrations

4) Radiative forcing and global climate

5) Regional climate and weather

6) Direct impacts (e.g., crops, forests, ecosystems)

7) Socio-economic impacts

Specifically as it relates to the FSCC and synching EMF-22 with DICE, PAGE, and FUND, boxes 1-2 correspond to economic activity and its relationship to CO_2 emissions.

The IWG's standardized inputs to DICE, PAGE and FUND, taken from EMF-22, are listed in Figure 5 of Dr. Hanemann's Direct testimony.

What changes did IWG make to EMF-22 socioeconomic and emissions scenarios?

There was substantial dispute in this proceeding with regard to how IWG incorporated the EMF-22 exercise. Peabody, for example, argued that IWG's choice to use only four models was not peer-reviewed, and the fifth scenario did not exist until the IWG invented it. Dr. Hanemann, on the other hand, contended it was appropriate for the IWG to draw the standardized values of the socioeconomic/emissions inputs from the EMF-22.

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[30] Ex. 800, Hanemann Direct, at 25.

In addition, the IWG then made a series of extrapolations associated with extending the time horizon from year 2100 (which is when the EMF-22 scenarios ended) to year 2300. The IWG made these extrapolations to better align with the lifetime of a molecule of carbon dioxide emitted into the atmosphere. The reasonableness of IWG's extrapolations, and its choice to do so, is among the most consequential and contentious issues for this case.

Some key inputs IWG extrapolated from the socioeconomic and emissions trajectories from 2100 to 2300 were:[31]
   1. The population growth rate declined linearly, reaching zero in the year 2200.
   2. The GDP/ per capita growth rate also declined linearly, reaching zero in the year 2300.
   3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 was maintained from 2100 through 2300.
   4. Net land use CO_2 emissions declined linearly, reaching zero in the year 2200.
   5. Non-CO_2 radiative forcing remained constant after 2100.

IWG's extrapolations maintained the decline in the 2090-2100 carbon intensity growth rate (i.e., CO_2 per dollar of GDP) through 2300 to account for "technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods)."[32] This is important because Xcel and GRE/MP/OTP argued that IWG's SCC estimates are too high due to IWG's failure to appropriately capture technological improvements, innovations, and adaptations.

Figure 4A of IWG's 2010 *Technical Support Document*, which is also shown as Figure 1B in Dr. Hanemann's Rebuttal, shows that IWG assumed CO_2 emissions to level off and then, in approximately the 2150-2200 time period, start to decline.[33,34]

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[31] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 43.
[32] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 44.
[33] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 46.
[34] Ex. 801, Hanemann Rebuttal, at 23.

Figure A4. Global Fossil and Industrial CO₂ Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO₂ intensity (CO₂/GDP) over 2090-2100 is maintained through 2300.)
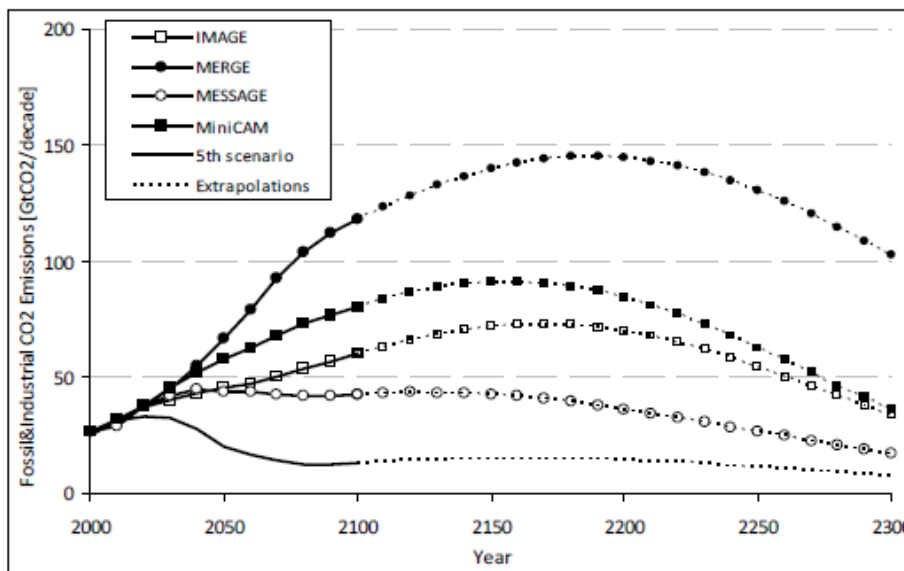
Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Staff notes that just because emissions decline, or increase at a slower rate, this does not necessarily mean the atmospheric CO_2 concentration declines. Due to the long lifetime of carbon dioxide, reducing CO_2 intensity and CO_2 emissions overall may still increase atmospheric CO_2 concentrations. And atmospheric concentration is important to consider when projecting increases in global mean surface temperature and global mean sea level change.

How do climate models become economic estimates?

SCC estimates depend on the damage functions, which monetize the damages associated with the physical impacts of climate change. In Dr. Hanemann's words, the damage function "expresses the damage in the given region and period as a fraction of the GDP that would have occurred in that region absent any warming."[35]

GRE/MP/OTP's witness, Dr. Smith, characterized damage functions as follows:

> Through a series of computational steps, the damage function translates projected changes in climate metrics into monetized societal value or "welfare." The damage functions of the three IAMs are based on a limited number of studies of the economic impact of warming of 3°C or less.[36]

Issues raised in this proceeding include whether the IWG used the IAMs appropriately and whether the IWG applied excessive subjective judgement. While the IWG did standardize the

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[35] Ex. 800, Hanemann Direct, at 28.
[36] Ex. 300, Smith Direct, at 18.

IAMs so that each model could be run with some consistent assumptions—such as the equilibrium climate sensitivity and discount rates—as Dr. Polasky noted, the IWG did not change the damage functions as used by the IAMs' developers:

> The IWG did not change the damage functions used in the IAMs and therefore these inputs—unlike projected carbon emissions, climate sensitivity, and discount rates—were not consistent across the IAMs. The approach taken in the three IAMs differs in terms of what they include in damages and in terms of parameter values used in the damage functions. In this way, the IWG incorporated three different estimates of climate change damages.[37]

IWG explained this choice in its 2015 *Response to Comments*:

> To date, the IWG has accepted the models as currently constituted, and omitted any damages or beneficial effects that the model developers themselves do not include. The IWG recognizes that none of the three IAMs fully incorporates all climate change impacts, either positive or negative. … Using an ensemble of three different models was intended to, at least partially, address the fact that no single model includes all of the impacts. We recognize that there may be effects that none of the three selected models addresses.[38]

A substantial amount of uncertainty (and therefore disagreement) exists along every step of the "causal chain" used to develop the SCC estimates. This "causal chain," portrayed in Figure 1 of Mr. Martin's Direct, below, requires assumptions about population growth, GDP growth, etc. to project emissions, which are then translated into temperature change, which then proceed to estimate climate damages.[39]

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[37] Ex. 100, Polasky Direct, at 13.
[38] Ex. 101, Schedule 2 of Polasky Rebuttal, at 9-10.
[39] Ex. 600, Martin Direct, at 16.

Figure 1
The Causal Chain Used in SCC Modeling[11]
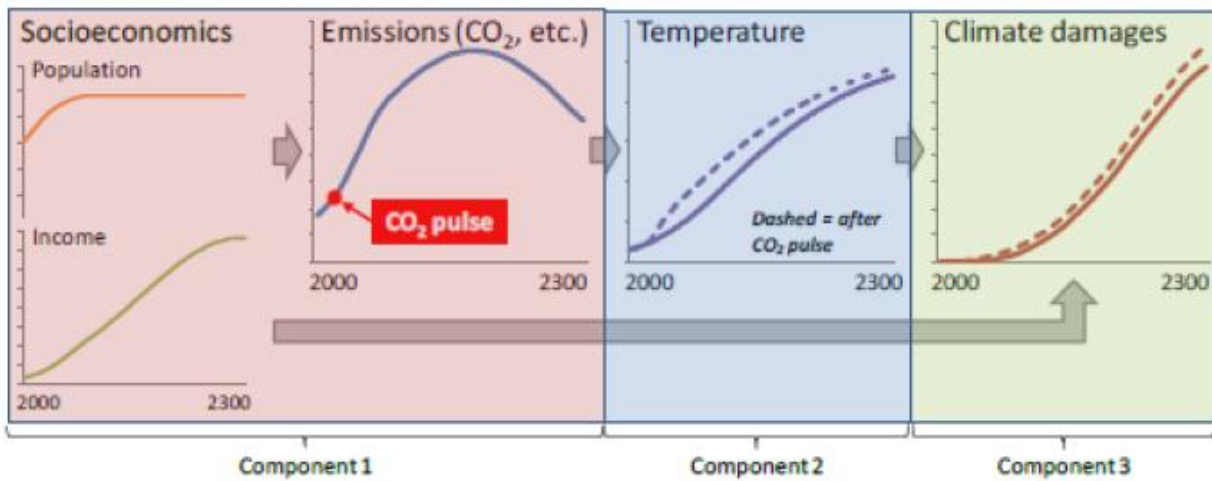
The first step (referred to in Mr. Martin's Figure 1 as "Component 1") refers to the five different socioeconomic-emissions scenarios adopted from EMF-22. The five socioeconomic and emissions scenarios from Step 1 function as exogenous inputs to the IAMs.[40]

The second step ("Component 2") translates the emissions from step 1 into global mean surface temperature change, which requires assumptions about the global carbon cycle, radiative forcing, and equilibrium climate sensitivity. This step is conducted using the three IAMs selected by the IWG—DICE, FUND, and PAGE.

The third step ("Component 3") translates estimated temperature changes from step 2 into estimated climate damages. This step is also conducted within the IAMs.[41]

As there are differences across the EMF-22 scenarios the IWG considered, there are also differences in how each IAM functions. Figure 2 of Dr. Hanemann's Direct, below, compares some of these differences across the three IAMs. As shown in Dr. Hanemann's Figure 2, the IAMs use different damage functions, consider different regions, and all three account for catastrophic climate change differently (FUND does not consider it at all).

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[40] Ex. 600, Martin Direct, at 17.
[41] Ex. 600, Martin Direct, at 17.

Figure 2: IAM Comparisons

	Dice	**Fund**	**Page**
Spatial Resolution	1 Region The World	8 Regions USA, EU, Other OECD, FSU & ROE, China & CP Asia, India &SE Asia, Africa & ME, Latin America	16 Regions USA, WEU, CAN, JPK, ANZ, CEE, FSU, MDE, CAM, SAM< SAS, SEA, CHI, NAF, SSA, SIS
Population Growth	Determined **outside** of the model	Determined **outside** of the model	Determined **outside** of the model
Income Growth	Determined **within** the model	Determined **outside** of the model	Determined **outside** of the model
CO2 Emissions: **Land use change** **Fossil fuel usage**		Land use emission determined **outside** of the model Fossil fuel usage determined **within** the model	Both determined **outside** of the model
Non-CO2 Emissions: **Land use change** **Fossil fuel usage**	Emission determined **outside** of the model	Some emission determined **outside** of the model Some emissions determined **within** the model	Other than SO2 emission determined **outside** of the model SO2 emissions determined **within** the model
Time Steps	10 year steps	Yearly	10 year steps (2000-2006) 20 year steps (2060-2100
Representation of Carbon Cycle			
Impacts of Warming	Sea level rise, Non-sea level	Sea level rise; Agriculture; forests; heating; cooling; water resources; tropical storms; extra-tropical storms; migration; biodiversity; cardiovascular, respiratory, vector-borne disease; diarrhea.	Economic (market), Non-economics (non-market), Sea Level, Catastrophic
Damage Function **Sea-level**	Quadratic of mean sea-level rise	Elaborate formula	Power function of sea-level rise
Non sea-level	Quadratic of temperature	Separate formula for each category	Power function of temperature
Catastrophic	No separate estimate	Probabilistic	Probabilistic when warming over 3°C

Source: Table based on Table 4.1 and 4.3 in EPRI 2014

Why was the social cost of carbon revised?

As explained above, in 2013, the IWG released an update to the SCC estimates that *maintained the same methodology* underpinning the previous estimates, but applied the most current

versions of the three IAMs.[42] According to IWG, "Subsequent to the release of the 2010 TSD, all three of the models used in the development of the SCC estimates were updated by their (academic) developers, in part, to reflect more recent information on the potential impacts of climate change. The three models remain the most widely cited models capable of estimating the SCC."[43]

In its July 2015 *Response to Comments*, the IWG explained that, for the most part, "IWG undertook the 2013 revision because of updates to the models, which include new or enhanced representation of certain impacts, such as sea level rise damages."[44]

What were the federal SCC results from the IWG?

The IWG produced a set of results for the SCC in 2010 (Schedule 2 of Dr. Polasky Direct) and updated the estimates in 2013 (Schedule 3 of Dr. Polasky Direct). Thus, to be clear, adopting the FSCC means adopting the revised estimates, which, as of May 2013, were:[45]

Table 2: Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton of CO_2)

| Discount Rate | 5.0% | 3.0% | 2.5% | 3.0% |
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

As shown in Table 2 above, the average FSCC per metric ton of CO_2 emitted in Year 2015 (measured in 2007 dollars) was:[46]
- $12 on average at the 5.0% discount rate;
- $38 on average at the 3.0% discount rate;
- $58 on average at the 2.5% discount rate; and
- $109 on average at the 95th percentile of the 3.0% discount rate.

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[42] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 4.
[43] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 4.
[44] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 9-10.
[45] Staff notes that the passage of time changes the FSCC estimate even without any methodological change to the values. Thus, the Commission will notice several different sets of estimates that vary by the date when they are re-published. Staff will discuss this further later in the briefing paper.
[46] Ex. 100, Polasky Direct, at 15.

Because climate impacts from future emissions are greater than those caused by current emissions, the SCC value is different depending on when emissions occur. Again referring to Table 2 above, for emissions in 2040, for example, the estimated SCC was:

- $21 on average at the 5.0% discount rate;
- $62 on average at the 3.0% discount rate;
- $87 on average at the 2.5% discount rate; and
- $192 on average at the 95th percentile of 3% discount rate.

This point, increasing values in later years, will be important for the Commission's consideration of how to measure the marginal ton.

What are the "the 95th percentile at a 3 percent discount rate" values?

The 95th percentile at a 3% discount rate values are intended to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. Generally speaking, it represents "catastrophic outcomes."[47] Because IWG used the mean as the expected value, the 95th percentile effectively reflects a lower probability data point on the frequency distribution curve, but one with much higher economic damages.

The ALJ recommended the Commission not adopt the 95th percentile at a 3 percent discount rate SCC estimates.

What is the social cost of carbon frequency distribution curve?

As discussed above, IWG used three IAMs, applied a probability distribution for ECS values that largely matched the range of *likely* estimates determined in the IPCC's Fourth Assessment, and incorporated sets of socioeconomic-emissions trajectories aligned with EMF-22. The estimates were further discounted at 2.5%, 3%, and 5% discount rates.

Each IAM was run 10,000 times with random draws from the ECS probability distribution (and other inputs) and for all five EMF-22 scenarios. This means there were 150,000 data points (estimates) that were discounted at 2.5%, 3%, and 5%, then averaged to produce an expected value under each discount rate.

A probability distribution accounts for the possibility that increased CO_2 concentrations will have a smaller or larger impact on global temperatures than the average expected value.[48] According to IWG, the probability distribution captures the uncertainty reflected in each IAM and each scenario:

> To produce a range of plausible estimates that still reflects the uncertainty about the SCC estimates, the results from the various model and scenario combinations

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[47] ALJ Report, Finding of Fact 420.
[48] Ex. 100, Polasky Direct, at 10.

(150,000 observations per emissions year for each of the three discount rates) were pooled to produce three separate probability distributions for the SCC for emissions in a given year, one for each assumed discount rate (2.5, 3 and 5 percent).[49]

The IWG calculated the SCC in this way for the years 2010, 2020, 2030, 2040, and 2050. To obtain values for the SCC years in between (e.g. 2015, 2025, and so on), the IWG used a simple linear interpolation.[50]

The figure below shows the frequency distribution for each discount rate, based on the combined set of runs for each model and scenario.[51] The y-axis represents the fraction of simulations that produced a particular SCC estimate.
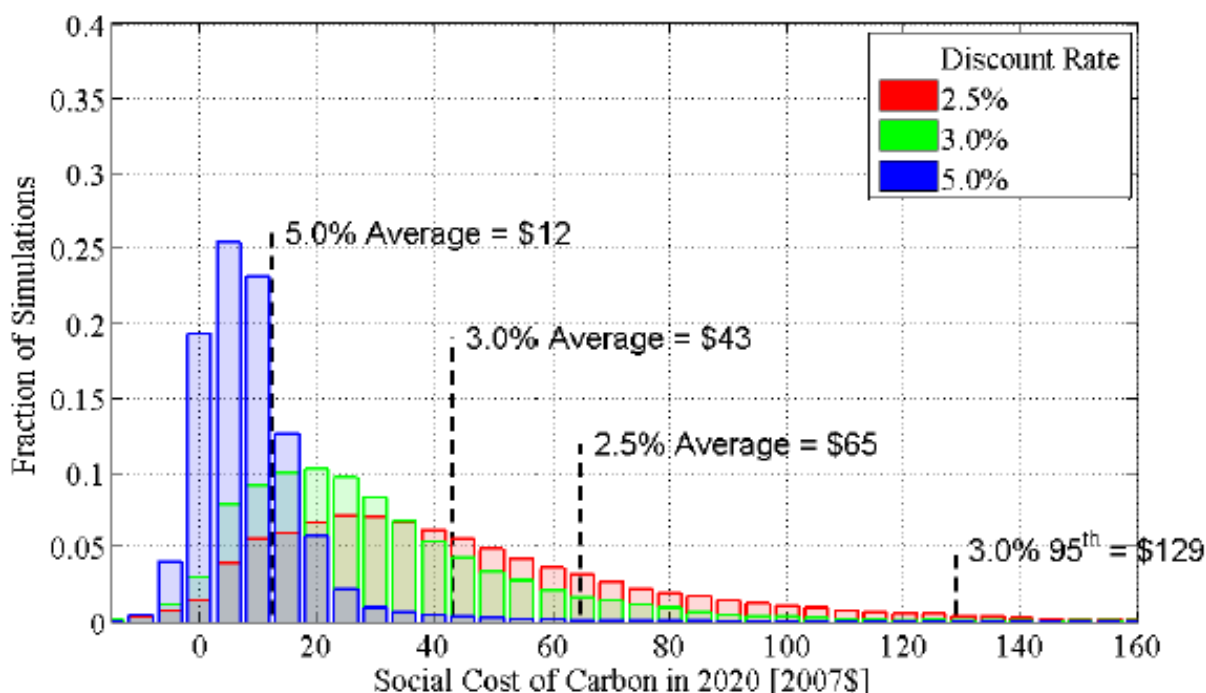
As shown in the figure above, the IWG's SCC estimates do not have, in statistical terms, a normal distribution; rather, they are skewed with a long right tail. The figure also shows that the lower the discount rate, the longer the right tail of the distribution.

Because IWG averaged the data points to establish the expected value, as far as IWG was concerned, the mean is the most likely value. However, as shown by the y-axis of the figure above, there were *more* simulations (i.e. a higher frequency of outcomes) with SCC values *lower* than the average.

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[49] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, at 25.
[50] ALJ Report, Finding of Fact 135.
[51] Ex. 100, Schedule 3 of Polasky Direct, at 14.

What did the ALJ recommend?

Importantly, the ALJ did not recommend explicit CO_2 values, but the Judge did conclude that "the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO_2, establishing a range of values including the 2.5 percent, 3 percent, and 5 percent discount rates" [52]

To establish the CO_2 values to be used in resource planning, the ALJ recommended two changes to the FSCC:

    a. Shorten the modeled time horizon by 100 years, to year 2200; and
    b. Exclude values from the 95th percentile at a 3 percent discount rate scenario.

If the Commission adopts the ALJ's recommendations, the Commission will also need to decide how to proceed in re-calculating the SCC so it can be used in Minnesota resource plan proceedings. Xcel noted in its Exceptions

> The ALJ does not provide the explicit FSCC values on which she bases her recommendation, but from the record we may conclude that she is referring to the values presented in the executive summary of the latest (July 2015) Federal SCC Technical Support Document (TSD).[53]

These values, notably, are slightly different than those shown in Schedule 3 of Polasky Direct, which is from IWG's **May 2013** Technical Support Document.

Possibly more confusing yet, ALJ Report Finding of Fact 139 includes a table showing IWG's FSCC estimates derived from the **November 2013 revised FSCC** (in 2007 dollars per metric ton of CO_2), and these values are slightly different from those provided in Xcel's Exceptions and Polasky Direct.

The three FSCC tables are compared below. Staff notes that, when comparing each emission year—i.e. the May 2013 estimate for Year 2020 to the July 2015 estimate for Year 2020—the SCC values are lower in each subsequent publication. This is most obvious to see by referring to the right-most column, the 95th percentile at the 3% discount rate.

May 2013 (Dr. Polasky Direct)

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[52] ALJ Report, at 123.
[53] Xcel Exceptions, at 2.

Revised Social Cost of CO$_2$, 2010 – 2050 (in 2007 dollars per metric ton of CO$_2$)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

November 2013 (ALJ Report)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th				
2010	11	32	51	89				
2015	12	37	57	109	2010 Results			
2020	12	43	64	128	7	26	42	81
2025	14	47	69	143				
2030	16	52	75	159				
2035	19	56	80	175				
2040	21	61	86	191				
2045	24	66	92	206				
2050	26	71	97	220				

July 2015 (Xcel Exceptions)

Figure 1: FSCC Executive Summary Values from July 2015 Technical Support Document.[2]

Revised Social Cost of CO$_2$, 2010 – 2050 (in 2007 dollars per metric ton of CO$_2$)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	10	31	50	86
2015	11	36	56	105
2020	12	42	62	123
2025	14	46	68	138
2030	16	50	73	152
2035	18	55	78	168
2040	21	60	84	183
2045	23	64	89	197
2050	26	69	95	212

The (slight) differences in values across all three tables might be the result of discounting or minor adjustments in some of the inputs. In any case, starting with the first publication of the Revised SCC in May 2013, there have indeed been different values, which the parties may be able to explain, and this may require clarification about which FSCC estimates are being discussed. Staff agrees with Xcel that, for clarity, it may be easiest to use the table Xcel presents in its Exceptions.

Concerning the choice of discount rates, the ALJ recommended the Commission adopt the values in the 5%, 3%, and 2.5% discount rate columns. However, the ALJ did not recommend the Commission adopt the 95th percentile at 3% discount rate values. This means that if the Commission adopts the ALJ's recommendation, it would neglect the fourth column of values.

How might the Commission consider making its own changes or adjustments?

There are several ways the Commission could approach the record to determine whether the FSCC is reasonable and the best available measure of the environmental cost of CO_2.

First, the Commission could sequentially address each of the ALJ's Conclusions, which are the bases for her recommendations. That is more or less the approach staff took in developing the briefing paper and decision options.

Second, the Commission could adopt an alternative proposal provided by the witnesses who oppose the FSCC as the best available measure. These witnesses include:
- Mendelsohn (Peabody)
- Tol (Peabody)
- Bezdek (Peabody)
- Smith (GRE/MP/OTP, "Utilities")
- Gayer (MLIG)
- Martin (Xcel)

Third, the Commission could start with the IWG's FSCC and proceed to make changes to the underlying "framing assumptions," a term used by GRE/MP/OTP, to ultimately determine the final SCC estimates. The ALJ adopts this approach to some extent, although in a different way and to a far less degree than the GRE/MP/OTP proposal. For example, GRE/MP/OTP witness, Dr. Smith, replicated the IWG's SCC estimates to use as a base case, then made adjustments to the modeling time horizon, geographic scope, ton emitted, and discount rate. The ALJ, on the other hand, concluded that the IWG's FSCC was a reasonable to begin with, but that it would be more reasonable if the time horizon was shortened time horizon by 100 years and if the estimates at the 95th percentile were excluded.

What does it mean to recalculate the FSCC?

Despite many of Xcel Energy's strong criticisms of the FSCC, Xcel nevertheless based its own proposal on the IWG's FSCC, in part because it "was a simple matter of re-running the same code."[54] Xcel concluded that, while the FSCC is not statistically sound or reasonable on its own, Xcel "was not able to identify a damage cost approach that would be a better starting point than the IWG data."[55] The Commission required the use of a damage cost approach in its October 2014 *Order for Hearing*, so Xcel chose to start with the IWG data that also takes this approach, but Xcel developed a new range of values "by balancing uncertainty, practicability, and risk tolerance."[56]

Xcel noted in its Exceptions that the ALJ's recommendation to shorten the time horizon could be a very labor-intensive exercise, and there is no obvious path forward:

> The ALJ does not specify how, or by whom, this adjustment would be made. Adjustment of the values would entail acquiring the IAMs; adjusting their internal code to eliminate damages after 2200 (but otherwise following the Interagency Working Group's (IWG) methodology); re running the IAMs; and recalculating the average across IAM results at each of the three discount rates. It is difficult to estimate, without actually re-running the models, by how much this shortening of the modeling horizon would affect the FSCC average values.[57]

In GRE/MP/OTP's opening statement at the evidentiary hearings, GRE/MP/OTP explained that Dr. Smith's analysis enables the SCC to be recalculated with some ease:

> [Dr. Smith] has not only offered her analysis, but set out in a very open and transparent manner, showing all her underlying work, a proposal for how the Commission could adjust some of the key framing assumptions in the federal social cost the carbon to update the CO_2 environmental cost value on a sound evidentiary basis.[58]

However, as Mr. Martin explained in his Rebuttal testimony, transparency may not equate to practicability:

> Dr. Smith's approach involves acquiring, re-coding and re-running the IAMs. It is transparent, since she describes clearly how she did this, but would require significant effort to replicate and update compared to the Company's approach, which requires no new modeling.[59]

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[54] Martin Rebuttal, at 29.
[55] Xcel Initial Brief, at 13.
[56] Xcel Initial Brief, at 13.
[57] Xcel Exceptions, at 3-4.
[58] Hearing Transcript Vol. 1, September 24, 2015, at 35.
[59] Martin Rebuttal, at 29.

Thus, one issue the Commission will need to address is whether any modifications will require re-coding and re-running the IAMs, as well as who will do it.

How might the environmental externality values be used?

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

Under Chapter 7843 of Minnesota Rules, the Commission must evaluate resource plans by their ability to: (1) maintain or improve the adequacy and reliability of utility service, (2) keep the customers' bills and the utility's rates as low as practicable, given regulatory and other constraints, (3) minimize adverse socioeconomic effects and adverse effects upon the environment, (4) enhance the utility's ability to respond to changes in the financial, social, and technological factors affecting its operations, and (5) limit the risk of adverse effects on the utility and its customers from financial, social, and technological factors that the utility cannot control.

In other words, environmental externality values are one factor to consider among several others in resource plan proceedings. The Commission's five factors to consider in resource planning, taken together, do not always work perfectly in concert, and the Commission's IRP Rule does not state or imply preferences for one factor over another. Therefore, the Commission must balance what may be several competing goals in the context of whether a utility's proposed plan fits within the boundary of reasonableness. This makes it difficult to say, with any actual certitude, how the externality values will be "used," but even more so, it is difficult (if not impossible) to declare what impact they will have on Minnesota's generation landscape.

A common issue discussed by the parties is how the updated environmental externality costs might impact future resource plans. Xcel, for example, argued that the updated values "will directly affect what kind of resources Minnesota utilities will rely on and build in the future."[60] The Commission might interpret such claims as not only presumptuous but speculative, because they imply a knowledge of what utilities will propose to the Commission and what the Commission will ultimately approve, reject, or modify. Many parties (including Xcel) urge the Commission to avoid undue speculation in this case, and in this vein, the question of applicability may only be pertinent insofar as it relates to the statutory language and the Commission's IRP Rule.

Consider the following example: if a utility is considering re-licensing a nuclear plant or, in the alternative, constructing a new carbon-emitting resource, like a natural gas plant, one might

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[60] Xcel Energy, initial brief. at 25.

make an assumption that an externality value will necessarily favor the nuclear facility (because it is carbon-free). However, while it could be true that the externality costs would matter from a strictly economics perspective, assuming that the Commission will, beyond doubt, ultimately prefer re-licensing a nuclear plant is simply not how IRP works, as the Commission well knows. Socioeconomic impacts, grid reliability, and other factors listed above are also important to the decision-making process.

More broadly, externality values will be incorporated into resource plans as a variable cost to carbon-emitting generation. The chain of events will therefore occur as follows. First, the Commission will update the existing externality values. Then, the utility will incorporate those values into its resource plan modeling and, ideally, propose a resource plan that performs well under both a utility cost test and a societal cost test. After comments from interested stakeholder, the Commission will approve, reject, or modify a resource plan consistent with the public interest, incorporating several other factors to consider. After that, the utility will endeavor to procure actual resources aligned with the size, type, and timing determined in the IRP. Cost recovery and ratemaking are addressed in later petitions and proceedings.

Considering this long chain of events, claims that purport the Commission's decision in this case will result in, for example, an unbearably high price of electricity leaps several steps beyond the threshold question of the best available estimate of the external cost of a ton of carbon emitted into the atmosphere. How the Commission will ultimately "use" the externality values in various, future generation-related dockets is unknown, and unknowable, and the record evidence provides no indication of the effect CO_2 values will have on specific generators or resource portfolios. CEO recognized this, stating in its Reply Brief:

> [H]ow the Commission will use the externality values in specific resource planning contexts is unknown and the record evidence shows it is very unlikely that the values will dictate specific resource decisions. Indeed, Mr. Martin when testifying on the stand acknowledged that there is no direct link between an externality value and a specific resource decision: "**Q**. …that externality value alone is not going to be the thing that determines whether or not a power plant is modified or replaced? **A**. No. The commission would consider at least also direct rate impacts to customers, reliability, fuel diversity, a number of other things."[61,62]

Of course, this is not to downplay the importance or impact of updating the environmental externality values—the Commission obviously opened the investigation for a reason—but staff would suggest not hyper-inflating the application question either. The externality values were sent to the OAH for a contested case to develop a record so that the environmental externalities can be updated and because the facts to achieve this end are more complex than the typical method of developing IRP assumptions, such as obtaining a natural gas forecast from a third-party consultant.

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[61] CEO Reply Brief, at 12.
[62] Hearing Transcript. vol. 4 at 227:21-25; see also Hearing Transcript vol. 4 at 14:9-12.

The scope of this investigation has been defined: the Commission sought to determine what values represent reasonable estimates of the social impacts from CO_2 emissions. To state unequivocally that the externality values will, by themselves, overhaul the State's generation landscape fundamentally mischaracterizes the holistic nature of IRP and makes presumptions about unforeseeable Commission actions. Laboring over what may or may not happen to resource plans distracts from the very clear question the Commission asked the ALJ to answer, which was:

> The purpose of the proceedings shall be to determine whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO_2 and, if not, what measure is better supported by the evidence.[63]

What are the environmental externality values at present and how are they updated?

In its May 3, 2001 *Order Updating Externality Values*, the Commission adopted the Gross Domestic Product Price Deflator Index (GDPIPD) to update the externality values set in its January 3, 1997 Order in Docket No. E-999/CI-93-583. The Commission determined that the values will continue to be updated as data becomes available from that index.

The Commission's environmental externality values were most recently updated in its June 16, 2017 Notice, using the 2015 GDPIPD values published by the U.S. Department of Commerce on May 26, 2017.

Currently, the Commission differentiates the geographic scope of the criteria pollutants by four areas—Urban, Rural, Metropolitan Fringe, and Within 200 miles of Minnesota. Because the Commission determined in the prior externalities case that CO_2 has a global geographic scope, CO_2 values were (initially) kept the same across those areas.[64] However, in its July 2, 1997 Reconsideration Order, the Commission set the CO_2 value to zero in the Within 200 Miles area.[65]

The table below, from the Commission's June 16, 2017 *Notice of Updated Environmental Externality Values*, shows the high/low range of the original values (1995 dollars, in $/ton) and the current inflation-adjusted values (2015 dollars, in $/ton), used for the Urban, Rural, and Metropolitan Fringe areas:

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[63] Commission Order Establishing Environmental Cost Values, ordering paragraph 2 (January 3, 1997).

[64] Commission Notice and Order for Hearing, October 15, 2014, ordering paragraph 2.

[65] Commission Order Affirming In Part and Modifying In Part Order Establishing Environmental Cost Values (July 2, 1997).

	Original (1995, $/ton)		Inflation-Adjusted (GDPIPD, 2015, $/ton)	
	Low	High	Low	High
CO_2 Value	0.30	3.10	0.44	4.64

What is the distinction between the environmental externalities docket and the CO_2 values docket?

Throughout this briefing paper, staff will use the terms CO_2 costs, externality costs, and social cost of carbon interchangeably. To be clear, these terms, as used in this case, refer only to the Commission's environmental externality values, which is a measure of the *social* impact of CO_2 emissions, not *regulatory* compliance costs for environmental policy. This is relevant for understanding not only how the CO_2 externality costs might be used in future resource planning, certificate of need, and purchase power agreement dockets, but also for distinguishing externalities from another form of carbon pricing used in these Commission proceedings, costs for potential CO_2 compliance (regulatory costs).

Notably, the environmental externalities docket is separate to the Commission's CO_2 Values Docket (E-999/CI-07-1199), which estimates the range of CO_2 *regulatory* costs likely to be incurred by the utility for compliance measures. The CO_2 Values Docket was opened pursuant to Minn. Stat. § 216H.06, where the Legislature directed the Commission to "establish an estimate of the likely range of costs of future carbon dioxide regulation on electricity generation." [66] The most recent Commission order in the CO_2 Values Docket was issued on August 5, 2016, setting the range of likely CO_2 costs at $9 and $34 per ton of CO_2 emitted in 2022 and thereafter.

As discussed above, the Commission's June 16, 2017 *Notice of Updated Environmental Externality Values* updated the values strictly for environmental externalities. However, for its use in resource plan proceedings, a utility need not apply the CO_2 externality values provided in the table above in any year to which the utility applies the CO_2 costs derived pursuant to Minn. Stat. §216H.06 (i.e., the CO_2 Values Docket). This is to avoid double counting CO_2-priced emissions. Accounting for CO_2 values in this way stems from a Commission Order issued December 21, 2007, which determined:

> While the calculation of externality values under § 216B.2422 is not directly comparable to the estimate of regulatory costs under § 216H.06, they both reflect steps to account for the burdens that CO_2 emissions impose on third parties. When a utility calculates the cost of emitting another ton of CO_2 in any given year, therefore, it would be inappropriate to use both the CO_2 externality value and the

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[66] Minn. Stat. § 216H.06

CO_2 regulatory cost estimate. But utilities should continue to apply the Commission's CO_2 externality values otherwise.[67]

The range of regulatory costs set in the Docket No. 07-1199, $9-$34 per ton emitted in 2022 and thereafter, is not subject to change in this proceeding and will be unaffected by the Commission's decision in this case. This is not to imply anything about how resource plan modeling and evaluation may or may not change once the environmental externality values are updated, but staff raises the CO_2 Values Docket in order to provide the Commission with a more complete picture of how CO_2 prices are considered in resource plan proceedings at present.

How might the Commission consider the Presidential Executive Order Promoting Energy Independence and Economic Growth?

Executive Order

On March 28, 2017, President Donald Trump issued an Executive Order, "Promoting Energy Independence and Economic Growth." The Executive Order, among other things, disbanded the IWG and withdrew certain technical support documents related to the social cost of carbon for consideration in federal rulemaking.

On June 30, 2017, MLIG filed a Motion requesting the Commission take notice of (1) the March 28, 2017 Executive Order (Exhibit A of MLIG Motion) and (2) June 14, 2017 comments by career staff at the White House Office of Information and Regulatory Affairs (OIRA) (Exhibit B of MLIG Motion). MLIG noted:

> [T]he Interagency Working Group on Social Cost of Greenhouse Gases ("IWG") was disbanded, its technical support documents were withdrawn, and the critical premise that the federal Social Cost of Carbon considered during the evidentiary hearing and briefed by the parties will continue to exist and will continue to be updated has shattered.[68]

The Motion was filed in e-dockets on July 3, 2017. Pursuant to Minn. R. 7829.0410, parties can file written responses to the Motion within 14 days of service of the motion filing. GRE/MP/OTP filed a letter supporting MLIG's Motion two business days following the Motion, on July 6, 2017. GRE/MP/OTP further requested the Commission delay this matter and grant the parties an opportunity to file written comments. No other party filed responses by the time this briefing paper was finalized, so their views could not be incorporated.

With regard to what was "withdrawn," the Executive Order listed six documents which were "withdrawn as no longer representative of governmental policy." In other words, the Executive

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[67] Commission order, Docket No. E-999/CI-07-1199, In the Matter of Establishing an Estimate of the Costs of Future Carbon Dioxide Regulation on Electricity Generation Under Minnesota Statutes § 216H.06, at 4..
[68] MLIG Motion to Take Notice, at 2 (June 30, 2017).

Order withdrew technical supports documents issued by the IWG as documents applicable to federal rulemaking. These documents were not, however, erased from existence, as they are part of this record, are referenced on the EPA website (although with links removed), and can be accessed online.

The Executive Order also makes clear that it will not infringe in any way on the authority of the States. According to the Executive Order:

> It further is the policy of the United States that, to the extent permitted by law, all agencies should take appropriate actions to promote clean air and clean water for the American people, while also respecting the proper roles of the Congress and the States concerning these matters in our constitutional republic.[69]

In addition, the Executive Order did not mention the credibility of the science on which the FSCC relies. Rather, the Order focuses on the federal regulatory cost-benefit analysis that should be used, directing that the analysis focus on the domestic impacts of carbon and use certain discount rates as set forth in a 2003 Office of Management and Budget (OMB) guidance:

> when monetizing the value of changes in greenhouse gas emissions resulting from regulations, including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates, agencies shall ensure, to the extent permitted by law, that any such estimates are consistent with the guidance contained in OMB Circular A-4 of September 17, 2003[.][70]

The guidance provided by Circular A-4 was discussed extensively in this proceeding. As Xcel noted, the Commission does not operate under OMB guidance.[71] And the ALJ concluded "the Circular A-4 is advisory and not mandatory in nature."[72]

Exhibit B of MLIG's motion is an article from insideepa.com, which MLIG filed to reflect comments from career staff at OIRA. However, according to the article, Jim Laity, chief of the natural resources branch of the White OIRA, was quoted to say:

> Trump's order "did not forbid us to work on this or tell us not to think about this." And he added that Trump's order also recognizes that agencies "would need to continue monetizing [greenhouse gas] damages."

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[69] MLIG Motion to Take Notice, Exhibit A, "Presidential Executive Order on Promoting Energy Independence and Economic Growth, Section 1.c.

[70] MLIG Motion to Take Notice, Exhibit A, "Presidential Executive Order on Promoting Energy Independence and Economic Growth, Section 5.c.

[71] Ex. 601, Martin Rebuttal, at 44.

[72] ALJ Conclusion 16.

In addition, Mr. Laity provided additional context regarding the federal government's position on geographic scope:

> [T]he guide [OMB Circular A-4] says that an assessment should focus on domestic costs and benefits. The SCC, however, uses global benefits -- because the climate models used to craft it are based on global damages, and because climate change is an inherently global problem.

The article later quotes an individual from Resource for the Future (RFF), who clarified:

> The IWG "has, at this point, been disbanded. But the need to update estimates of the social cost of carbon . . . is still necessary," … Additionally, RFF's Kevin Rennert noted that the SCC is "not going away," in part because it is starting to be adopted by states, other countries and even some businesses' internal planning decisions. "It really deserves to have the full, most up-to-date science behind it."

The article also noted that "a separate appellate court ruling has also upheld the use of the Obama SCC as 'reasonable' in the development of an Energy Department appliance efficiency standard."

Underlying Science and Economics

The IWG based its SCC estimate "on results from the three most widely-used integrated economic-climate change assessment models."[73] These IAMs were authored independent of the federal government. All three IAMs were developed in the early 1990s and have been updated several times since then.[74] The IAMs calculate damages by using a "reduced-form" approach, which was required by the Commission in its October 14, 2014 *Order for Hearing*.[75]

Because some input parameters were treated differently across models, IWG needed to make choices about how to be consistent with certain parameters such as GDP, population, CO_2 emissions, and non-radiative forcing. In doing so, IWG adopted scenarios from the Stanford Energy Modeling Forum (EMF) exercise, EMF-22. EMF-22 was an undertaking independent of the federal government (although it included experts from government agencies). The EMF-22 scenarios have also been peer-reviewed, published, and are publically available.[76]

An exogenous variable for the standardized IAMs was the equilibrium climate sensitivity. The IWG chose a probability distribution from the peer-reviewed literature based on its evaluation of the scientific literature and the relationship between this distribution and the IPCC's ECS *likely* range. The IPCC is independent of the federal government. Moreover, the IPCC has been

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[73] ALJ Finding of Fact 163.
[74] ALJ Finding of Fact 79.
[75] Commission order, October 14, 2014, at 5.
[76] ALJ Finding of Fact 107.

determined to be an authoritative voice on climate science by the ALJ and the Commission in the prior externalities case. The Minnesota Court of Appeals concluded in the prior case that "the commission properly relied on . . . expert testimony and the IPCC report."[77]

In short, IAMs monetize climate impacts. Both the physical science component and economics component, which were the foundation for the IWG's social cost of carbon, originated well before the IWG was even established and are widely accepted and credible sources in their respective fields of study. If the IWG and the FSCC no longer exist for the purposes of federal rulemaking, this does not mean that authoritative, peer-reviewed expertise no longer exists. While political winds may have shifted and changed course, the science has held steady, so at the very least, the Commission has the ingredients and a recipe with which to construct an environmental cost value for CO_2 consistent with State law.

The Commission may take an approach that is the same, similar, or different than the choices and assumptions IWG made to estimate the social cost of carbon. The Commission also has the option to adopt a CO_2 environmental externality value that begins with the IWG's methodology but is then tailored to be more relevant to the State of Minnesota, which is essentially the approach taken by the ALJ and Xcel. Alternatively, the Commission could adopt any one of the following proposals presented in this case that are not the FSCC (although some are based on the FSCC):

- Mendelsohn Proposal
- Tol Proposal
- Bezdek Proposal
- Smith Proposal
- Gayer Proposal
- Martin Proposal

Part 2: Party Positions

This section, the summary of Party Positions, is intentionally limited, because the Issues Matrix that Xcel developed is perhaps the most succinct yet comprehensive representation of party positions. Therefore, staff refers the Commission to the November 12, 2015 CO_2 Issues Matrix as perhaps the best representation of Party Positions in the record. For this briefing paper, staff will briefly state party positions, provide a short discussion, and mostly discuss party positions through discussions of each topic.

Overall, regarding the ultimate question—whether the federal social cost of carbon is the best available estimate of CO_2 emissions—there are three general categories of party positions: some parties support the SCC, some do not, and some could accept it in a modified form. These parties could be categorized as follows:

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[77] ALJ Finding of Fact 49.

Support	*Do Not Support*	*Could Accept with Modifications*
• Agencies (DOC, MPCA) • Clean Energy Business Coalition • Clean Energy Organizations • Doctors for a Healthy Environment	• Midwest Large Industrial Customers (MLIG) • Peabody Energy	• GRE/MP/OTP • Xcel Energy

As shown above, GRE/MP/OTP and Xcel fall into the same general category, in that they could accept some modified form of the FSCC, but they do not have precisely the same view of the FSCC or recommend the same approach regarding how to modify it. For instance, GRE/MP/OTP could accept basing a final SCC estimate on a significantly modified form in which many of the underlying economic assumptions are changed, while leaving the physical science aspect unchanged. Xcel, on the other hand, concluded that "the underlying SCC methodology and raw modeling outputs should be used as a reasonable and best available starting point,"[78] but some of the public policy decisions on how to use them should be changed to some degree.

Next, staff will provide brief summaries of each party's position to further explain the agreements and disagreement that exist among the three general categories.

A. Agencies (Department of Commerce, Pollution Control Agency)

The Agencies support the adoption of the FSCC methodology and damage values developed by the IWG. The Agencies believe it is "consistent with the Commission's requirement that the parties to this proceeding evaluate the environmental cost of CO_2 using a damage cost approach, and that the Agencies' consultants use reduced-form modeling to estimate damage costs."[79] In particular, the three IAMs used to develop the FSCC estimates are computable, numerical models that account for several categories damage estimates. IAMs also ably capture the behavior of a modeled system.

According to the Agencies, the IWG's methodology is the best available methodology that has been put forth in the record. The IWG process was based on actual and peer-reviewed science, and the decision-making was open and transparent, up-to-date and comprehensive, and, from the practicability standard, is easily updatable as science continues to progress. Further, it is consistent with the Commission's precedence of establishing values that reflect a global scope.

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[78] Xcel Initial Brief, at 1.
[79] Agencies Initial Brief, at 2.

The FSCC comports with the statutory requirement that the Commission establish a range of values that appropriately reflect uncertainty, and it would allow for the testing of resource plans for sensitivity to a range of changes.

B. Clean Energy Business Coalition

The Clean Energy Business Coalition (CEBC) supports the FSCC as the best available measure of the environmental costs of CO_2. CEBC and its witnesses, Mr. Kunkle and Mr. Rumery, largely responded to Peabody's claims that future economic growth requires fossil fuels, and that wind is unreliable, expensive, and non-scalable. Mr. Kunkle and Mr. Rumery also discussed renewable resources' performance, particularly their improved reliability at high penetration levels.

C. Clean Energy Organizations

CEO concluded that the IWG's FSCC is a reasonable measure to determine the environmental cost of CO_2 emissions, that it is the best available measure to measure the environmental cost of CO_2 emissions, and that no party has offered an externality value that is superior.

CEO noted that several witnesses from other parties offered their own SCC estimates or recommended certain changes. CEO contended that it would be unreasonable to adopt values based on one researcher's run of one model by making assumptions that, unlike the IWG's estimate, were not peer-reviewed. CEO recommends the Commission give weight to the fact that the IWG involved twelve federal agencies that made assumptions using a consensus-based approach.

According to CEO, the IWG's FSCC is also supportable because it relies on the best available climate science, including that produced from the IPCC, whose Reports have been previously determined to be credible by the Commission. Thus, the best available climate science was incorporated into the IAMs used to estimate the social damages.

D. Doctors for a Healthy Environment

The Doctors for a Healthy Environment (DHE) supported the FSCC as the best available measure of the environmental costs of CO_2, although DHE qualified that the FSCC is likely a conservative estimate.

DHE agreed with several other parties that the IAMs' damage functions contain "rudimentary approximations of economic damages attributable to global climate change,"[80] but DHE also identified several limitations in these damage functions that likely underestimate the social cost of carbon. Minnesota's resource planning statute directs the Commission to establish

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[80] Doctors for a Healthy Environment, Initial Brief, at 2.

environmental cost values "to the extent practicable,"[81] and this statutory language recognizes the impossibility of eliminating uncertainty entirely or developing a perfect estimate.

DHE's witness, Dr. Rom, discussed limitations as they pertain to the public health impacts not fully included (if at all) in the damage functions. Mortality rates, for example, is just one public health concern not appropriately accounted for in the IAMs and is projected to cause 90-100,000 deaths and 900,000 years of life lost. [82] Dr. Rom further concluded that "the SCC likely underestimates the health impacts of climate change by at least $930 billion (by 2100), and likely much more in unquantified health impacts."[83]

Despite these limitations it is DHE's view that the SCC represents a best-case scenario, even though the uncertainty in public health concerns should not assume that the best-case scenario will come to pass.

E. Midwest Large Industrial Group (MLIG)

The Midwest Large Industrial Group (MLIG) retained Dr. Ted Gayer as its expert witness, who testified regarding the geographic scope of damage. Dr. Gayer recommended the Commission the use the State of Minnesota rather than a global geographic scope of damages.

Dr. Gayer's testimony emphasized the need to account for "reciprocity" rather than providing full benefits to other countries.[84] Dr. Gayer contended that establishing a social cost of carbon in Minnesota "will not lead others to reduce their emission levels, which is why the global scope of the SCC is at this time inappropriate for Minnesota to use for considering a state regulation."[85]

If the Commission does proceed with establishing a cost value for CO_2, according to Dr. Gayer's calculations, the Commission should adjust IWG's estimates to the state-level and commensurate with the State's proportional share of global GDP. In this alternative, the Minnesota social cost of carbon would yield "extremely small damage estimates, with a high-end estimate of $0.37 per metric ton of CO_2 (2010 damage value in 2007 dollars)."[86]

F. Peabody Energy

Overall, Peabody concluded that the proponents of the FSCC have failed to carry their burden of proving by a preponderance of the evidence that the FSCC is the reasonable or best available measure for an externality value.

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[81] Minn. Stat. § 216B.2422, subd. 3.
[82] Doctors for a Healthy Environment, Initial Brief, at 8.
[83] Ex. 500, Rom Rebuttal, at 19.
[84] Ex. 401, Gayer Surrebuttal, at 5.
[85] Ex. 401, Gayer Surrebuttal, at 8.
[86] Ex. 400, Gayer Direct, at 10.

According to Peabody, no value can command a preponderance of the evidence because the degree of uncertainty is simply too great. Thus, Peabody recommended that the Commission should set the externality value at zero. In the alternative, Peabody could support a negative externality value. One Peabody witness, Dr. Mendelsohn, argued that certain factors, such as increased crop productivity, could be considered a *benefit* from increased CO_2 emissions, which in turns translates to a *negative* externality value in economic terms.

Peabody had several criticisms of both the climate models and the IAMs employed to develop the record in both aspects of this proceeding. For instance, the IWG ran economic modeling based by incorporating data used in climate models. But, according to Peabody, the climate models have historically failed in their predictive capability, and over the last 20 years warming has not kept pace with the CO_2 emissions. There has been an increase in CO_2 emissions, but there has been much less warming than the models had predicted. And regarding the economic modeling, Peabody argued that the IWG both misused and inappropriately manipulated the IAMs. Additionally, the discount rates IWG used were arbitrary and violated OMB guidance.

Overall, the IAMs are not appropriately suited to estimate Minnesota-specific impacts. The most reliable and applicable evidence could actually support a negative value to correspond with the current environmental and social benefits from carbon in a place like Minnesota, where moderate warming is helpful to both the natural environment and the human environment.

G. Great River Energy, Minnesota Power, and Otter Tail Power (GRE/MP/OTP, or "Utilities")

GRE/MP/OTP's comments, analysis, and recommendations are largely based on tying the methodology and evidentiary basis for deriving the SCC in this case to the Commission's standard practice and past precedent for using and setting environmental externalities under existing law.

GRE/MP/OTP's witness, Dr. Anne Smith, worked with the same integrated assessment models IWG used to generate the FSCC and produced a sensitivity analysis considering changes to four main assumptions: time horizon, discount rate, geographic scope, and marginal ton. According to GRE/MP/OTP, "these framing assumptions are necessary to tailor the federal social cost of carbon for purposes of Minnesota's CO_2 environmental cost value."[87]

In its Exceptions, GRE/MP/OTP recommended that the Commission decline to change the methodology it now uses to update the CO_2 externality values, due to the excessive uncertainty and speculation associated with use of the FSCC. In the alternative, the Commission should adopt a modified version of the FSCC that use more appropriate and reasonable assumptions

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[87] Evidentiary Hearing Transcript, Vol. 1, September 24, 2015, at 34.

that reduce the uncertainty and are better suited for Minnesota resource planning. These include:

- reducing the time horizon to 2100 (instead of 2300);
- using of an average cost approach to calculate marginal ton;
- applying discount rates of 3.0 percent and 5.0 percent discount rates; and
- considering global damages.

Under GRE/MP/OTP's alternative economic framing assumptions, the Commission, the range of CO_2 values would be approximately from $8.75 (2014$/net tonne, based on 5 percent discount rate) to $20.97 (2014$/net tonne, based on 3 percent discount rate).

H. Xcel Energy

Like GRE/MP/OTP, Xcel Energy believes the record in this proceeding shows that the social cost of carbon values are not reasonable, and they and do not represent the best available measure. Among other flaws, Xcel argued that the social cost of carbon values do not

- reasonably address uncertainty,;
- use statistically sound methods;
- reflect appropriate risk tolerance;
- yield a practicable range; or
- minimize subjective judgments.

Also like GRE/MP/OTP, Xcel supported an alternative approach to the IWG's social cost of carbon. But, whereas GRE/MP/OTP developed an alternative proposal by changing the assumptions upon which the SCC was estimated, Xcel's proposal used as the FSCC as the basis for developing CO_2 environmental cost values, by relying on the results from the same IAMs, but Xcel narrowed the probability distribution at both ends.

In addition, Xcel averaged the 2.5%, 3%, and 5% discount rates instead of including separate scenarios for each. This approach, Xcel argued, produced a true range more aligned with Minnesota IRP proceedings. (It also received a great deal of criticism from the parties.) In addition, Xcel argued, weighting all three discount rates equally when producing the low and high ends of its proposed range is reasonable in part because "the choice of discount rate is inherently subjective and normative."[88]

Xcel's proposal was initially envisioned by identifying eight "standard of review criteria." Table 1 of Xcel's Initial Brief[89] shows each criterion and compares the Xcel proposal to Xcel's assessment of other proposals under the same criteria. Green boxes indicate that Xcel believes a criterion is met, yellow that a criterion is met partially, and red that a criterion is largely not met.

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[88] Ex. 602, Martin Surrebuttal, at 30.
[89] Xcel Initial Brief, at 6.

Table 1. Matrix Comparing all Parties' Proposals to Company's Criteria[7]

Criterion	Dr. Hanemann	Dr. Polasky	Dr. Smith	Dr. Gayer	Dr. Mendelsohn	Company
Uses damage costs approach	Green	Green	Green	Green	Green	Green
Reasonably addresses uncertainty	Red	Red	Yellow	Yellow	Yellow	Green
Reflects absence of consensus on discount rate	Green	Green	Red	Green	Red	Green
Uses statistically sound methods	Red	Red	Red	Red	Red	Green
Reflects appropriate risk tolerance	Red	Red	Red	Yellow	Red	Green
Minimizes subjective judgments	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Yields a practicable range	Red	Red	Green	Red	Green	Green
Transparent, replicable and updatable	Green	Green	Red	Green	Red	Green

After establishing a set of review criteria, Xcel then proceeded to construct a practicable range. To assist Xcel with developing the SCC range out of IWG data, Xcel retained The Brattle Group (Brattle), an independent consultancy that provides advisory services for utility regulatory proceedings. Staff refers the Commission to pages 54-60 of Mr. Martin's Direct for a detailed explanation of Xcel's and Brattle's collaboration and quantification of the range of SCC estimates.

Mr. Martin's method for establishing a practicable started with an range using the FSCC modeling output data at the 25th percentile at the 5% discount rate to the 75th percentile at 2.5% discount rate. Then, Mr. Martin equally weighted the SCC values for each of the three discount rates at the low and high ends of the initial range. The final range Xcel Energy proposes is from $12.13 to $41.40 and corresponds with the 36th and 74th percentiles of the IAMs' distribution of 450,000 SCC estimates for emission year 2020.[90]

Xcel used the same methods as IWG to calculate corresponding ranges for each of the other decades for which SCC values were provided by the IWG (2010, 2030, 2040 and 2050), as shown in Table of Mr. Martin's Direct.[91]

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[90] Xcel Initial Brief, at 10.
[91] Ex. 600, Martin Direct, at 62.

Table 4
CO$_2$ Environmental Cost Values Proposed for Commission Adoption. In 2014 Dollars per Short Ton.[64]

Range proposed for Commission adoption	Emission year				
	2010	2020	2030	2040	2050
Low	$9.78	$12.33	$14.52	$16.88	$19.35
High	$33.71	$41.80	$49.49	$57.90	$66.94

Xcel truncated the percentiles because IWG's estimates, according to Xcel, "do not reasonably address uncertainty, and do not use statistically sound methods,"[92] although IWG data reflected the Commission requirement to use a damage cost approach, not a cost-of-compliance approach, for this case. Xcel explained:

> Because we believed the four Federal SCC point estimates do not constitute a reasonable and best available measure, the Company then considered two options: 1) derive a new damage cost estimate by modeling climate damages, using an IAM or other methods, or 2) use the IWG modeling outputs as a starting point, but find a way to make them more practicable and appropriate for integrated resource planning in Minnesota. The first option would have required the Company to make the myriad scientific and subjective policy judgments that witnesses who took this approach (Dr. Smith and Dr. Mendelsohn) have made, and would also have made our proposed range, like theirs, difficult and costly to update. Instead, we chose the second option, using the IWG's raw modeling outputs but creating a method to derive from them a range that we believe appropriately balances the Company's eight proposed standard of review criteria.[93]

Xcel did not take a position on the physical sciences component of this proceeding. However, Xcel emphasized that it is important for the Commission to recognize the small contribution to climate change that a SCC would have. According to Xcel, any resulting resource planning decisions, even if they lead to a complete elimination of CO$_2$ emissions in Minnesota, would have a small impact on global climate damages or on damages experienced by Minnesotans.[94,95]

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[92] Xcel Reply to Exceptions, at 15.
[93] Ex. 602, Martin Surrebuttal, at 5.
[94] ALJ Report, at 78.
[95] Ex. 601, Martin Rebuttal, at 39.

I. *Staff Discussion*

Support/Oppose/Accept with Changes

Even though GRE/MP/OTP and Xcel Energy introduced alternative approaches in the event the Commission wishes to adopt some form of a social cost on CO_2 emissions, this should not imply any endorsement of the IWG's calculation of the FSCC whatsoever. In fact, GRE/MP/OTP and Xcel strongly opposed IWG's work, and both consider the FSCC to be unreasonable on many levels. GRE/MP/OTP recommended the Commission not to change the externality values from where they are at present, and only in the alternative should the Commission consider an adjusted form of the SCC. Xcel witness, Mr. Martin, explained that "key variables in the IAMs suffer from a lack of empirical basis, and the IAMs are highly dependent on assumptions that cannot easily be verified." In addition, "the Federal SCC was not designed for integrated resource planning or other Commission decisions, and is inherently and irreducibly uncertain."[96]

Moreover, GRE/MP/OTP and Xcel Energy do not believe any of its actions taken under the auspices of climate change are likely to have any material societal benefit, no matter how a "society" is defined geographically.

According to GRE/MP/OTP, "[t]he actual scenario Minnesota faces is that it will be one of the few state jurisdictions to consider externality values in its resource planning … while providing little or no benefit to the state or the rest of the world."[97]

According to Xcel Energy, "the Company opposes adoption of *any* falsely precise point estimate in an area as rife with uncertainty as predicting climate change and the damages it may cause."[98] Xcel further argued that, while it takes no position on whether global warming exists,[99] "any reductions in Minnesota's emissions are likely to have little effect on global damages."[100] The reason Xcel proposed a global SCC was because, as Mr. Martin put it, "the Commission may have an interest in demonstrating environmental leadership."[101]

If, as GRE/MP/OTP and Xcel claim, Minnesota electric generation has a *de minimus* impact on climate change and, in addition, any effort to reduce CO_2 to address climate change is ineffectual if not injurious, the Commission has the option to set the CO_2 cost value at $0, at least as a lower bound estimate. Peabody Energy recommended a $0 CO_2 value, and it did so arguing that the climate science is too uncertain, the economic IAMs are rife with speculation and methodological flaws. GRE/MP/OTP and Xcel neither endorsed nor disputed Peabody's

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[96] Ex. 600, Martin Direct, at 47 and 50.
[97] GRE/MP/OTP Reply Brief, at 19.
[98] Ex. 602, Martin Surrebuttal, at 3.
[99] Xcel Reply Brief, at 1.
[100] Xcel Initial Brief, at 26.
[101] Ex. 601, Martin Rebuttal, at 39.

position on climate science, but they did make similar claims about the uncertainty of economic damages.

The 1996 ALJ Report

Several parties in this proceeding favored the 1996 ALJ Report (Judge Allan Klein) from the prior externalities case over Judge Schlatter's Report for the instant case. Peabody, for example, cited Judge Klein's finding that "[g]iven the current uncertainty regarding the estimation process, overestimating the damages is a distinct possibility."[102,103] Peabody later concluded, "Nearly 20 years later, we have new and better data, which shows that scientific support underlying predicted future damages is now even more uncertain."[104]

GRE/MP/OTP recommended that the Commission employ the same approach for this record, and even reach the same decision, as Judge Klein did in the prior case. According to GRE/MP/OTP's Exceptions:

> In the earlier proceeding, ALJ Allan Klein undertook a substantial analysis of the legal requirements and the policy concerns relating to the establishment an quantification of the CO_2 ECV. The Commission adopted the analysis in Judge Klein's report and the Commission's order was affirmed by the Minnesota Court of Appeals. We believe the legal and policy analysis adopted by the Commission in the earlier proceeding remains relevant and appropriate today.[105]

GRE/MP/OTP continued:

> Judge Klein went on to grapple with the uncertainty that inevitably arises in connection with the establishment of environmental cost values. … Judge Klein put this analysis into practice when he recommended the Commission adopt "conservative values."[106]

Ultimately, in its Exceptions, although GRE/MP/OTP provided an alternative option, GRE/MP/OTP's preferred Commission action for this case is:

> Under the circumstances, we recommend the Commission decline to change the methodology that it now uses to update the CO_2 ECV due to the excessive uncertainty and speculation associated with use of the FSCC.[107]

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[102] Peabody Initial Brief, at 2.
[103] Ex. 305, Findings of Fact, Conclusions, Recommendation, and Memorandum, at 17 (Mar. 22, 1996)
[104] Peabody Initial Brief, at 2.
[105] GRE/MP/OTP Exceptions, at 5.
[106] GRE/MP/OTP Exceptions, at 6.
[107] GRE/MP/OTP Exceptions, at 20.

MLIG, while also recommending an alternative, likewise indicated it could support the current externality values, citing Judge Klein's reasoning:

> The MLIG respectfully submits that if the Commission desires to protect important Minnesota values such as the affordability of energy, that it **maintain the conservative approach to the environmental cost of carbon recommended by ALJ Klein** and adopted in the Commission's January 3, 1997, Order Establishing Environmental Cost Values. As applied, the MLIG respectfully submits that the ALJs and the Commission should adopt a range for the environmental cost value of CO_2 of $0.37 to $5.14 per net metric ton (in 2014 dollars).[108] (Emphasis added.)

There are two dominant themes, each related to one another, underlying parties' preferences for Judge Klein's Order in the previous case over Judge Schlatter's in the instant case: (1) the existence of uncertainty, and (2) that the Commission should adopt conservative values in light of this uncertainty.

The ALJ addresses uncertainty throughout her Report, most directly in Section I of her Findings of Fact and Section IX of her Conclusions. In her Memorandum, the Judge responded to parties' claims regarding the "conservative cost value" approach in the prior proceeding:

> Contrary to the arguments made by Peabody, MLIG and the Utilities, there is no explicit language in the Commission's 1997 Order approving Judge Klein's reasoning regarding adopting conservative cost values. The values chosen by the Commission in 1997 were based on the lower of two ranges recommended by the Minnesota Pollution Control Agency (MPCA). The Commission's reasoning for choosing the lower range was based on its determination that the lower range was better supported by the evidence in the record. The Commission made no mention of Judge Klein's "conservative cost value" approach.[109]

A difficultly with taking a "conservative" approach is that there is little definition of what "conservative" means in specific terms, other than to equate "conservative" values with "low" values. If that is indeed how Judge Klein's Report should be interpreted, then the Commission could go through each of the fourteen sections of the ALJ's Conclusions and decide every scientific, economic, and policy issue based on its ultimate impact to the SCC value. But being conservative can mean different things to different parties. The Doctors for a Healthy Environment, for example, likewise recommended the Commission use a conservative estimate, but DHE did so because its conclusion was that the SCC itself was conservative and "almost certainly an underestimate."[110]

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[108] MLIG Reply Brief, at 40.
[109] ALJ CO_2 Report, at 126.
[110] Doctors for a Healthy Environment, Initial Brief, at 4.

Also, the SCC estimates rely, in large part, on the physical sciences. Global mean surface temperature, for example, is the primary climate variable driving the damage estimates in all three IAMs. This means that relatively "higher" SCC estimates are derived from climate projections with higher levels of CO_2 concentrations and/or the upper bound of climate sensitivity.

Under a "conservative" approach, does this mean giving greater weight to lower atmospheric CO_2 concentrations and the low bound for ECS, even if IPCC considered high and low bounds to be equally likely? And when constructing socioeconomic-emissions trajectories, is it more conservative to assume future CO_2 emissions will have a "business-as-usual" trajectory, a lower emissions growth rate trajectory, or that major global shifts in climate policy, which successfully stabilize CO_2 concentrations, will inevitably be employed?

Staff raises these issues because, in some ways, the Commission is being asked to consider two ALJ Orders. Some quoted findings and/or conclusions from the 1996 ALJ Report, but without the full context, a sentence or two from 20 years ago could be misconstrued. To the extent the Commission is asked to find the current externality values are more reasonable than new, revised values, or that a previous ALJ considered important issues more reasonably than Judge Schlatter, agreeing with these recommendation might require a complete review of the prior case. Second, since uncertainty is a fundamental, central issue of this proceeding, and since many recommend the Commission use a conservative approach, it is important to know what conservative means in a practical sense, especially as it relates to each issue under the physical sciences and economics aspects of the case.

Part 3: Physical Sciences and Climate Impacts

In Part 3, staff will discuss the physical sciences component of this proceeding. Part 3 will not be sequenced in the same way as the ALJ Report, but it will be consistent with the topics she covered. Part 3 will begin with the ALJ's Conclusion Regarding Climate Change.

Next, staff will discuss climate sensitivity, an issue to which the ALJ dedicates a separate section of her Conclusions. Climate sensitivity is relevant to the decision-making for both the physical sciences and economics components of this proceeding; there is dispute about the appropriate ECS range (physical sciences) and dispute about IWG's probabilistic treatment of that range in the IAMs (economic).

Finally, staff will discuss several "sub-issues" that underlie certain sections of the ALJ Conclusions, such as issues to consider beyond global temperature change and whether the SCC may underestimate or overestimate damages. These sub-issues include: extreme events, human health, and Minnesota-specific impacts.

ALJ Section II.J. Administrative Law Judge's Conclusions Regarding Climate Change

Peabody Energy challenged much of the scientific literature that was used as the basis for the assumptions in the IAMs. The ALJ made her conclusions in Section II.J. of her Report:

J. Administrative Law Judge's Conclusions Regarding Climate Change

57. Peabody must demonstrate, by a preponderance of the evidence, that its claims that climate change is not occurring or, to the extent it is occurring, the warming and increased CO_2 in the Earth's atmosphere are not anthropogenically caused and are beneficial. This burden of proof is appropriate because Peabody presented the testimony regarding the existence and benefits of climate change and warming in support of its proposed values for the SCC in this proceeding. In its Post-Hearing Brief in this matter, Peabody states that the most appropriate SCC value is zero. Alternative values proposed by Peabody are set forth in section V.C. of this Report.

58. The Administrative Law Judge concludes that Peabody Energy has failed to demonstrate, by a preponderance of the evidence, that climate change is not occurring or, to the extent climate change is occurring, the warming and increased CO_2 in the Earth's atmosphere are beneficial.

Sections I and J of the ALJ Report pertain to the climate science issues raised in this case. No party objected to the Judge's findings and conclusions on climate science in Exceptions. While Peabody initially disputed the scientific literature and accuracy of the climate models, the ALJ concluded otherwise, and the Judge's findings and conclusions 49-58 are on pages 22-23 on her Report in Sections I and J. Peabody did not file Exceptions to the ALJ Report.

MLIG referenced Peabody witnesses' on scientific issues in its Exceptions, but MLIG's exceptions on the climate-related aspects of the case generally referred to the economic treatment of the equilibrium climate sensitivity in the IAMs.

Of course, the Commission can rely on any evidence introduced in the proceeding, and it can certainly agree with Peabody's claims about the observational evidence of temperature change and climate models, topics which will be discussed later in this section. But, to the extent the Commission disagrees with the ALJ on her findings and conclusions on climate science, it may need to address conclusions 49-58 and determine where the ALJ specifically erred.

IPCC Assessment Reports

A. ALJ Report

The Intergovernmental Panel on Climate Change (IPCC), as discussed previously, is an intergovernmental scientific body that produces Assessment Reports—and IPCC has produced five thus far—that aim to reflect the most complete and current understanding in the field of climate science.

In Section I. Additional Findings Regarding Climate Change, the Judge made the following Conclusions about the IPCC Reports:

> 49. The Commission and the Minnesota Court of Appeals recognize the IPCC as a source of expertise on climate change.[111] On appeal of the first Externalities case, the Minnesota Court of Appeals concluded that "the commission properly relied on . . . expert testimony and the IPCC report."[112]
>
> …
>
> 52. The IPCC AR5 "presents clear and robust conclusions in a global assessment of climate change science — not the least of which is that the science now shows with 95 percent certainty that human activity is the dominant cause of observed warming since the mid-20th century."[113]

B. Discussion

To understand what IPCC's findings actually mean, it should first be understood how IPCC expresses what it reports. In essence, IPCC always accounts for some level of inherent uncertainty, which is described in terms of (1) confidence, a qualitative description, and (2) probability, a quantitative description.

In its Fourth Assessment, IPCC described how it accounts for uncertainty as follows:

> Where uncertainty in specific outcomes is assessed using expert judgment and statistical analysis of a body of evidence (e.g. observations or model results), then the following likelihood ranges are used to express the assessed probability of occurrence:[114]
> * *virtually certain >99%;*
> * *extremely likely >95%;*
> * *very likely >90%;*
> * *likely >66%;*
> * *more likely than not > 50%;*

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[111] *In the Matter of the Quantification of Envtl Costs Pursuant to Laws of Minn. 1993, Chap. 356, Sec. 3,* PUC Docket No. E-999/CI-93-583, ORDER ESTABLISHING ENVIRONMENTAL COST VALUES at 24 (Jan. 3, 1997); *In re Quantification of Envtl Costs*, 578 N.W.2d 794, 800-01 (Minn. Ct. App. 1998), *review denied* (Minn. Aug. 18, 1998).
[112] *In re Quantification of Envtl Costs*, 578 N.W.2d 794, 800 (Minn. Ct. App. 1998), *review denied* (Minn. Aug. 18, 1998).
[113] Ex. 405 at v (IPCC AR5).
[114] Staff applied bullet points to IPCC's typeset; also, IPCC uses italicized text when referring to assessed likelihood.

- *about as likely as not* 33% to 66%;
- *unlikely* <33%;
- *very unlikely* <10%;
- *extremely unlikely* <5%;
- *exceptionally unlikely* <1%.[115]

Box TS.1 of IPCC's Fifth Assessment shows essentially the same probabilistic treatment of uncertainty, which means that the Commission can view AR4 and AR5 interchangeably when reading descriptive terms such as *likely* or *unlikely*:

The following terms have been used to indicate the assessed likelihood, and typeset in italics:

Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms (*extremely likely*: 95–100% probability, *more likely than not*: >50–100% probability, and *extremely unlikely*: 0–5% probability) may also be used when appropriate.

According to IPCC's Fourth Assessment, "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations."[116] This translates to a 90% or greater probability.

According to IPCC's Fifth Assessment, "Greenhouse gases contributed a global mean surface warming *likely* to be in the range of 0.5°C to 1.3°C over the period 1951 to 2010."[117] This translates a 66% or greater probability.

IPCC also determined, "It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together."[118] (Attribution is discussed in more detail later in this section.)

This means that IPCC determined there is a 95% or greater probability that the increase in global mean surface temperatures over the period 1951 to 2010 can be attributed to anthropogenic causes, and this is reflected by ALJ Conclusion 52.

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[115] Ex. 268, IPCC, AR4 – Climate Change Summary 2007 (Full Summary), at 27.
[116] Ex. 268, IPCC, AR4 – Climate Change Summary 2007 (Full Summary), at 39.
[117] Ex. 405, IPCC Fifth Assessment, at 17.
[118] Ex. 405, IPCC Fifth Assessment, at 17.

One important factor to consider about how IPCC considers "likelihood," is that it is expressed probabilistically. The consideration of uncertainty and probability differed among the parties and strongly influenced the parties' recommendations on certain issues in this case. A primary example of this was the *likely* range IPCC report for equilibrium climate sensitivity. From AR4 to AR5, IPCC decreased the low-bound ECS estimate by a half-degree, from 2°C to 1.5°C, while keeping the upper bound the same, at 4.5°C. Some parties focused far more attention than others to the lower bound of the *likely* range IPCC reported.

Another disputed issue was which IPCC Assessment Report should be given more weight, and this was accompanied by references to the fact that IWG choice *not* to identify a "best estimate" for ECS in AR5, whereas in AR4, it did. In its Fourth Assessment, IPCC determined that 3°C was the best estimate for ECS, but for AR5, IPCC refrained from making a best estimate. Some parties took this as evidence lower climate sensitivity values is where the science is trending, or that IWG was wrong to rely on AR4 for the ECS probability distribution. The IWG explained its decision to use the AR4 ECS range in its 2013 *Technical Support Document Response to Comments*:

> At the time the 2013 SCC update was released, the most authoritative statement about ECS appeared in IPCC's AR4. Since that time, as several commenters noted, the IPCC issued a Fifth Assessment Report that updated its discussion of the likely range of climate sensitivity compared to AR4. The new assessment reduced the low end of the assessed likely range (high confidence) from 2°C to 1.5°C, but retained the high end of the range at 4.5°C. Unlike in AR4, the new assessment refrained from indicating a central estimate of ECS. This assessment is based on a comprehensive review of the scientific literature and reflects improved understanding, the extended temperature record for the atmosphere and oceans, and new estimates of radiative forcing.[119]

The IWG's excerpt above is rather loaded with technical concepts, including the differences between AR4 and AR5, likely ranges, climate sensitivity, and radiative forcing. Thus, in the next section, staff will discuss how the Commission can apply some of the concepts addressed in the IPCC reports, particularly the difference between AR4 and AR5 and the importance of concepts like radiative forcing and anthropogenic influence. Radiative forcing is particularly relevant because the scenarios defined by the scientific community for use in the IPCC Assessment Reports are identified by their approximate total radiative forcing in year 2100 relative to 1750.

Radiative Forcing

In his Direct testimony, Dr. Hanemann enumerated the steps in estimating the social cost of carbon as follows:

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[119] Ex. 101, Schedule 1 of Polasky Rebuttal, at 12.

> To estimate the marginal external cost associated with an additional unit of [greenhouse gas] emissions one needs to estimate, in general terms, (1) how that emission changes the existing accumulation of [greenhouse gases] in the atmosphere via the carbon cycle; (2) how that, in turn, changes the amount of energy stored in earth's system (the change in radiative forcing); (3) how the change in radiative forcing leads to changes in the climate worldwide, (4) how those changes in climate affect things that matter to humans, such as water supply and drought, crop production, disease and human health, outbreaks of wildfire, coastal flooding, and ecosystem functioning etc.; and (5) how humans value the changes in those things.
>
> The calculation of these items is conducted within the framework of what is known as an Integrated Assessment Model (IAM) – this is a computable, numerical model that accounts for items (1), (2), (3), (4) and (5).[120]

Dr. Hanemann's excerpt references "radiative forcing" as an estimate needed to calculate the marginal external cost of an emission. The radiative forcing concept is important for several reasons, namely that it is a measure (in watts per square meter, or W/m^2) of the influence a particular forcing, like greenhouse gas emissions or volcanic activity, has in altering the energy balance of the Earth system.[121]

Radiative forcing determines the rate and magnitude of global climate change and is one of the most widely used metrics to establish cause and effect from individual factors on climate impact.[122] Forcing agents may be characterized as "anthropogenic," such emissions of greenhouse gases, or "natural," such as changes in solar irradiance and volcanic eruptions; these forcing agents affect the amount of radiation that is reflected, transmitted, and absorbed by the atmosphere.

IPCC assessments model radiative forcing for "evaluating and comparing the strength of the various mechanisms affecting the Earth's radiation balance and thus causing climate change."[123] One conclusion from IPCC's Fifth Assessment was:

> Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.

This explains, partially, why CO_2 emissions projections and radiative forcing assumptions are important inputs to the IAMs.

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[120] Ex. 800, Hanemann Direct, at 22-23.
[121] Ex. 268, IPCC Fourth Assessment (AR4) Climate Change Summary (Full Summary), at 36.
[122] Ex. 405, IPCC Fifth Assessment, at 664.
[123] Ex. 405, IPCC Fifth Assessment, at 661.

Equilibrium climate sensitivity and radiative forcing are related concepts. The ECS, an important parameter used to calculate the SCC, is a measure of the climate system's response to sustained radiative forcing. The ECS is commonly described as the increase in global mean surface temperature resulting from a doubling of the atmospheric CO_2 concentration relative to pre-industrial levels. This doubling of atmospheric CO_2 concentration corresponds to a radiative forcing of approximately 3.7 W/m^2. The important takeaway here, at least as far as the modeling is concerned, is that equilibrium warming is proportional to the radiative forcing and is calculated as a function of present and future CO_2 concentrations relative to some historical timescale.

Modeling Projections of Future Changes in Climate

For the IPCC Fourth Assessment, IPCC assumed prescribed CO_2-equivalent concentrations corresponding to a radiative forcing due to anthropogenic GHGs and aerosols in 2100 relative to 1750. The six scenarios, referred to as the SRES (Special Report on Emissions Scenarios), assumed atmospheric CO_2 concentrations of about 600, 700, 800, 850, 1,250 and 1,550 ppm.

These SRES scenarios included various demographic, economic, and technological variables (and resulting GHG emissions), but did not include any additional climate policies beyond what existed at the time. In addition, no likelihood was ascribed to any of the SRES scenarios.

Figure 3.2 of the Fourth Assessment, below, shows projections of surface warming by 2100. Solid lines are multi-model global averages of surface warming (relative to 1980-1999)[124] for the SRES scenarios A2, A1B and B1. The bars in the middle of the figure indicate the best estimate (the solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios at 2090-2099 relative to 1980-1999.

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[124] The y-axis is negative to reflect the amount of warming from 1750-1900.
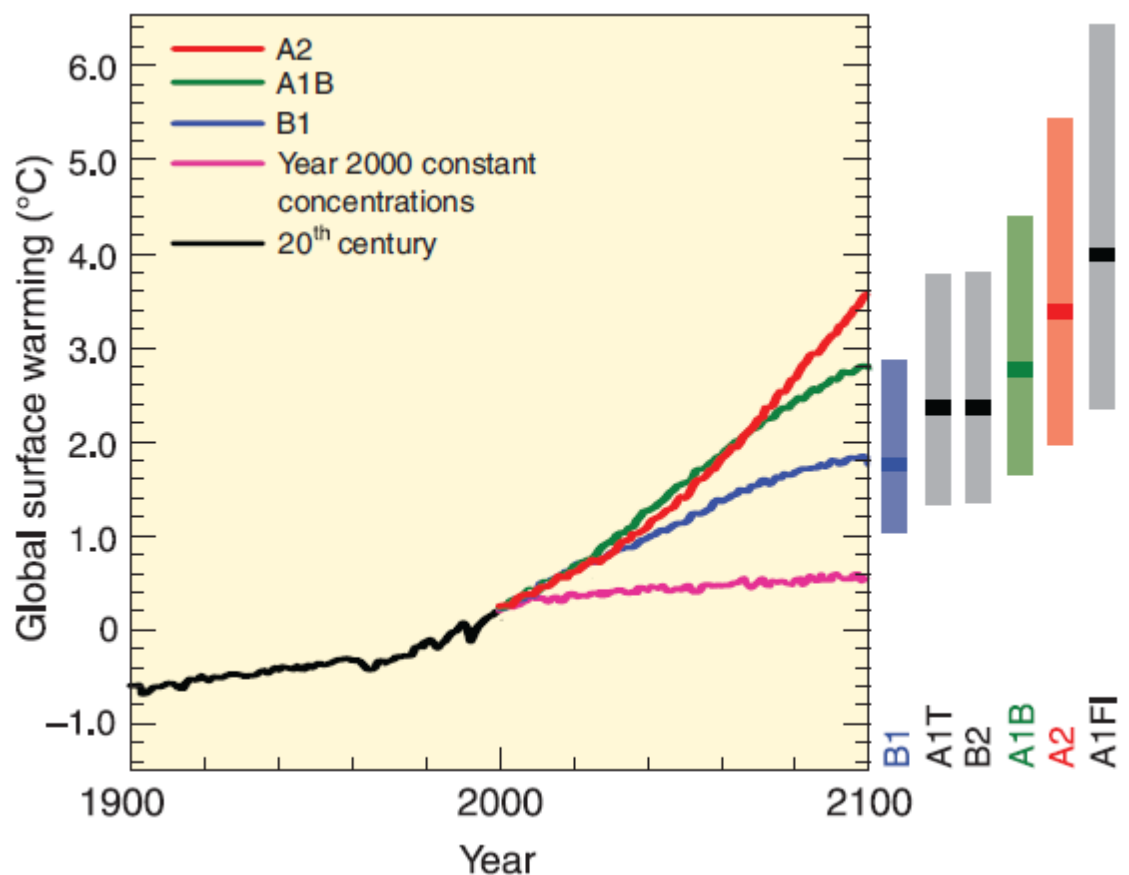
For the Fifth Assessment, IPCC defined a set of four new scenarios called Representative Concentration Pathways (RCPs). Each scenario—RCP2.6, RCP4.5, RCP6.0, and RCP8.5—considered radiative forcing values within the range of 2.6 – 8.5 W/m^2 and, like in AR4, were projected through year 2100.

RCP2.6, RCP4.5, RCP6.0, and RCP8.5 represent a range of future climate scenarios that make different assumptions about greenhouse gas emissions, agriculture, mitigation, and industry-specific air pollution. RCP2.6 is an emissions mitigation scenario at a "very low" radiative forcing level. RCP4.5 and RCP6.0 are two emissions "stabilization scenarios." RCP8.5 represents a "very high greenhouse gas emissions scenario."[125] In other words, RCP2.6 assumes significant greenhouse gas concentration reductions (to a level below 1990 levels), whereas RCP8.5 represents greenhouse gas concentrations on a "business-as-usual" trajectory.

As shown in Figure SPM.10 of AR5, below, global mean surface temperatures increase as a function of cumulative total global CO_2 emissions.[126] Modeling results for each RCP, through 2100, are shown with colored lines and decadal means. Figure SPM.10 also shows the total

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[125] Ex. 405, IPCC Fifth Assessment, at 29.
[126] Ex. 405, IPCC Fifth Assessment, at 28.

anthropogenic CO_2 emissions and the associated "temperature anomaly" for the four RCPs relative to the historical period (1860 to 2010), indicated by the black line. The red shaded area represents the collective range of all four RCP scenarios.
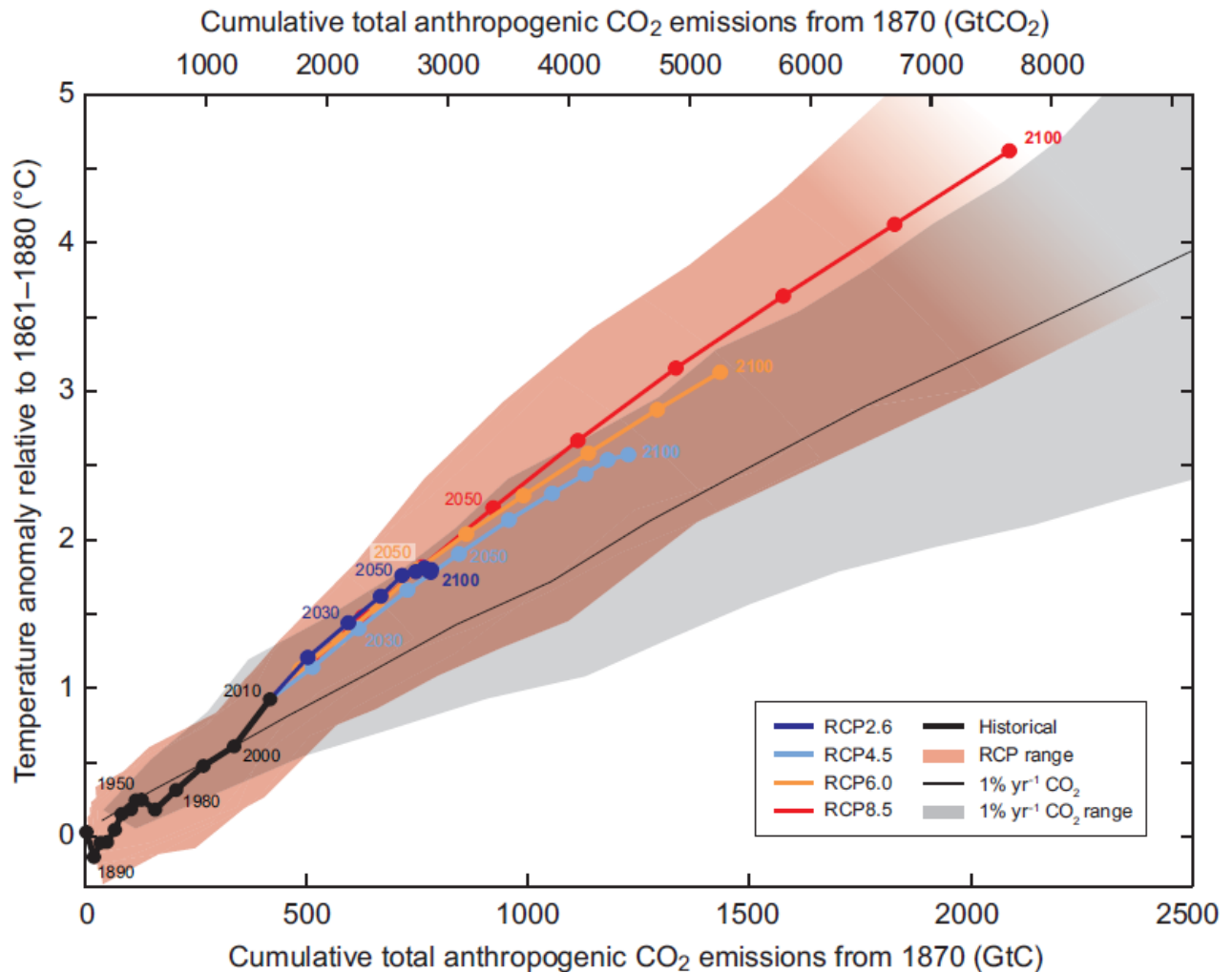
Some takeaways from the above figure, and radiative forcing generally, include:

- The slope of the RCPs indicates there is an approximately linear relationship between radiative forcing and the global mean surface temperature response. As can be seen by the purple line representing RCP2.6, the anthropogenic temperature anomaly is slightly less than 2°C by 2100. RCP4.5 and RCP6.0, the stabilization scenarios, show an increase of roughly 2.5°C -3°C Celsius by 2100. RCP8.5 shows an approximately 4.5°C change relative to 1870.

- The width of the shaded areas indicate there is great uncertainty at both ends, and in three of the four RCPs (all but RCP2.6), the spread indicates a strong possibility of warming of at least 2°C by 2100. In terms of cumulative warming, both AR4 and AR5

agree that to remain under a 2°C increase, relative to the pre-industrial era, CO_2 concentrations would need to be roughly the same as the atmospheric CO_2 concentrations in year 1990 or 2000 (depending on the Report).

- Cumulative total emissions of CO_2 and global mean surface temperature response are approximately linearly related.[127] Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond.[128]

As noted in the Introduction, CMIP3 refers to the modeling conducted in the Fourth Assessment, and CMIP5 refers to the modeling conducted for the Fifth Assessment. When comparing the two, as IPCC noted in AR5, "The multi-model ensemble mean in ECS is 3.2°C, a value nearly identical to that for CMIP3, while the CMIP5 ensemble range is 2.1°C to 4.7°C, a spread which is also nearly indistinguishable from that for CMIP3."[129]

Anthropogenic Influence

The terms "detection" and "attribution" are used to explain the causes from natural and anthropogenic (human activity) sources. "Detection" is defined as the "process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense without providing a reason for that change."[130] "Attribution" is defined as "the process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence."[131]

Detection and attribution are important concepts because, as IPCC states:

> In IPCC Assessments, detection and attribution involve quantifying the evidence for a causal link between external drivers of climate change and observed changes in climatic variables. It provides the central, although not the only line of evidence that has supported statements such as 'the balance of evidence suggests a discernible human influence on global climate' or 'most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.'[132]

Demonstrating how historical forcings can be calculated and attributable to both anthropogenic and natural causes is important for modeling future climate impacts because improves confidence in causal links between greenhouse gas emissions and associated temperature change over modeled time horizons.   For more detail on detection and attribution, staff refers the Commission to Chapter 10 of IPCC's Fifth Assessment. Stated briefly, though, Chapter 10

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[127] Ex. 405, IPCC Fifth Assessment, at 27.
[128] Ex. 405, IPCC Fifth Assessment, at 27.
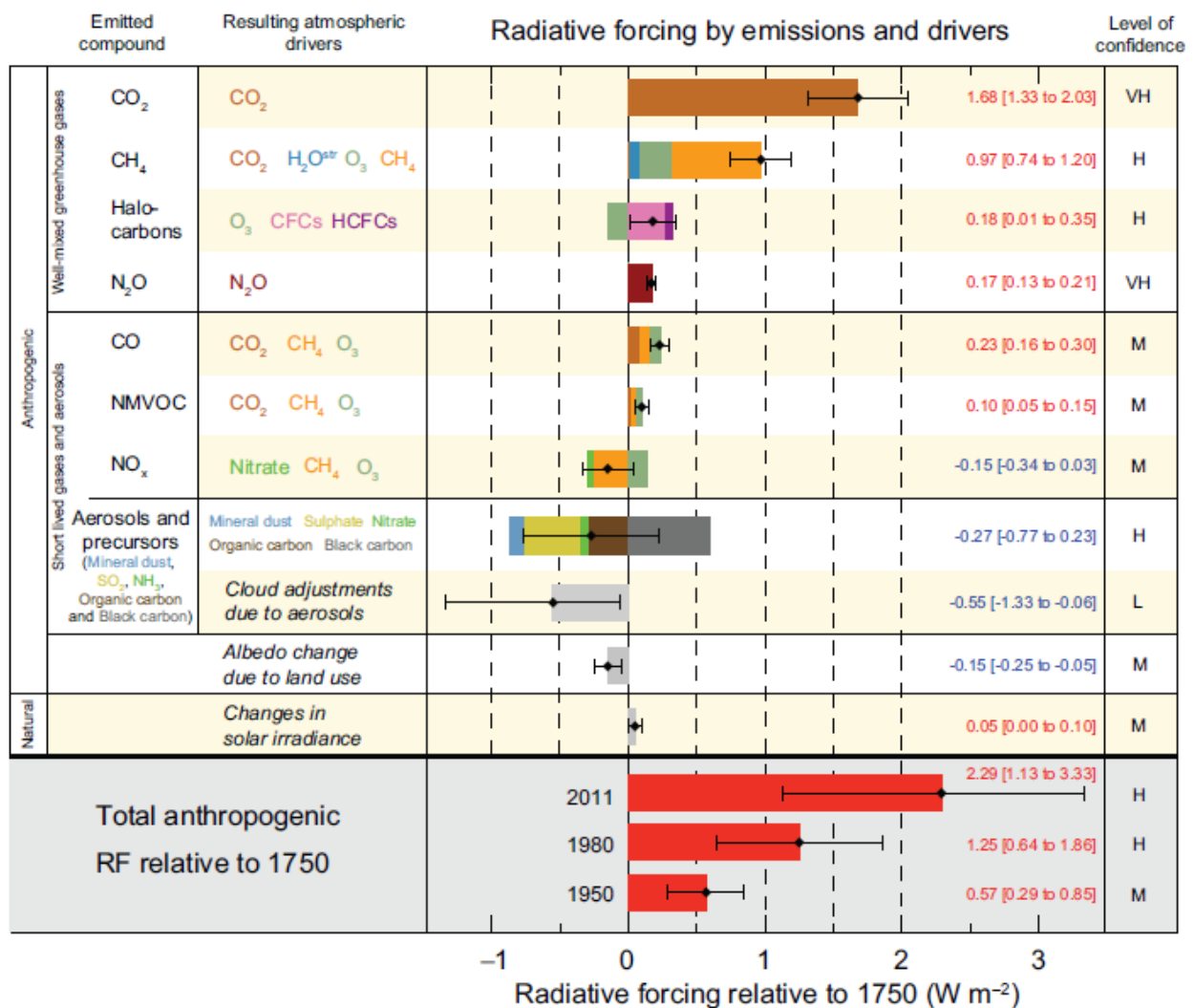[129] Ex. 405, IPCC Fifth Assessment, at 817.
[130] Ex. 405, IPCC Fifth Assessment, at 872.
[131] Ex. 405, IPCC Fifth Assessment, at 872.
[132] Ex. 405, IPCC Fifth Assessment, at 872.

assesses the causes of observed changes using climate models and statistical approaches. Specifically, Box 10.1 of Chapter 10 provides an example of an attribution study, expressed as a linear regression. Due to its length and complexity, staff does not provide the figures in this briefing paper, but rather notes that the attribution study demonstrates how IPCC takes several methodological steps to assess climate impact attribution, and it can separate anthropogenic from natural forcings. Separating these forcings allows IPCC to make projections about greenhouse gas emissions' role in temperature anomalies.

Considering these anthropogenic forcing individually, Figure SPM.5 of AR5 shows radiative forcing estimates by forcing agent in 2011 relative to 1750, as well as the range of uncertainties.

Emitted compound	Resulting atmospheric drivers	Radiative forcing by emissions and drivers	Level of confidence
		Well-mixed greenhouse gases	
CO_2	CO_2	1.68 [1.33 to 2.03]	VH
CH_4	CO_2 H_2O^{str} O_3 CH_4	0.97 [0.74 to 1.20]	H
Halo-carbons	O_3 CFCs HCFCs	0.18 [0.01 to 0.35]	H
N_2O	N_2O	0.17 [0.13 to 0.21]	VH
CO	CO_2 CH_4 O_3	0.23 [0.16 to 0.30]	M
NMVOC	CO_2 CH_4 O_3	0.10 [0.05 to 0.15]	M
NO_x	Nitrate CH_4 O_3	-0.15 [-0.34 to 0.03]	M
Aerosols and precursors (Mineral dust, SO_2, NH_3, Organic carbon and Black carbon)	Mineral dust Sulphate Nitrate Organic carbon Black carbon	-0.27 [-0.77 to 0.23]	H
	Cloud adjustments due to aerosols	-0.55 [-1.33 to -0.06]	L
	Albedo change due to land use	-0.15 [-0.25 to -0.05]	M
	Changes in solar irradiance	0.05 [0.00 to 0.10]	M
Total anthropogenic RF relative to 1750	2011	2.29 [1.13 to 3.33]	H
	1980	1.25 [0.64 to 1.86]	H
	1950	0.57 [0.29 to 0.85]	M

Radiative forcing by emissions and drivers

Radiative forcing relative to 1750 (W m^{-2})

(Left side labels: Anthropogenic — Short lived gases and aerosols; Natural)

Notably, the table above shows the negative effect of anthropogenic radiative forcing from "Cloud adjustments due to aerosols." As can be seen by the right-most column, while the level

of confidence in the positive contribution of CO_2 to total anthropogenic radiative forcing is very high (VH), the negative effect due to aerosols is low (L). According to IPCC:

> Aerosols of anthropogenic origin are responsible for a radiative forcing (RF) of climate change through their interaction with radiation, and also as a result of their interaction with clouds. Quantification of this forcing is fraught with uncertainties and aerosols dominate the uncertainty in the total anthropogenic RF. Furthermore, our inability to better quantify non-greenhouse gas RFs, and primarily those that result from aerosol– cloud interactions, underlie difficulties in constraining climate sensitivity from observations.[133]

How aerosols affect the climate and measurements of the climate response to anthropogenic emissions is explained in Chapter 7 of AR5:

> Atmospheric aerosols are composed of small liquid or solid particles suspended in the atmosphere, other than larger cloud and precipitation particles. They come from natural and anthropogenic sources, and can affect the climate in multiple and complex ways through their interactions with radiation and clouds. Overall, models and observations indicate that anthropogenic aerosols have exerted a cooling influence on the Earth since pre industrial times, which has masked some of the global mean warming from greenhouse gases that would have occurred in their absence. **The projected decrease in emissions of anthropogenic aerosols in the future, in response to air quality policies, would eventually unmask this warming**.[134] (Emphasis added.)

Why this is important for the Commission's consideration of ECS is because IPCC is suggesting the possibility that the observations could be masked by the influence of aerosols, which is not currently well-understood. What is well-understood is that the change in global mean surface temperature has a proportional relationship to radiative forcing, which is additive and has natural and anthropogenic origins. Uncertainty in climate sensitivity still exists, in part due to the complex nature of cloud-aerosol interactions, which are negative. Over the "observational," or "Instrumental," record, the uncertainty in aerosol effects, among other factors, means there is uncertainty in the total effect of anthropogenic radiative forcing since 1750 . Thus, it is not well-understood how a future in which climate policies may rid planet of anthropogenic emissions, including anthropogenic-sourced aerosols, would affect future scientific studies of climate sensitivity. The point here is that ranges for ECS are important for capturing many areas of complex systems with different levels of scientific understanding. Making a one-off assumption—for example, climate policy causes CO_2 emissions go down by X, therefore the planet cools down by Y—can be problematic, especially given the many different layers of climate response.
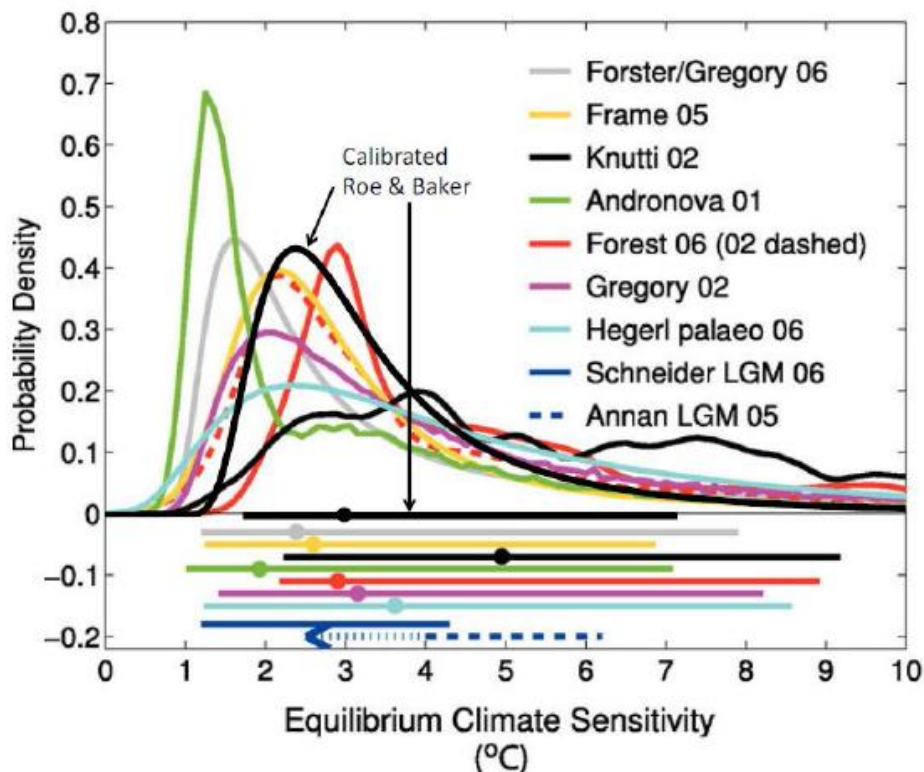
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[133] Ex. 405, IPCC Fifth Assessment, at 576.
[134] Ex. 405, IPCC Fifth Assessment, at 622.

ALJ Conclusions Section IV: Equilibrium Climate Sensitivity

The equilibrium climate sensitivity "quantifies the response of the climate system to constant radiative forcing on multi-century time scales;" the ECS is defined as "the change in global mean surface temperature at equilibrium that is **caused by a doubling of the atmospheric CO$_2$ concentration.**"[135] (Emphasis added.)

IWG's methodology applied a probability distribution for ECS based on a range of estimates from IPCC and the scientific literature. As mentioned in the Introduction, the IWG used a Roe & Baker distribution. The chart below, included in ALJ Finding of Fact 112, graphs the various estimates the IPCC considered for the probability density function for the ECS, including the calibrated Roe & Baker distribution (black line):

The range of climate sensitivity values was standardized across all three models and incorporated, not as any single fixed value, but as a random variable.[136] As Hanemann explained, for the purposes of calculating the social cost of carbon, "IWG used a numerical simulation procedure, randomly drawing 10,000 possible values of the climate sensitivity" that existed within IPCC's likely range.[137]

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[135] Ex. 405, IPCC Fifth Assessment, at 16.
[136] Ex. 405, IPCC Fifth Assessment, at 52.
[137] Ex. 800, Hanemann Direct, at 52.

A. ALJ Report

Section IV of the ALJ Report includes the Judge's Conclusions on equilibrium climate sensitivity. These conclusions are:

IV. Equilibrium Climate Sensitivity

22. The Administrative Law Judge concludes that Peabody failed to demonstrate, by a preponderance of the evidence, that an ECS value of 1 or 1.5 degrees centigrade is correct and that an ECS of more than 2 degrees centigrade is "extremely unlikely."

23. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the ECS doubling ranges as reported by the IPCC in the IPCC AR4 (2.0-4.5 °C) and the IPCC AR5 (1.5-4.5 °C) are more accurate ECS ranges than the range advanced by Peabody because the IPCC ranges are representative of a comprehensive, peer-reviewed body of scientific study based on multiple lines of evidence.

24. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates the IWG had a reasoned basis to refrain from adopting the IPCC AR5 ECS values in the IWG's 2013 FSCC update. While the IWG could have chosen to adopt the updated values at that time, it stated that it viewed that IPCC AR4 ECS values as the most authoritative at the time of the 2013 update and affirmed its intention to update the ECS values as appropriate in the future, based on the latest science and external expert advice.

25. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that it was reasonable for the IWG to adopt the ECS range of 2.0-4.5 °C as stated in the IPCC AR4.

B. Party Comments

Some witnesses and parties argued that there is an ECS value that is "more correct" or "more likely" than another, specifically whether those at the low end of the IWG range are more likely to represent actual temperature response. Another common argument was whether IWG erred in considering a 3°C ECS as a best estimate, in accordance with IPCC's Fourth Assessment.

Dr. Mendelsohn (Peabody) developed alternative SCC estimates using the DICE model (2013 version) and explored several climate sensitivity values, including 1°C, 1.5°C, 2°C, 2.5°C, and 3°C. In Dr. Mendelsohn's analysis, ECS was a fixed value, not a randomly drawn exogenous variable along a probability distribution.

MLIG argued that the FSCC values should be re-calculated using an ECS in the lower part of the range from 1.5°C to 4.5°C, pursuant to the IPCC's Fifth Assessment Report, which would equate to a conservative average or central ECS of 2.5°C (if one were to use one number for computational purposes).

According to Dr. Gurney (Agencies), the IPCC *likely* 1.5°C- 4.5°C ECS range is a "range of values representative of the large body of peer-reviewed scientific literature on the topic" and are "based on multiple lines of evidence (e.g. paleoclimate, model simulations, and instrumental measurements)."[138]

Dr. Gurney further provided Box 12.2, Figure 1 from Chapter 12 of IPCC's Fifth Assessment. In addition to this figure, Box 12.2 discusses probability density functions, distributions and ranges for ECS, and results from CMIP5. The grey shaded area marks the *likely* 1.5°C to 4.5°C range.

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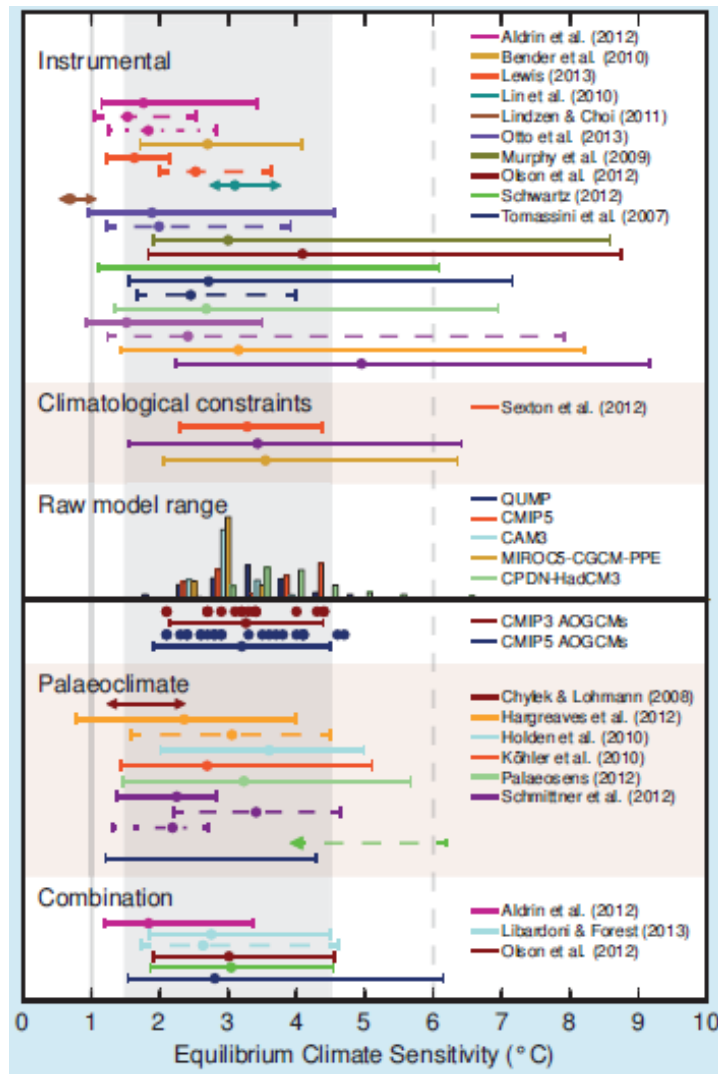
[138] Ex. 803, Gurney Rebuttal, at 17.

As Dr. Gurney explained, Figure 1 does not indicate a stronger likelihood at the lower end of the range.

At the evidentiary hearings, Box 12.2 was discussed at length during the cross-examination of Dr. Dessler, mostly with respect to the importance of and distinctions among each line of evidence, such as the instrumental, climate modeling, and paleoclimate data.[139]

The "Instrumental" range of Figure 1 above is derived from actual measurements of surface temperature, ocean heat content, and estimates for how much heat is trapped by greenhouse gases.[140] These indeed tend toward the lower end of the range, relative to other lines of evidence that is, although the error bars do extend to the upper bounds of the *likely* range (and beyond). The "Raw model range" showed a "CMIP5 model mean at 3.2°C, similar to CMIP3."[141]

According to CEO, "the ECS used by the IWG is a distribution and includes the lower values that opponents of the Federal SCC advocate. MLIG and others opposed to the Federal SCC ignore that the IWG used a distribution of values for the ECS rather than a single value. The distribution includes values on the very low end."[142]

Dr. Abraham (CEO) discussed excess heat in many aspects of the climate. According to Dr. Abraham, "[to] quantify climate change, a more accurate approach is to look at the largest thermal reservoirs," and "ocean heating is the clearest evidence that the Earth is warming."[143]

Figure 1 of Dr. Abraham's Rebuttal provided the sizes of various thermal reservoirs of Earth's climate system. According to Dr. Abraham, oceans (the blue portion) represent 93% of the thermal reservoir. The atmosphere, on the other hand, is a very small part of the climate (~1%), so to focus solely on warming in the atmosphere is to focus on about 1% of the climate system.[144]

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[139] See Hearing Transcript Vol. 3A, September 28, 2015, at 67-86 and 107-123.
[140] Hearing Transcript Vol. 3A, September 28, 2015, at 113.
[141] Ex. 405 IPCC Fifth Assessment, at 1110.
[142] CEO, Reply Brief, at 4-5.
[143] Ex. 102, Abraham Rebuttal, at 8.
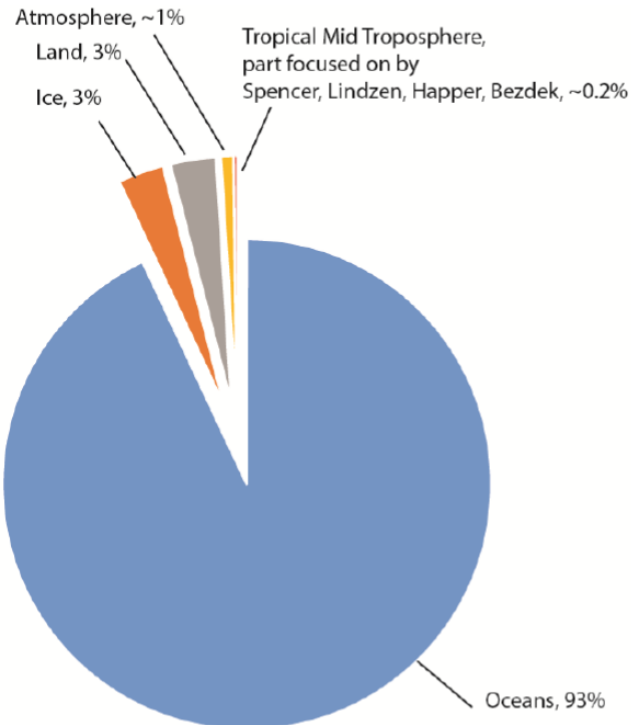[144] Ex. 102, Abraham Rebuttal, at 8.

Figure 1. Various thermal components of the Earth system

Nevertheless, despite its small scale relative to ocean warming, Dr. Abraham testified that the rate surface warming during the last 15 years has been as fast or faster than that seen during the latter half of the 20th century.[145]

C. Staff Discussion

ECS versus Total Warming

First, as a matter of clarification, it is important to distinguish the ECS from the anticipated cumulative climate warming expected to occur over a certain timescale. The ECS is commonly described as the doubling of CO_2 concentrations above pre-industrial levels. Based on IPCC's projections, in both the CMIP3 and CMIP5, atmospheric CO_2 concentrations could double from pre-industrial levels by, roughly, the mid-21st century (see figure below). Under IPCC's high-concentration scenarios in AR5 and AR4 (RCP8.5 for the Fifth Assessment and A1F1 for the Fourth Assessment), atmospheric CO_2 concentrations could approach the 1,000 ppm concentration level by 2100, which would mean CO_2 concentrations could almost double twice by 2100.[146,147]

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[145] Ex. 102, Abraham Rebuttal, at 11.

[146] Ex. 405, IPCC Fifth Assessment, at 149.

[147] For instance, RCP4.5 is close to SRES B1, RCP6 is close to SRES A1B, and RCP8.5 is somewhat higher than A2 in 2100 and close to the SRES A1FI scenario. RCP2.6, however, is lower than any of the SRES scenarios.
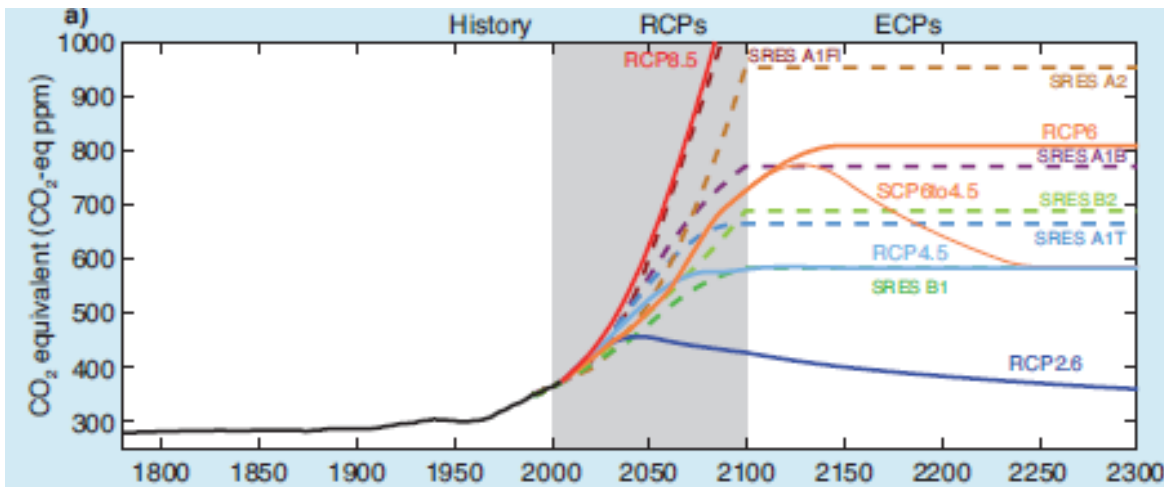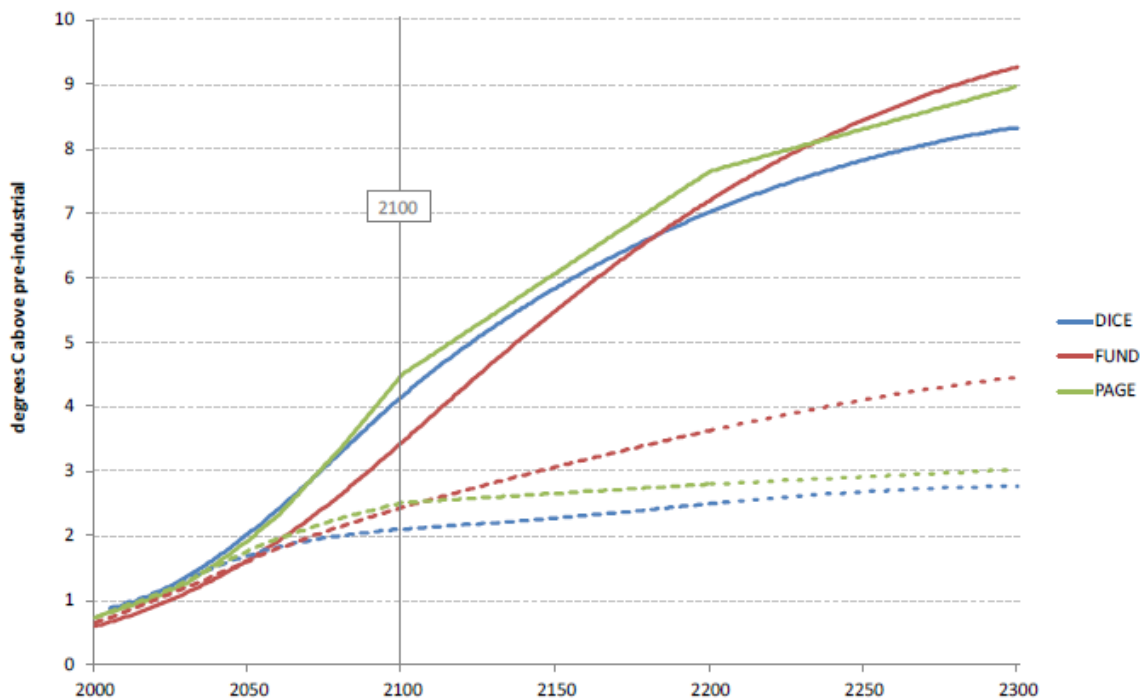
Figure 6 (c) of Mr. Martin's Direct shows the predicted temperature change (measured in degrees Celsius above pre-industrial average temperature) across DICE, FUND and PAGE. The solid lines represent the highest EMF-22 emissions scenario, MERGE Optimistic, and the dotted lines represent the lowest EMF-22 emissions scenario, the 550 ppm average.[148]


Alternatively illustrated, Dr. Smith's Expert Report shows IWG's extrapolations of the five EMF-22-adopted scenarios where ECS is held constant at 3°C.[149] As shown, the projected warming rises, but at a slower rate, due to IWG's assumption that emissions will level off then decline.

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[148] Ex. 600, Martin Direct, at 38.
[149] Ex. 302, Appendix B of Expert Report, Smith Direct, at 113.

Figure 8. Projections of Changes in Temperature for IWG's PAGE Runs for Each of the IWG's Socioeconomic Scenarios When Equilibrium Climate Sensitivity Is at Its Median Value (ECS=3) (Global mean temperature °C)
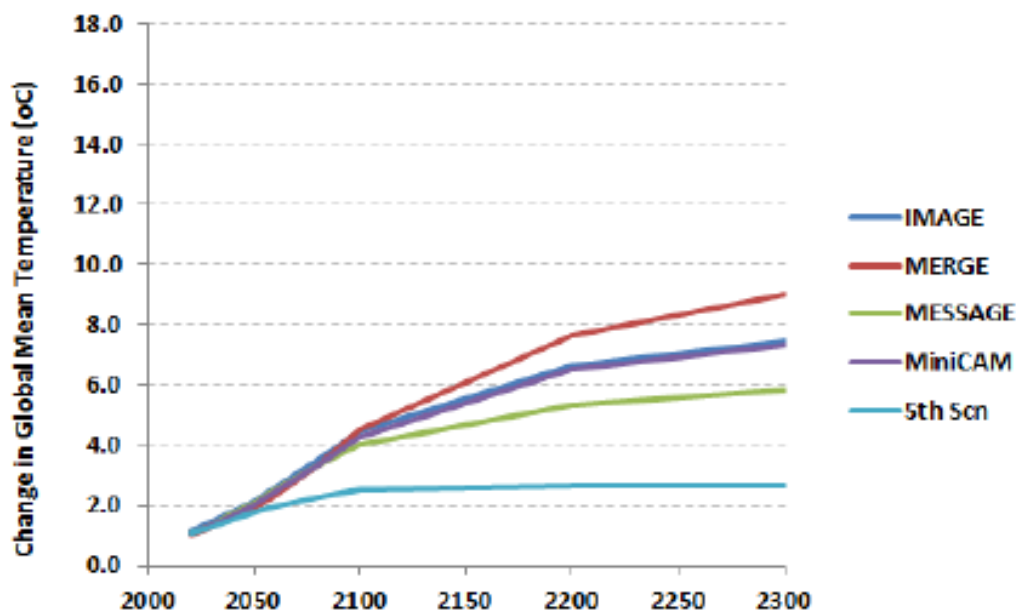

ECS Range

The probability and confidence associated with IPCC's *likely* range depends on, as Dr. Gurney explained, multiple lines of evidence. This includes instrumental, paleoclimate, and model simulations. Including these additional lines of evidence increases the confidence in the assessed *likely* ECS range.

Arguments that the lower end of the ECS range is more accurate seem to rely more heavily (or entirely) on the Instrumental portion of the ECS literature. According to Dr. Happer (Peabody), "Observations over the past two decades indicated that the warming from doubling CO_2 is closer to 1°C, or less than to the 3°C to 3.5°C assumed in most IPCC models."[150] This is a statement about the Instrumental record.

Referring back to Box 12.2, Figure 1, provided in its entirety above as well as on page 18 of Dr. Gurney's Rebuttal, staff shows below only the Instrumental portion:

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[150] Ex. 204, Happer Rebuttal Ex. 1 at 2.
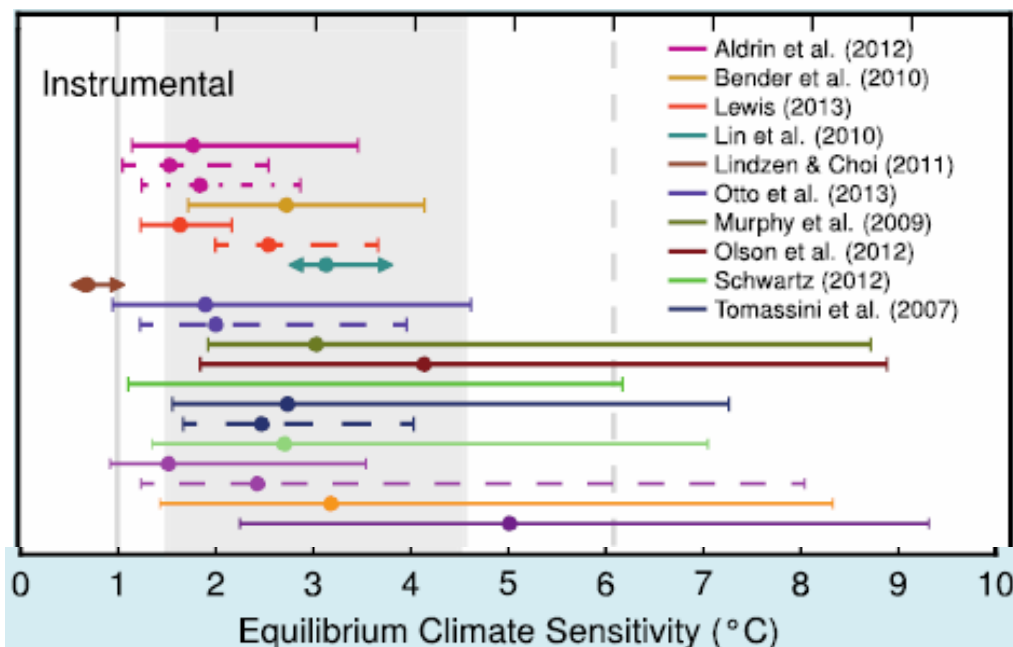
First, by referring to the wide error bars, one may not agree that the Instrumental evidence overwhelmingly demonstrates that lower ECS values are more likely. Second, while weighing the Instrumental evidence more heavily is not necessarily an unreasonable approach, other lines of evidence continue to support a broader range. For example, IPCC's climate model estimates indicated a range of 2°C to 4.5°C, with a multi-model ECS mean of 3.2°C.[151] And according to Chapter 5 of AR5, Section 5.3.3.2 (Last Glacial Maximum Constraints on Equilibrium Climate Sensitivity), ECS estimates based on the Last Glacial Maximum using three separate approaches all exhibited a range closely mirroring the 1.5°C to 4.5°C ECS range.

In addition, the level of scientific consensus on climate feedbacks, especially at high levels of atmospheric concentrations, is still very much evolving. For example, IPCC states:

> To limit the warming caused by anthropogenic CO_2 emissions alone to be likely less than 2°C relative to the period 1861-1880, total CO_2 emissions from all anthropogenic sources would need to be limited to a cumulative budget of about 1000 PgC since that period. About half [445 to 585 PgC] of this budget was already emitted by 2011.[152]

IPCC further explained that climate warming is projected to reduce oceanic carbon uptake in most oceanic regions.[153] Here, IPCC is alluding to what Dr. Abraham discusses in his testimony regarding thermal reservoirs.

With respect to other areas of uncertainty, IPCC cites permafrost as one example:

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[151] Ex. 405 IPCC Fifth Assessment, at 1110.
[152] Ex. 405, IPCC Fifth Assessment, at 1033.
[153] Ex. 405, IPCC Fifth Assessment, at 520

> There is *high confidence* that reductions in permafrost extent due to warming will cause thawing of some currently frozen carbon. However, there is *low confidence* on the magnitude of carbon losses through CO_2 and CH_4 emissions to the atmosphere, with a range from 50 to 250 PgC between 2000 and 2100 under the RCP8.5 scenario. The CMIP5 Earth System Models did not include frozen carbon feedbacks.[154]

There are also limitations to consider regarding the ECS itself. For instance, IPCC explained (with parenthetical citations removed for readability):

> A number of recent studies suggest that equilibrium climate sensitivities determined from [Atmosphere-Ocean General Circulation Models] and recent warming trends may significantly underestimate the true Earth system sensitivity, which is realized when equilibration is reached on millennial timescales. The argument is that slow feedbacks associated with vegetation changes and ice sheets have their own intrinsic long time scales and are not represented in most models. … The climate sensitivity of a model may therefore not reflect the sensitivity of the full Earth system because those feedback processes are not considered.[155]

Finally, ALJ Conclusion 23 refers to "accurate ECS ranges," and staff considered the possibility that the Judge's language could lead to some confusion:

> 23. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the ECS doubling ranges as reported by the IPCC in the IPCC AR4 (2.0-4.5 °C) and the IPCC AR5 (1.5-4.5 °C) are more accurate ECS ranges than the range advanced by Peabody because the IPCC ranges are representative of a comprehensive, peer-reviewed body of scientific study based on multiple lines of evidence.

MLIG offered the following redline Exception:

> **23 (MLIG EXCEPTION).** The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the ECS doubling range~~s~~ as reported by the IPCC in ~~the IPCC AR4 (2.0-4.5 °C) and t~~he IPCC AR5 (the lower part of the 1.5°C-4.5 °C range) is ~~are~~ a more accurate ECS range~~s~~ than the range advanced by Peabody because the IPCC range~~s~~ is ~~are~~ representative of a comprehensive, peer-reviewed body of scientific study based on multiple lines of evidence.

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[154] Ex. 405, IPCC Fifth Assessment, at 468.
[155] Ex. 405 IPCC Fifth Assessment at 1105.

The ALJ and MLIG both refer to accuracy, but accuracy is a measure of the extent to which something is or is not correct. For example, IPCC aims to ensure that "the state of the science is concisely and accurately presented,"[156] meaning that it does not wish to misrepresent the scientific literature. IPCC also aims to mitigate model uncertainty by ensuring that "any particular climate model can provide an accurate representation of the real climate system."[157] When reporting the ECS *likely* range, however, the IPCC combined scientific evidence and agreement that resulted in different levels of probability and categories of confidence.

As staff compared the Judge's conclusion to MLIG's Exception, one might interpret the two to mean who is right and who is wrong. However, accuracy should refer to an accurate representation of the scientific literature. The important language of ALJ Conclusion 23 is its inclusion of "based on multiple lines of evidence." This means the Commission's consideration of this conclusion might most appropriately mean, not necessarily who is right, but what is more *likely* and what is a more accurate representation of the scientific literature along *multiple lines of evidence*, which means considering observations, modeling, and paleoclimate data.

ECS and TCR (Transient Climate Response)

MLIG stated in its Exceptions that "the IPCC expressly found in its 2013 Fifth Assessment Report (AR5) that the new studies underlying the lowering of the low end of the ECS range 'suggest a best fit to the observed surface and ocean warming for ECS values in the lower part of the likely range.' This lower part translates to an ECS range from 1.5°C to 3°C."[158]

This statement cites Box 12.2, but staff is unsure why this translates to a 1.5°C to 3°C range. In order to modify the lower bound, IPCC would obviously need to explain why it made the change. In doing so, IPCC referenced recent studies that informed its choice to lower the ECS by 0.5°C at the low bound. However, regarding those studies, IPCC discussed some uncertainties in their methodology and, more importantly, never give any indication that they were "better" studies.[159] In addition, IPCC retained the upper bound.

Box 12.2 does discuss a 1°C to 3°C range, but this is with regard to transient climate response (TCR). TCR is defined as "the change in global surface temperature at the time of atmospheric CO_2 doubling in a [climate model] simulation where concentrations of CO_2 were increased by 1% yr."[160] TCR is used to measure changes in radiative forcings gradually over time, and these "transient simulations" allow a much shorter timescale to be considered.

According to Dr. Dessler, TCR values are generally much lower than ECS because, under the TCR approach, the climate system is not at equilibrium. A potential limitation of TCR, for example, is that without taken an equilibrium state into account, CO_2 emitted into the atmosphere could

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[156] Ex. 405, IPCC Fifth Assessment, at 123.
[157] Ex. 405, IPCC Fifth Assessment, at 138.
[158] MLIG Exceptions, at 32-33.
[159] Ex. 405 IPCC Fifth Assessment at 1111.
[160] Ex. 405 IPCC Fifth Assessment at 128.

simply become absorbed by the oceans with no other effect.[161] The IPCC also discussed the limitations of TCR in Box 12.2, noting, "Accounting for short term variability in simple models remains challenging, and it is important not to give undue weight to any short time period that might be strongly affected by internal variability."[162] Nevertheless, IWG's methodology incorporated a distribution of ECS, not TCR values, and the two are entirely different metrics.

The Warming Hiatus

Peabody argued that "models used by the IWG failed to predict a nearly two-decade-long 'hiatus' in warming during the very period when CO_2 emissions have been greatest."[163] The IPCC described the "hiatus" as an observed global mean surface temperature that has shown a much smaller increasing linear trend over the past 15 years than over the past 30 to 60 years.[164]

To Peabody, the "hiatus" raises questions about the validity of using higher ECS estimates. But, according to IPPC, [e]ven with this 'hiatus' in the global mean surface temperature trend, the decade of the 2000s has been the warmest in the instrumental record.[165]

Dr. Abraham's Rebuttal cited three recent studies to refute the notion that there has been a hiatus in the rate of global warming in recent years. Dr. Abraham continued, "If the latest years (2014 which is the hottest year recorded and 2015 which is currently even hotter than 2014) were included in the analysis, their findings of no slowdown would be even stronger."[166]

IPCC's Fifth Assessment addressed the hiatus in various places, one being Figure TS.14. Figure TS.14 (b), below, compares the modeled and observed historical period to the RCPs' projected temperature anomaly within a 5% to 95% confidence range of annual mean CMIP5 projections.

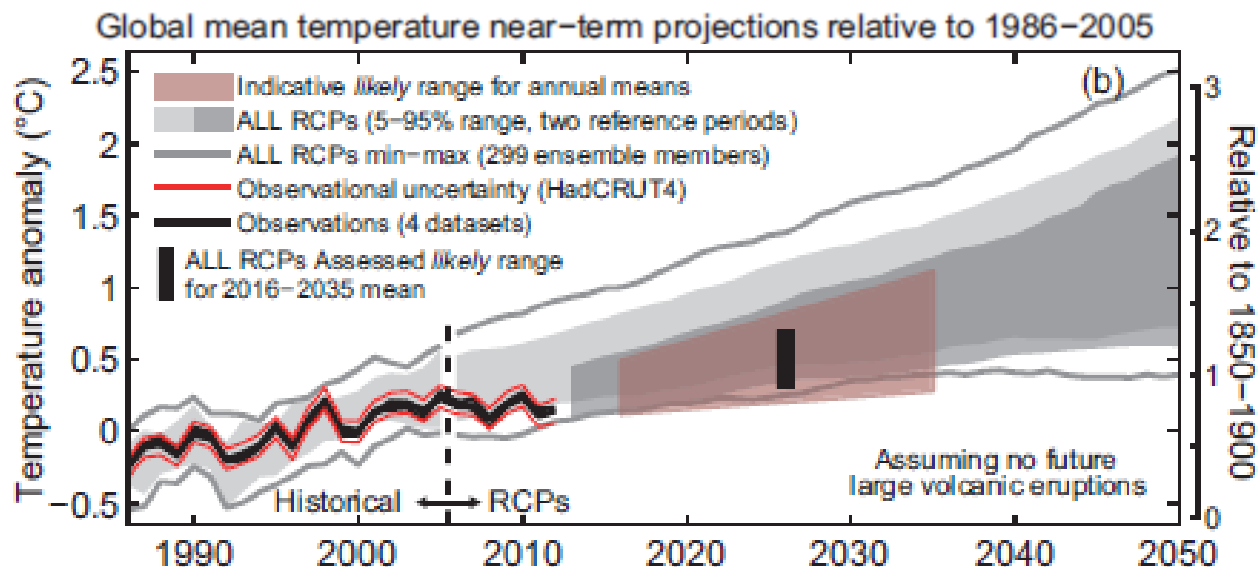[161] Hearing Transcript Vol. 3A, September 28, 2015, at 85.
[162] Ex. 405 IPCC Fifth Assessment at 1111.
[163] Peabody Initial Brief, at 22.
[164] Ex. 405, IPCC Fifth Assessment, at 61.
[165] Ex. 405, IPCC Fifth Assessment, at 61.
[166] Ex. 302, Abraham Rebuttal, at 11.

As shown in Figure TS.14 (b), the Observations (black line) and Observational uncertainty (red lines) are both somewhat volatile (dating to the 1986-2005 historical reference period), but they both remain within the 5-95% range of the RCPs. In addition, the "Indicative likely range for annual means" (red shaded area) are consistent with the RCPs' 5%-95% confidence range (grey shaded areas).[167]

In other words, some decades indicate a lower ECS while other decades indicate a higher ECS, but the volatility has remained within IPCC's expected range in the historical timescale. If one were to choose a different timescale—for example, isolating only the 1986-1998 timeframe— that person could make the opposite argument as Peabody, that the data shows a higher-than-expected ECS.

IPCC explained this as follows (with parenthetical citations removed for readability):

> During the 15-year period beginning in 1998, the ensemble of trends lies below almost all model-simulated trend, whereas during the 15-year period ending in 1998, it lies above 93 out of 114 modelled trends … There is hence *very high confidence* that the CMIP5 models show long-term GMST trends consistent with observations, despite the disagreement over the most recent 15-year period. Due to internal climate variability, in any given 15-year period the observed GMST trend sometimes lies near one end of a model ensemble.[168]

Dr. Abraham also addressed this point. Figure 6 of Dr. Abraham's Rebuttal, below, compares surface-temperature models with observations. Annotations on the left of the image indicate

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[167] Ex. 405, IPCC Fifth Assessment, at 87.
[168] Ex. 405, IPCC Fifth Assessment, at 61.

which temperature dataset corresponds to a particular color. Figure 6 shows that the 2015 temperature is nearly identical with the predicted value.[169]
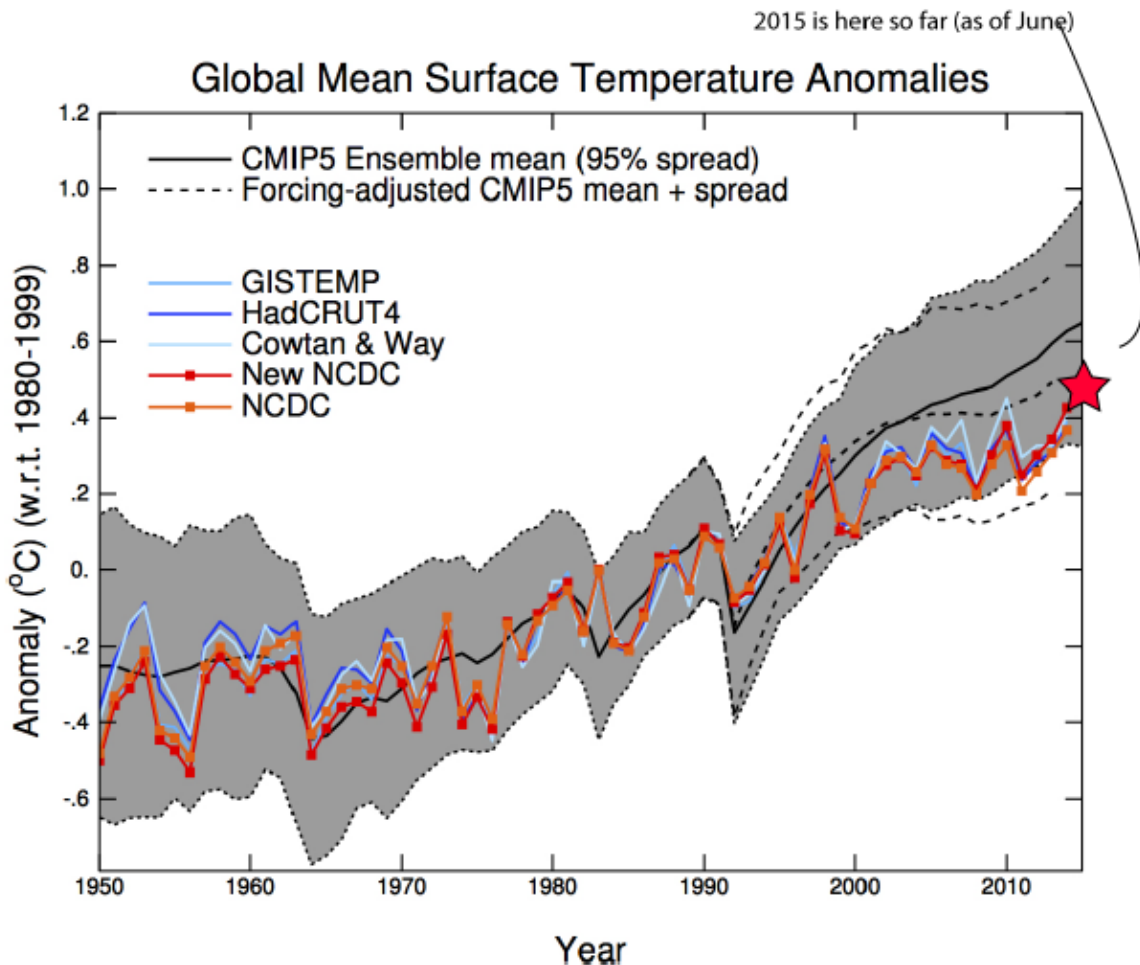

Figure 6. Comparison of computer models and observations of surface temperatures[9]

Dr. Gurney noted that the time period referenced in Dr. Happer's testimony (regarding the hiatus) means "since 1998." Dr. Gurney noted this was merely a span of roughly 17 years, which begins, curiously, at a very large El Nino year (1998) that had an unusually high global mean temperature.[170]

IPCC reported that the causes of both the observed hiatus and of the model–observation temperature trend difference during 1998–2012 imply that, barring a major volcanic eruption, most 15-year global mean surface temperature trends in the near-term future will be larger than during 1998–2012 (*high confidence*). The reasons for are fourfold:[171]

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[169] Ex. 102, Abraham Rebuttal, at 14.
[170] Ex. 803, Gurney Rebuttal, at 11.
[171] Ex. 405, IPCC Fifth Assessment, at 772.

1. Anthropogenic greenhouse-gas concentrations are expected to rise further in all RCP scenarios;
2. Anthropogenic aerosol concentration is expected to decline in all RCP scenarios, and so is the resulting cooling effect;
3. The trend in solar forcing is expected to be larger over most near-term 15-year periods than over 1998–2012 (*medium confidence*), because 1998–2012 contained the full downward phase of the solar cycle; and
4. It is *more likely than not* that internal climate variability in the near-term will enhance and not counteract the surface warming expected to arise from the increasing anthropogenic forcing.

Other Issues: Extreme Events, Human Health, and Minnesota-Specific Impacts

Extreme Events

An excerpt of Table SPM.1 of the IPCC Fifth Assessment shows examples of extreme weather events and their likelihood using (1) a global-scale assessment of recent observed changes and (2) projected changes for the early (2016–2035) and late (2081–2100) 21st century.[172]

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[172] Ex. 405, IPCC Fifth Assessment, at 7.

Phenomenon and direction of trend	Likelihood of further changes	
	Early 21st century	**Late 21st century**
Warmer and/or fewer cold days and nights over most land areas	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warmer and/or more frequent hot days and nights over most land areas	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warm spells/heat waves. Frequency and/or duration increases over most land areas	Not formally assessed[b] {11.3}	*Very likely* {12.4} *Very likely* *Very likely*
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	*Likely* over many land areas {11.3}	*Very likely* over most of the mid-latitude land masses and over wet tropical regions {12.4} *Likely* over many areas *Very likely* over most land areas
Increases in intensity and/or duration of drought	Low confidence[g] {11.3}	*Likely* (medium confidence) on a regional to global scale[h] {12.4} *Medium confidence* in some regions *Likely*[e]
Increases in intense tropical cyclone activity	Low confidence {11.3}	*More likely than not* in the Western North Pacific and North Atlantic[j] {14.6} *More likely than not* in some basins *Likely*
Increased incidence and/or magnitude of extreme high sea level	*Likely*[l] {13.7}	**Very likely**[l] {13.7} *Very likely*[m] *Likely*

Changes in many extreme weather and climate events have been observed since about 1950. According to IPCC, "It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is *very likely* that heat waves will occur with a higher frequency and duration. Occasional cold winter extremes will continue to occur."[173] Additionally, IPCC found there is "*high confidence* that the intensity of extreme precipitation events will increase with warming, at a rate well exceeding that of the mean precipitation."[174]

Global mean surface temperature is a primary driver of the damage estimates. As Dr. Hanemann explained, "While changes in average temperature are included in the IAMs, extreme temperature events are not accounted for in the IAM damage functions."[175] However, as shown in Figure 2 of Dr. Hanemann's Direct, some of the IAMs appear to be able to capture extreme phenomena as exogenous variables (i.e. determined outside the model).

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[173] Ex. 405, IPCC Fifth Assessment, at 20.
[174] Ex. 405, IPCC Fifth Assessment, at 72.
[175] Ex. 801, Hanemann Rebuttal, at 55.

In the IWG's 2015 *Response to Comments*, the IWG stated, "We agree with the commenters who suggested the IAMs do not fully capture the impacts associated with changes in climate variability and weather extremes."[176] IWG continued, "large-scale earth system feedback effects (e.g., Arctic sea ice loss, melting permafrost, large scale forest dieback, changing ocean circulation patterns) are not modeled at all in one IAM, and are imperfectly captured in the others."[177] This was one reason the IWG adopted the 95th percentile at the 3 percent discount rate scenario.

Peabody, however, challenged the claim that either anomalous extreme events or anthropogenic temperature increases have even been established, much less linked. According to ALJ Finding of Fact 19:

> Peabody disputed that extreme weather events are becoming more severe or more frequent than in the past. Peabody noted that, even more certainly than climate change, increased populations and wealth have been found to be major causes of economic damages from extreme weather events. "Concerns arising from the potential impact of global warming on drought, flooding, storminess, sea ice, and similar issues are largely unproven. There is no evidence that these matters are increasing due to warming (or in most cases increasing at all)." Moreover, Peabody claimed there is no evidence of increased hurricanes, tornadoes, wildfires, or droughts despite increases in atmospheric CO_2 levels.

Atmospheric CO_2 and Human Health

ALJ Conclusion 11 refers to the FSCC and human health:

> 11. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the FSCC underestimates the negative effects that increased warming will have on human health.

Peabody disputed the linkage between higher CO_2 concentration and impacts to human health, contending that medical impacts, such as respiratory disorders, will actually be lessened by climate warming. Peabody argued, "Proponents of the FSCC attempt to portray CO_2 as a traditional pollutant that causes various health effects. However, these alleged health effects – asthma and respiratory disorders – are not connected to CO_2 emissions. If CO_2 caused asthma directly, nobody would be able to breathe."[178]

Dr. Rom (DHE) responded to Peabody and argued that Peabody's witnesses do not have any training or experience in medicine or environmental health and that their evidence was not peer-reviewed by the medical or public health community.

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[176] Ex. 101, Schedule 1 of Polasky Rebuttal, at 15.
[177] Ex. 101, Schedule 1 of Polasky Rebuttal, at 15.
[178] Peabody Initial Brief, at 68.

Dr. Rom referenced the *Lancet* Commission on Health and Climate Change, a multidisciplinary, international academic collaboration that issued a report on June 23, 2015. The report found that climate change will directly affect human health through heat stress, floods, droughts, and storms, as well as indirectly through changes in air pollution, the spread of disease vectors, food insecurity and under-nutrition, population displacement, and mental ill health.[179,180]

Dr. Rom, in response to Dr. Happer's argument that cold-related deaths outnumber heat-related deaths, countered that "heat-related mortality skyrockets while cold-related mortality experiences a modest decline."[181] In fact, this conclusion is supported by the very same study upon which Dr. Happer based his claim.[182]

According to Dr. Rom, "Utilizing the SCC is a first step in this quantification, but the SCC is not a complete quantification of the health impacts of climate change."[183] This is because the SCC "omits several key damages incurred by the public as a result of CO_2-induced climate change, particularly exacerbated health harms from ozone and $PM_{2.5}$ and increased air pollution from wildfires."[184] While not exactly a direct link between a unit of CO_2 and human health hazards, a notable limitation of the economic IAMs is an understatement of the harmful interaction between warmer temperatures and exposure to ozone and $PM_{2.5}$. Epidemiological studies, for instance, demonstrate that higher temperatures produce higher rates of ozone-related mortality, indicating that higher temperatures heighten the physiological damage from ozone exposure.[185]

Minnesota-Specific Impacts

Some witnesses provided testimony regarding Minnesota-specific impacts. Dr. Bezdek (Peabody), in his Direct testimony, discussed CO_2 broadly and in the context of the State of Minnesota. Regarding CO_2, Dr. Bezdek testified:

> CO_2 is not a pollutant: It is not known to have any negative impacts on human health, it is essential for life, and is the basis of nearly all life on Earth -- without CO_2 life on this planet would not exist. It is the primary raw material or "food" utilized by the vast majority of plants to produce the organic matter out of which they construct their tissues, which subsequently become the ultimate source of food for nearly all animals and humans. Consequently, the more CO_2 there is in

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[179] Ex. 500, Rom Rebuttal, at 8.
[180] Watts, N et al. Health and Climate Change: Policy Responses to Protect Public Health. The Lancet, June 23, 2015. http://dx.doi.org/10.1016/S0140-6736(15)60854-6, at p. 2.
[181] DHE Initial Brief, at 15.
[182] DHE Initial Brief, at 15-16.
[183] Ex. 500, Rom Rebuttal, at 8.
[184] Ex. 500, Rom Rebuttal, at 8.
[185] Ex. 500, Rom Rebuttal, at 16-17.

the air, the better plants grow, as has been demonstrated in thousands of studies.[186]

Regarding CO_2 impacts to Minnesota, Dr. Bezdek continued:

[M]y conclusions are even more relevant for Minnesota than for the U.S. as a whole due to the state's northern location and relatively colder temperatures. It is thus exceedingly dependent on fossil fuels. Minnesota agriculture is highly petrochemical intensive, and to maintain or expand harvests will require more oil, natural gas, and other energy resources – not less.[187]

Dr. Bezdek emphasized the importance of CO_2 fertilization. According to Dr. Bezdek, "a doubling of the air's CO_2 content above present-day concentrations raises the productivity of most herbaceous plants by about one-third; and this positive response occurs in plants that utilize all three of the major biochemical pathways (C3, C4, CAM) of photosynthesis."[188] Dr. Bezdek forecasted that, over the 2012-2050 timeframe, the economic benefit of Earth's rising atmospheric CO_2 concentration would yield benefits of nearly $10 trillion.[189]

Dr. Bezdek did not determine a precise externality figure for CO_2, but, as explained in his Direct and in his Expert Report[190] (Exhibit 2 of his Direct), he explained that the empirical scientific evidence supports "an environmental externality figure for carbon dioxide of about zero."[191]

Dr. Mendelsohn (Peabody) also discussed how higher levels of carbon dioxide lead to carbon fertilization of plants. According to Dr. Mendelsohn:

Doubling carbon dioxide is expected to increase crop productivity by 30% and tree productivity by as much as 70%. These effects dominate the initial impacts over the next several decades to the forest and agriculture sectors. The carbon fertilization of trees has also led to an overall increase in ecosystem productivity and standing biomass which is an overall net benefit for ecosystems.[192]

The above excerpt, as Dr. Mendelsohn explained, is a broad statement regarding carbon fertilization across the planet. Thus, Dr. Mendelsohn continued that it "is important to understand is that the effect of warming is different in each affected sector. There can be some damage in places that generally benefit from warming and some benefits in places that are

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[186] Ex. 228, Bezdek Direct, at 9.
[187] Ex. 228, Bezdek Direct, at 6.
[188] Ex. 228, Bezdek Direct, at 16.
[189] Ex. 228, Bezdek Direct, at 17.
[190] Ex. 230, Report of Roger H. Bezdek, attached as Ex. 2 to Bezdek Direct Testimony.
[191] Ex. 228, Bezdek Direct, at 6.
[192] Ex. 214, Mendelsohn Direct, at 10.

overall harmed by warming."[193] In Minnesota, where there are net benefits, there are still damages associated with global warming such as hotter summers.[194]

Dr. Reich (CEO) responded to Drs. Bezdek and Mendelsohn's assessments of CO_2 impacts on Minnesota's silvicultural and agricultural production. The essence of Dr. Reich's Rebuttal is that Minnesota's forests, agriculture, water quality, soil water availability, and so on reflect a complex, balanced system, and that it is unreasonable to assume that Minnesota will fare better under higher CO_2 concentrations and warmer temperatures simply because Minnesota is relatively cold.

Dr. Reich acknowledged, "Rising CO_2 levels, warming temperatures, and a longer growing season will improve growth of some tree species, *if* they have sufficient water and are free from insect pests, diseases, and fires."[195] However, "other tree species, adapted to the historically cool climate of northern Minnesota and Canada, will fare poorly simply due to rising temperatures even if other factors are optimal."[196] Spruce and fir, which make up 30% of all trees in northeastern Minnesota, grow much more poorly (by as much as 30-40% more slowly) with even slight warming.

Evidence from Dr. Reich's experiments also shows that invasive species, such as buckthorn, benefit from climate change but they have "little (or negative) economic and ecological value and any extent to which its expansion is enhanced by climate change has negative repercussions for forest health and productivity."[197]

Other deleterious consequences Dr. Reich discussed include:

- Increased periods of limited water availability are already occurring due to climate change and will have a larger negative impact on forests than any positive effect of longer growing seasons and warmer summer temperatures.

- Insect pests and tree diseases in cold climates are held somewhat in check by the coldest temperatures of mid-winter (which can be lethal) and by the short growing season (that limits their population growth). Milder winters and longer growing seasons which will occur with climate change are likely to be beneficial to insects and diseases, which, in turn, will be detrimental to forest health in Minnesota.

- The greater incidence of high temperatures and dry conditions will lead to more opportunities for wildfire, and greater fuel loads will make such fires more destructive.

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[193] Ex. 214, Mendelsohn Direct, at 10.
[194] Ex. 214, Mendelsohn Direct, at 10.
[195] Ex. 107, Reich Surrebuttal, at 4.
[196] Ex. 107, Reich Surrebuttal, at 4.
[197] Ex. 107, Reich Surrebuttal, at 5.

Dr. Reich also criticized the scientific literature upon which Drs. Mendelsohn and Bezdek based their conclusions. According to Dr. Reich, "articles [Dr. Mendelsohn] cites to support his assertions about Minnesota forests are mostly global in nature (and thus have literally nothing tangible to say relevant to Minnesota), are largely computer models rather than empirical evidence, and are far from the most recent or relevant publication on the topic."[198] In response to the list of examples Dr. Bezdek provided, Dr. Reich stated, "The list is not useful in this or any other situation. It would be deemed unsatisfactory to any peer-reviewed scientific publication, because the citations are in no particular order and are largely irrelevant to the assertion he was asked to support."[199]

IPCC Assessment Reports' Relationship to the Social Cost of Carbon

In staff's view, in terms of having a scientific basis for projecting climate impacts on a global scale, there is arguably not any expert evidence more vetted, collaborative, comprehensive, and widely credible than that which was produced by the IPCC. As Dr. Hanemann testified, "IPCC reports are internationally regarded as authoritative on the topics covered."[200] The ALJ found, "The Commission and the Minnesota Court of Appeals recognize the IPCC as a source of expertise on climate change." [201] And on climate sensitivity, specifically, the ALJ concluded, "the IPCC ranges are representative of a comprehensive, peer-reviewed body of scientific study based on multiple lines of evidence."[202] As far as staff is aware, no party to this proceeding argued that IPCC lacks credibility as an authoritative voice on climate science, even though Peabody critiqued of many of IPCC's findings.[203] Therefore, the Commission would be justified in considering IPCC's AR4 and AR5 as elemental to many of the issues addressed in this proceeding, in large part to support a view that economic estimates must first have a sound basis in the physical sciences.

Assuming the IPCC is indeed among the most credible organizations in the field of climate change, ideally, it would be easy and straightforward to align the economic analysis with the IPCC multi-model analyses in order to accurately and precisely translate climate impacts into monetary terms. Unfortunately, even IWG acknowledges that attempting to do so is not precise and has limitations.[204] Still, even without this luxury, one could align some of the economic parameters with some of IPCC's parameters to match them the extent possible, practicable, and reasonable. Staff will discuss three such parameters below.

Time Horizon

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[198] Ex. 107, Reich Surrebuttal, at 10.
[199] Ex. 107, Reich Surrebuttal, at 11.
[200] Ex. 800, Hanemann Direct, at 34.
[201] ALJ Report on CO_2, page 12, Footnote 49 of Finding 12.
[202] ALJ Report on CO_2, page 118, Conclusion #23.
[203] In fact, one of Peabody's witnesses, Dr. Tol (creator of the FUND model) was a lead author for a working group for the Fifth Assessment.
[204] Ex. 101. Schedule 1 of Polasky Rebuttal, at 18.

Time horizon is a contentiously disputed issue in this case, for many reasons that will be discussed in the following sections. At this point, though, it might be worth noting that the IPCC ran its climate modeling in its Fourth and Fifth Assessments only through 2100, despite concluding the following:

> Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2.[205]

IPCC clearly acknowledges that CO_2 emitted today will remain in the atmosphere and have climate impacts beyond 2100, although longer-term impacts are discussed at length (see Chapter 12 of AR5). Additionally, in AR4 and AR5, IPCC chose to present its likely range of increases in global mean surface temperature across a 21st century time horizon. Of course, IWG's reasons for calculating the SCC beyond 2100 may be different than IPCC's reasons for presenting a range of likely temperature increases until 2100, especially since the point of the SCC is to monetize impacts from the emissions' persistence in the atmosphere in present value terms. Still, applying the same time horizon to this case as those used by the IPCC and EMF-22 is one approach the Commission could take.

Climate Sensitivity

For its Fifth Assessment Report, the IPCC revised its likely range of climate sensitivity compared to AR4 by reducing the low end of the assessed likely range from 2°C to 1.5°C and retaining the high end of the range at 4.5°C. Some parties view this change as incredibly significant and supportive of a value lower than 3°C for climate sensitivity; however, staff has the exact opposite view. Resource planning proceedings generally consider a full range of assumptions and sometimes view mid-points as reasonable estimates, and the climate sensitivity range is strikingly similar between the two reports. So regardless of whether AR4 or AR5 is given more weight, the results on ECS are not markedly different. In fact, IPCC concluded:

> The multi-model ensemble mean in ECS is 3.2°C, a value nearly identical to that for CMIP3, while the CMIP5 ensemble range is 2.1°C to 4.7°C, a spread which is also nearly indistinguishable from that for CMIP3.

Even if there is not an explicit best estimate for climate sensitivity in AR5, a median ECS value of 3°C also appears quite supportable regardless which Assessment Report is given more weight.

Geographic Scope

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[205] Ex. 405, IPCC Fifth Assessment, at 27.

The complexities of the carbon cycle and feedback effects described in IPCC's Assessments suggest that a global geographic scope is justified in this case, which means basing the SCC estimates on global climate impacts. For example, the IPCC models consider, among other things, interrelationships between land carbon uptake, ocean carbon sinks, and the feedback between climate and the carbon cycle. To estimate the climate effect of CO_2 emissions from Minnesota, it does not seem plausible or reasonable to simply ignore all carbon sinks outside the State's geographical boundary.

Part 4: Economic Analysis

ALJ Conclusions Section I: Integrated Assessment Models (IAMs)

In the Commission's October 15, 2014 *Order for Hearing*, the Commission gave guidance when setting the scope of the investigation and required parties to use a damage cost approach:

> The Commission will require parties in the contested case proceeding to evaluate the costs using a damage cost approach, as opposed to (for example), market-based or cost-of-control values. When last faced with the question of the preferred approach to estimate environmental cost values, the Commission stated that, as between estimates based on damage or based on cost-of-control, the damage-cost approach is superior because it appropriately focuses on actual damages from uncontrolled emissions.

> Nothing in this proceeding justifies reaching a different conclusion now. Where a damage cost can be reasonably estimated, it represents a superior method of valuing an emission's environmental cost. The Commission is persuaded that a damage-cost approach can be used for the emissions under investigation, and will therefore require it.[206]

The Commission also specified that it preferred "reduced form" modeling, which essentially means that the Commission preferred a more simplified, less resource intensive method to model the relationship between emissions and the physical environment and economy:

> The Commission, having considered the relative merits of damage modeling approaches discussed by the Agencies, prefers reduced-form modeling in this case.[207]

A. ALJ Report

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[206] Commission Notice and Order for Hearing, at 4-5 (Oct. 15, 2014)
[207] Commission Notice and Order for Hearing, at 5 (Oct. 15, 2014)

The ALJ concluded in her Report:

> 6. The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that the IWG's use of the DICE, PAGE, and FUND models to calculate the FSCC is a damage-cost approach consistent with the Commission's Notice and Order for Hearing in this docket.
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> …
>
> 8. The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that it was reasonable for them to rely on an environmental cost valuation for CO_2 based on the use of the DICE, PAGE and FUND models, given the combined requirements of a damage-cost approach and reduced-form modeling.

B. Party Positions

Credibility of the IAMs

Dr. Hanemann's Direct testimony explained how the IAMs used in this proceeding are consistent with the Commission's direction in its October 2014 Order:

> In the present context, an IAM combines a reduced form representation of the carbon cycle and the climate system together with a reduced form representation of the economy, economic growth and the generation of GHG emissions and a reduced form representation of the impacts of climate change and how those impacts are valued (the external cost generated).

> The strength of an IAM is that it combines the three components in one integrated model – the representation of how economic activity generates emissions, the representation of how the emissions lead to climate change, and the representation of the economic cost of the resulting impacts.[208]

According to Dr. Hanemann, DICE, PAGE, and FUND "are well known and have been widely cited in the economic literature on climate change and mitigation policy for the last two decades. In fact, to most people familiar with this literature, it would have been surprising had the IWG *not* used DICE, PAGE and FUND."[209]

CEO argued, "The IWG's decision to use the three most-cited and accepted Integrated Assessment Models in the academic literature was reasonable and has not been seriously

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[208] Ex. 800, Hanemann Direct, at 23-24.
[209] Ex. 800, Hanemann Direct, at 66.

contested in this proceeding. Dr. Polasky stated that the IWG selected 'the three most prominent and commonly cited'[210] models to perform its analysis."[211]

Some refuted arguments that the IAMs chosen by the IWG were applicable to or reasonable to use for Minnesota's resource planning process. Many opposing views expressed the concern that IAMs contain excessive speculation, or oversimplification, in the modeling assumptions.

GRE/MP/OTP, for example, argued there is "overwhelming evidence establishing the uncertainty associated with the values produced by the IAMs."[212] In its Exceptions, GRE/MP/OTP claimed, "every expert who appeared in this proceeding, including those offered by the Agencies and the CEOs, as well as those experts cited from the academic literature, share the view that the FSCC values are highly uncertain."[213]

Included as part of its criticisms of the IAMs, GRE/MP/OTP[214] and Peabody[215] both cited a paper from economist Dr. Richard Pindyck, titled "Climate Change Policy: What Do the Models Tell Us," which is critical of IAM-based analyses in general, calling IAMs "close to useless" and "misleading."

CEO responded to GRE/MP/OTP and Peabody by including an excerpt from the same paper, in which Dr. Pindyck concluded:

> My criticism of IAMs should not be taken to imply that, because we know so little, nothing should be done about climate change right now, and instead we should wait until we learn more. Quite the contrary. One can think of a GHG abatement policy as a form of insurance: society would be paying for a guarantee that a low-probability catastrophe will not occur (or is less likely). As I have argued elsewhere, even though we don't have a good estimate of the SCC, it would make sense to take the Interagency Working Group's $21 (or updated $33) number as a rough and politically acceptable starting point and impose a carbon tax (or equivalent policy) of that amount. This would help to establish that there is a social cost of carbon, and that social cost must be internalized in the prices that consumers and firms pay. (Yes, most economists already understand this, but politicians and the public are a different matter.) Later, as we learn more about the true size of the SCC, the carbon tax could be increased or decreased accordingly.

IWG also responded to general claims that the IWG was not transparent or that it failed to explain or justify the choice of models and/or inputs used to run the models.

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[210] Ex. 100, Polasky Direct, at 6
[211] CEO Initial Brief, at 12.
[212] GRE/MP/OTP Exceptions, at 12.
[213] GRE/MP/OTP Exceptions, at 11.
[214] GRE/MP/OTP Exceptions, at 11.
[215] Peabody Initial Brief, at 30.

[T]he IWG disagrees with the comment that insufficient justification has been provided for the models, data inputs, and assumptions used to estimate the SCC. The IWG has regularly and repeatedly provided detailed explanations and justifications for the data, assumptions, and models used to estimate the SCC. The 2010 TSD thoroughly detailed each of these aspects, justified their use, and elucidated their limitations. The 2013 TSD provided a detailed explanation of updates and revisions made to the SCC. The additional OMB public comment solicitation provided a further opportunity for the public to comment on the data, assumptions, and models used in developing the SCC estimates; in this Response to Comment the IWG is responding to those comments received. Thus, the IWG has provided clear, transparent analytic defenses of its estimates, explained the rational connections that underlie these estimates, and responded to public comments.[216]

Changes Made to the IAMs, by IWG and Witnesses to this Proceeding

GRE/MP/OTP's witness, Dr. Smith, had several criticisms of IAMs, and a unique feature of her testimony was that she conducted a replication analysis. Dr. Smith's "Expert Report," attached as Exhibit 2 of her Direct testimony, replicated the IWG's 2013 computations for the 2020 value of the SCC. This analysis required, first, obtaining from EPA all the files that the IWG used to produce its 2013 SCC estimates. Then, Dr. Smith's team ran each of the three IAMs for each of the IWG's five socioeconomic scenarios.

Dr. Smith's analysis encountered problems early in the replication process. According to Dr. Smith's Expert Report, "The general lack of ability to replicate the IWG's PAGE results should give participants in the Minnesota proceeding pause before accepting the CEO's statement that the Federal SCC estimates are robust because they are peer-reviewed and 'well-supported.'"[217] Ultimately, though, Dr. Smith was able to reproduce the estimates with a difference of less than $1/tonne when PAGE results were averaged with FUND and DICE results.

Dr. Tol, Peabody witness and author of the FUND model, offered the following critique of how IWG used FUND in setting the SCC estimates:

As the author of FUND, my assessment is the IWG may not have correctly operated FUND in generating its estimates. Because the IWG process and the calculations themselves are not immediately transparent, it is has not been possible for me to ascertain exactly how the IWG generated its estimates or whether they are economically and scientifically valid. However, the inconsistency between the numbers that my operation of the FUND model generates and those produced by

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[216] Ex. 101, Schedule 1 of Polasky Direct, IWG Response to Comments (July 2015), at 7.
[217] Ex. 302, Smith Direct, Exhibit 2 –Expert Report - CO2 Environmental Cost Values Phase, at 37.

the IWG raises serious questions as to whether the IWG's estimates lack economic and scientific reliability.[218]

Figure 6 of Dr. Hanemann's Direct shows the changes made in the three IAMs used by the IWG and their implications.[219]

Model	Modification	SCC Implication	Type
DICE	Carbon cycle parameters – weaker ocean uptake	+	Revision
	Sea level dynamics and valuation – explicit modeling	-	Change
FUND	Space heating	+	Fix
	Sea level rise and land loss	?	Fix
	Transient temperature response	+	Change
	Methane – account for additional radiative forcing effects	+	New
PAGE	Sea level rise	?	Change
	Revised damage function to account for saturation – modified GDP loss function	?	Fix
	Regional scaling factors	?	Revision
	Probability of discontinuity	+	Revision
	Adaptation	+	Revision
	Change in land/ocean carbon update	?	Revision
	Regional temperature change	?	Revision

A plus sign implies an increase in the model's SCC relative to that model's 2010 values.

Revision types: Revision = updated; Change = formulation change; Fix = issue fixed; New = new feature.

Source: Based on Table 2.4 in EPRI (2014)

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[218] Ex. 236, Tol Rebuttal, at 7.
[219] Ex. 800, Hanemann Direct, at 58.

Peabody witness, Dr. Mendelsohn, used the most recent version of DICE (DICE2013), received from the website of its author, Professor William Nordhaus. Dr. Mendelsohn developed two alternative damage functions in DICE that adjusted the temperature whereby damages would begin to occur. One modified damage function assumed that net damage would not begin until temperature rises above 1.5°C. The second modified damage function assumed net damages do not begin until temperature rises 2°C above 1900 levels. Dr. Mendelsohn then calculated the social cost of carbon with both (1.5°C and 2.0°C) damage functions.[220]

C. Staff Discussion

In the ALJ's Memorandum to her report, the Judge discussed the Guiding Criteria of this case:

I. Guiding Criteria

In reviewing the issues raised by the parties, the Administrative Law Judge has been guided by several criteria. The Commission established certain of these criteria in the first Externalities case.

In the first Externalities case, the Commission considered the statutory requirement that its task under Minn. Stat. § 216B.2422, subd. 3, is "to the extent practicable, [to] quantify and establish a range of environmental costs associated with each method of electricity generation." In its January 1997 Order, the Commission adopted the Administrative Law Judge's definition of the term "practicable" for purposes of the statute, finding that "practicable" means "feasible" or "capable of being accomplished." Practicability must be demonstrated by a preponderance of the evidence, as discussed earlier in this report.

The Commission established several additional criteria in 1997, several of which are relevant to this portion of the present docket. Those criteria are that: 1) the damage-cost approach is preferred; 2) using a range of environmental cost values appropriately takes into consideration a certain level of unavoidable scientific uncertainty; and 3) while it is generally appropriate to focus on damages occurring in Minnesota, that approach does not apply to values adopted for CO_2, for which damages should be assessed globally.[221]

The ALJ's Guiding Criteria are directly applicable to the Commission's consideration of IAMs, and while several parties raise valid points regarding the IAMs' limitations and deficiencies, perfection was not the bar for reasonableness. The ALJ's conclusions and recommendations were based on whether the IAMs:
- Are "practicable," meaning "feasible" or "capable of being accomplished;"
- Use a damage cost approach;

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[220] Ex. 214, Mendelsohn Direct, at 9.
[221] ALJ Report, Memorandum, at 125.

- Reasonably consider unavoidable uncertainty; and
- Can assess global climate impacts.

There are different levels of disagreement with regard to each bullet point. Probably the most significant is whether the IAMs can reasonably account for uncertainty, which makes sense because IAMs inherently must make simplified representations of the climate and their projections involve the future. There is also dispute about the global geographic scope—i.e. whether to consider state, national, or global impacts—and the usefulness of the IAMs is a more relevant question as the geographic scope shrinks. In other words, clearly the IAMs can "practically" take into account global impacts, but if the geographic scope is limited to the State of Minnesota, then what the IAMs can capably produce is, in staff's view, less reliable. This is because what one would endeavor to estimate, presumably, under a localized geographic scope is a series of disaggregated damage functions specific to one state, and such damage functions do not exist.

In its July 2015 *Response to Comments*, IWG provided a response to some of the criticisms of its choice of IAMs used to estimate the SCC:

> While the development of the DICE, FUND and PAGE models necessarily involved assumptions and judgments on the part of the modelers, the damage functions are not simply arbitrary representations of the modelers' opinions about climate damages. Rather they are based on a review by the modelers of the currently available literature on the effects of climate change on society. The conclusions that the modelers draw from the literature, and the bases for these conclusions are documented, and all three models are continually updated as new information becomes available. [222]

ALJ Conclusions Section XII: Scientific Process

This section concerns whether the IWG used a reasonable and transparent scientific process. The ALJ Report has two conclusions on Scientific Process, Conclusions 47 and 48.

A. ALJ Conclusions 47 and 48

XII. Scientific Process

47. The Administrative Law Judge concludes that Peabody failed to demonstrate by a preponderance of the evidence that the IWG is neither peer-reviewed nor transparent. While the FSCC itself is not peer-reviewed, a preponderance of the evidence demonstrated that the IWG relied primarily on peer-reviewed literature, particularly the work of the IPCC, which is recognized by the Commission, the

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[222] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG July 2015 Response to Comments, at 8.

Minnesota Court of Appeals and the United States Supreme Court as a credible source of expertise in the area of climate change. The experts in this proceeding reviewed the FSCC process exhaustively, providing extensive analysis and critique. While technically not a peer review, this contested case process has provided a thorough level of scrutiny of the FSCC and the IWG's process in developing the FSCC. The IWG's Technical Support Documents are all part of the record in this proceeding, along with numerous commentaries regarding the IWG's process and the FSCC.

48. The Administrative Law Judge concludes that Peabody failed to demonstrate by a preponderance of the evidence that the Agencies and the CEOs relied primarily on non-peer-reviewed literature. The Administrative Law Judge was unable to verify Peabody's non-specific assertions that the Agencies and CEOs relied on such literature.

Peabody asserted that that the IWG's process was neither peer-reviewed nor transparent; however, Peabody did not file any Exceptions to the ALJ Report. MLIG was the only party to take exception to the Judge's conclusions on Scientific Process.

B. Staff Discussion

Public Input and Transparency

Mr. Martin (Xcel) in his Direct testimony criticized the IWG for not asking for public input when it developed the SCC in 2009-10, and further that IWG updated it twice "with very little public input."[223] However, in November 2013, IWG published a Technical Support Document (TSD) entitled *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*. Also in November 2013, OMB issued a notice requesting public comments. OMB received 140 sets of comments and over 39,000 form letter submissions.

In addition, according to IWG's February 2010 *Technical Support Document*:

Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.[224]

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[223] Ex. 600, Martin Direct, at
[224] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document on the Social Cost of Carbon, at 1.

IWG addressed the question of peer-review and transparency in its July 2015 *Response to Comments*. Due to the length to which IWG addressed to the concern, staff will provide only a brief excerpt from IWG's *Response to Comments*:

> The IWG thus believes that it was appropriate to base the SCC estimates on the DICE, FUND and PAGE models. Moving forward, the IWG will continue to follow and evaluate the latest peer reviewed literature applying IAMs. The IWG will seek external expert advice on the technical merits and challenges of using additional models (e.g., CRED, ENVISAGE) to estimate the SCC and/or removing existing models from the ensemble (DICE, FUND, and PAGE) used to estimate the SCC.
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> Finally, the IWG disagrees with the comment that insufficient justification has been provided for the models, data inputs, and assumptions used to estimate the SCC. The IWG has regularly and repeatedly provided detailed explanations and justifications for the data, assumptions, and models used to estimate the SCC. The 2010 TSD thoroughly detailed each of these aspects, justified their use, and elucidated their limitations. The 2013 TSD provided a detailed explanation of updates and revisions made to the SCC. The additional OMB public comment solicitation provided a further opportunity for the public to comment on the data, assumptions, and models used in developing the SCC estimates; in this Response to Comment the IWG is responding to those comments received. Thus, the IWG has provided clear, transparent analytic defenses of its estimates, explained the rational connections that underlie these estimates, and responded to public comments.[225]

Peer Review and the Evidentiary Standard

A concern raised numerous times by a number of parties for nearly all issues of this proceeding can be classified under the broad issue of credibility. Whether noting a lack of peer-review or citing an individual or organization who may be more or less of an authority on a particular subject matter, credibility permeates nearly all aspects of this case.

Xcel, for example, criticized the FSCC because "IWG used its own, non-peer-reviewed methods"[226] to make extrapolations beyond 2100. However, Xcel's own approach started with the same estimates it considered to be flawed and lacking in peer-review, and Xcel changed these estimates in a fashion that was likewise not peer-reviewed. The Agencies, in fact, referred to Xcel's proposal as a "non-peer-reviewed truncation methodology."[227]

Similarly, GRE/MP/OTP, in its Exceptions, cited ALJ Conclusion 32 to further criticize IWG's extrapolations. The ALJ concluded that, while the IWG "used the peer-reviewed EMF-22

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[225] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG July 2015 Response to Comments, at 8.
[226] Ex. 600, Martin Direct, at 33.
[227] Agencies, Reply to Exceptions, at 1.

emissions scenarios," the IWG "extrapolated the EMF inputs to the year 2300 based on limited data, without the benefit of peer review."[228,229] With the intention of rectifying this defect in the methodology, GRE/MP/OTP recommended the also non-peer-reviewed framing assumptions consistent with its witness, Dr. Smith. Xcel noted this in its Initial Brief, stating, "Dr. Smith's modifications simply replace the IWG's policy judgments with a different set of policy judgments, and her assumptions are by no means more objective than the IWG's."[230]

All of this is to say that both parties criticize the IWG for its lack of peer-review, claim each other's witnesses employ subjective judgments, yet propose non-peer-reviewed values themselves. With this in mind, the Commission could begin with the fact that subjective judgements are inherent. Furthermore, peer-review, while ideal, is not necessarily prerequisite to resolve each issue. If it is, then this may only serve as a justification to reject Xcel's and GRE/MP/OTP's proposals, since neither proposal relied on peer-review from start to finish. If the Commission's standard is to gauge, roughly, what a peer-reviewed SCC estimate might look like, the evidence it has could be gleaned from Dr. Polasky's Rebuttal testimony, in which he compared peer-reviewed SCC estimates using DICE to Dr. Mendelsohn's non-peer-reviewed estimates using DICE.[231]

In staff's view, it is important to consider the peer-review question in the context of an issue staff has raised repeatedly, which is that there is both a physical sciences component and economics component of this proceeding. Perhaps it is more imperative that the physical sciences component more strictly rely on observable facts and peer-reviewed scientific literature, whereas the economics component, while of course not abandoning theoretically sound principles and methods, might be more artful in nature. This is large part because the Commission has a very specific task: to establish a CO_2 externality value for use in Minnesota resource plan proceedings. There is simply not a wealth of peer-reviewed studies regarding this question. Thus, for the economics component, staff generally agrees with Dr. Smith's observation that any framing assumptions "are not objective issues that can be tested by scientific methods. Rather, they reflect the judgments of the analysts who use the IAMs on behalf of policy makers."[232]

Circling back to ALJ Conclusion 32, even though the Judge concluded that the IWG's extrapolations were not peer-reviewed, the Commission might contextualize this to merely mean that the IWG employed one approach, Xcel employed an alternative approach, and GRE/MP/OTP employed yet another approach, all of which required subjective decisions at some point. CEO recommends, though, that the Commission consider the vastly different levels of involvement (including public comment) into the IWG process relative to witness proposals. But a lack of peer-review at certain points in all three cases does not inherently make one more

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[228] ALJ Report, Conclusion 32, at 119.
[229] GRE/MP/OTP Exceptions, at 16-17.
[230] Xcel Initial Brief, at 29.
[231] Ex. 101, Polasky Rebuttal, at 50-52.
[232] Ex. 300, Smith Direct, at 16.

or less reasonable than another, but the Commission can consider whether each methodology employed theoretically sound principles and is most applicable to Minnesota IRP proceedings.

ALJ Conclusions Section V: Marginal Ton

The FSCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. The approach taken by the IWG was to compute the cost of a marginal ton emitted in the future by running the models for a set of perturbation years out to 2050. Table 3 of IWG's 2013 *Technical Support Document* illustrates how the growth rate for these four SCC estimates varies over time.[233]

Table 3: Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate (%)	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010-2020	1.2%	3.2%	2.4%	4.3%
2020-2030	3.4%	2.1%	1.7%	2.4%
2030-2040	3.0%	1.8%	1.5%	2.0%
2040-2050	2.6%	1.6%	1.3%	1.5%

A. ALJ Report

Below are the ALJ's Conclusions on marginal ton:

V. Marginal Ton

26. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that the proposal to value CO_2 emissions by using baselines in which there are no additional emissions of CO_2 after the incremental emission is a reasonable approach to measuring damages in this proceeding. The Utilities and MLIG based this approach on the idea that incremental emissions reduction costs should be balanced with societal damage costs in calculating the SCC. This approach is contrary to the Commission's understanding of a damage-cost approach because, by incorporating the cost of emissions reductions, the Utilities' and MLIG's proposal incorporates a "cost-of-control" approach.

27. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that the proposal to value CO_2 emissions by using baselines in which there are no additional emissions of CO_2

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[233] Ex. 100, Schedule 3 of Polasky Direct, IWG May 2013 Technical Support Document, at 14.

after the incremental emission is a reasonable approach because this approach presumes an effective global emissions reduction program will be in effect. The Utilities and MLIG failed to present any evidence of such a program.

28. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate by a preponderance of the evidence that the proposal to value CO_2 emissions by using an average ton approach is a reasonable approach in this proceeding. The Administrative Law Judge concludes that by averaging the first and last tons to calculate the average ton, the Utilities' and MLIG's average ton incorporates the cost of emissions reductions. Therefore, the Utilities' and MLIG's proposal incorporates a "cost-of-control" approach. In addition, the Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate that the Commission used an average ton approach in the first Externalities case.

29. The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence that the FSCC's approach to counting the last ton of CO_2 emitted as the marginal ton is reasonable and the best approach to calculate damages. This is the best and most reasonable approach because it most closely matches the scientific understanding of what is known about the nature of CO_2, which is that each ton of CO_2 emitted has a cumulative impact, both with respect to the CO_2 emitted in the past and the CO_2 emitted in the future, as long as that ton of CO_2 remains in the atmosphere.

B. Party Responses

In its Exceptions, GRE/MP/OTP objected to ALJ Conclusion 29. The "last ton" approach, according to the Utilities, "overstates the impact of emissions in Minnesota by treating those emissions as if they will be produced after all other tons of carbon, including all those emitted elsewhere, are released into the atmosphere."[234]

GRE/MP/OTP reasoned that, because the FSCC value for 2020 includes damages from the CO_2 concentration expected to exist *by 2020* and all CO_2 emissions projected to occur *from 2020* to 2300, a ton of CO_2 emitted in Minnesota is effectively treated as the most damaging ton in history. A more appropriate approach, GRE/MP/OTP argued, is to employ an ***average*** damage per ton approach. Because the average ton is defined as the average of the first and last ton of emissions, SCC estimates would start with the time in which a unit of CO_2 is emitted (first ton) and incorporate whatever time horizon the Commission selects (last ton).

GRE/MP/OTP also objected to Conclusion 28, specifically with the ALJ's determination that "the Utilities and MLIG failed to demonstrate that the Commission used an average ton approach in

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[234] GRE/MP/OTP Exceptions, at 17.

the first Externalities case."[235] The Utilities described the previous externalities proceeding as follows (citations removed):

> In the earlier case, the Commission established the CO_2 ECV based on the approach offered by the MPCA's witness, Peter Ciborowski. In his findings, which were adopted by the Commission, ALJ Klein confirmed Mr. Ciborowski's "method involved estimating long-term discounted global costs based on the existing economic literature and dividing by long-term CO_2 emissions to arrive at an average cost per ton." In addition, in her testimony in this case, Dr. Smith described the approach taken by Mr. Ciborowski, and no party objected to this testimony. On this matter, we believe there is no serious issue of fact and it is possible for the Commission to verify that an average cost approach was used in the earlier case.[236]

MLIG joined GRE/MP/OTP in recommending the average cost approach, adding, "No other party has sought to determine what the damages value would be if Minnesota emissions would be stopped, while the rest of the world would continue on a business-as-usual approach. That calculation is important, however, to determine the damage caused by the Minnesota pulse, which is what is being measured in this proceeding."[237]

MLIG continued, "the marginal damage estimate varies with the baseline projection of greenhouse gas emissions and is higher if it is calculated against a baseline reflecting a world in which no greenhouse gas control policies are in place, compared to a world that includes global greenhouse gas control policies."[238] An average ton approach establishes for Minnesota resource planning, in effect, a reference case to estimate damages through whatever time horizon the Commission sets.

Xcel agreed with GRE/MP/OTP and MLIG that the IWG's "last-ton" approach likely overstates damages from Minnesota emissions, and would similarly overstate the benefits that would accrue from an incremental reduction in emissions in Minnesota.[239] Xcel supported the idea of the average ton approach in theory, but did not recommend it because it would not be practicable to implement.[240] In addition, Mr. Martin disagreed with Dr. Smith's (GRE/MP/OTP) general approach to derive the average ton:

> Dr. Smith used a "first ton" and "average ton" approach to model marginal damages, because the IWG modeling treats the marginal ton of CO_2 as if it were the last ton of CO_2 emissions added to the global atmosphere, and therefore effectively assumes no further mitigation by future generations. The IWG ran a

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[235] ALJ Conclusion 28.
[236] Utilities Exceptions, at
[237] MLIG Exceptions, at 83.
[238] MLIG Initial Brief, at 78.
[239] Ex. 601, Martin Rebuttal, at 46.
[240] ALJ Report, Finding of Fact 249.

"reference" case (including all past and future emissions) and a "pulse" case (adding an incremental ton of CO2), and then assigned all the difference in damages to the "pulse" case. We agree that this approach assumes no further actions to reduce emissions in the future and treats the marginal ton of CO_2 as if it were the last ton of CO_2 emissions. However, again, we disagree how Dr. Smith addressed this issue in her modeling. She set all emissions to zero starting in 2020, which is not at all realistic or based on empirical evidence.[241]

CEO's witness, Dr. Polasky, responded to Dr. Smith's marginal ton approach at great length in his Rebuttal, and some of Dr. Polasky's disagreements with Dr. Smith's analytical technique are as follows:

[Dr.] Smith's discussion of what is meant by "marginal" damage is unnecessarily confusing and not consistent with the way in which economists discuss marginal damage. Marginal analysis is a fundamental principle agreed upon by economists and is the correct basis on which to analyze to create an efficient or desirable outcome. [The] efficient decision occurs where marginal cost equals marginal benefit, not where average cost equals average benefit, and certainly not where the cost of the first unit is equal to some measure of benefits.[242]

[Dr.] Smith's actual argument is with the emission projections from which marginal damage is calculated. She alleges, for example, that if the marginal damage from a scenario in which emissions continue under a business-as-usual projection were calculated, it would be a marginal "last ton" damage. If, however, we constructed a scenario (however unrealistic) in which there are no more emissions after 2020, the marginal damage from this scenario would be what she calls "first ton."[243]

[Dr.] Smith's analysis does not actually identify an optimal level of emissions, however, instead she uses an average between a future in which there are no emissions after 2020 and the IWG's projections.[244]

The Agencies disagreed with the GRE/MP/OTP and MLIG generally, contending that "To estimate the damages caused by an additional ton of CO_2 emitted at any given time, it is necessary to consider all the preceding emissions."[245]

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[241] Xcel Initial Brief, at 29.
[242] Ex. 101, Polasky Rebuttal, at 10.
[243] Ex. 101, Polasky Rebuttal, at 10.
[244] Ex. 101, Polasky Rebuttal, at 11.
[245] Agencies, Reply to Exceptions, at 21.

Agencies witness, Dr. Hanemann, disagreed with how Dr. Smith developed the first ton, arguing that it was unreasonable to assume there would be no anthropogenic emissions emitted after 2020.[246] Dr. Hanemann showed this graphically in Figure 1C of his Rebuttal:

Figure 1C: PROJECTIONS THROUGH 2300 SHOWING DR. SMITH'S "FIRST TON" ANALYSIS
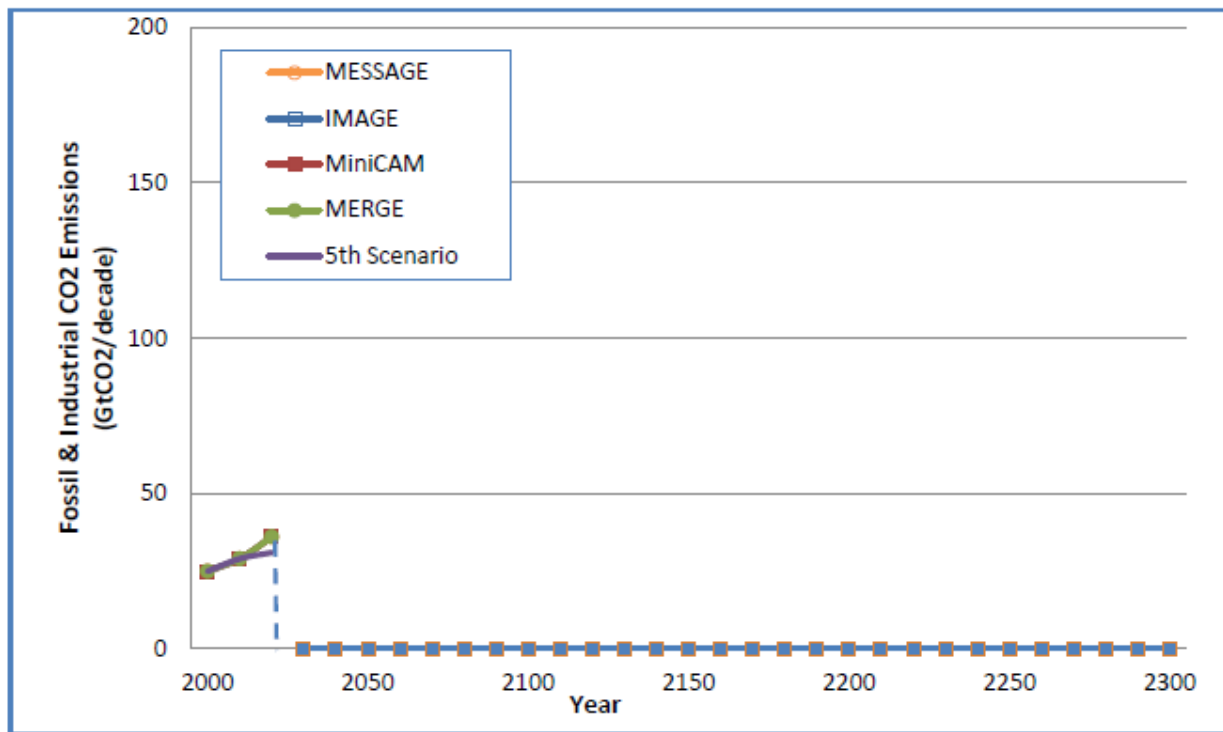
In her Surrebuttal testimony, Dr. Smith responded to Dr. Hanemann's assessment of using "first ton" as a baseline scenario:

> The emissions projection I used to estimate the marginal damage of the "first ton" was never intended to be an accurate projection of total actual future outcome, but only to understand the sensitivity (i.e., range of variation) of the SCC estimate to different levels of projected future emissions. That analytical device allows me to inform the Commission on how much of the IWG's SCC estimates are due to emissions yet to be emitted, as opposed to due to historical GHG emissions.[247]

C. Staff Discussion

First, as staff understands it, GRE/MP/OTP is correct that the Commission currently uses an average ton approach, and this is reflected by the fact that the externality value is the same across the planning horizon (in real terms). The FSCC values increase over time because, as Dr.

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[246] Ex. 801, Hanemann Rebuttal, at 28.
[247] Ex. 304, Smith Surrebuttal, at 22.

Polasky noted, "damages from future emissions will be greater than the damage caused by current emissions."[248]

Second, it seems there are three main issues with Dr. Smith's average ton approach. The first has to do with how Dr. Smith treated the First Ton. Dr. Hanemann was critical of the fact that Dr. Smith dropped emissions to zero in 2020 to represent the First ton, but according to Dr. Smith's Surrebuttal, the intention was to understand the range of variation of the SCC estimate to future emissions, not, as Dr. Hanemann explained, to project actual future emissions. The other issue is whether a baseline should be included in the first place. Dr. Polasky argued that marginal damage "is not constant but depends on the level of [greenhouse gases] in the atmosphere both now and in the future, which in turn depends on emissions both now and in the future.[249] Mr. Martin argued about the feasibility of an average ton approach; he explained that Xcel would have to conduct new modeling to arrive at the average ton.

Finally, staff notes that if the Commission has a preference for the first, last, or average ton, Dr. Smith included SCC estimates under each approach to the marginal ton. But to adopt the average ton approach, the Commission might need to first decide not only whether the first ton *approach* is reasonable but whether the first ton *value* is reasonable.

ALJ Conclusions Section II: Discount Rates

The discount rate is a key parameter that is used to aggregate damages that occur at different times into a single measure of the "present value" of damages.[250] As Dr. Polasky explained in his Direct testimony:

> Because climate change impacts go so far into the future, what one assumes about the discount rate matters hugely. For example, one million dollars in damages in 100 years is valued at $85,000 today with a discount rate of 2.5%, $52,000 with a discount rate of 3%, and only $7,600 with a discount rate of 5%. This means that we would apply equal weight to $1 million of damages in 100 years as we would $7,600 in damages if those damages occurred today when using a 5% discount rate. A higher discount rate generally results in a lower SCC because it more heavily discounts future damages from climate change.[251]

According to IWG's February 2010 *Technical Support Document (TSD): Social Cost of Carbon for Regulatory Impact Analysis*, the IWG explained how it chose the 2.5%, 3%, and 5% discount rates to calculate the FSCC:

F. Discount Rate

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[248] Ex. 100, Polasky Direct, at 15.
[249] Ex. 101, Polasky Rebuttal, at 10-11.
[250] Ex. 100, Polasky Direct, at 10.
[251] Polasky Direct, at 11.

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because carbon dioxide emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we 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 IAMs. Then we discount the stream of future damages 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.[252]

…

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 in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.[253]

The ALJ recommended that the environmental externality range include the 2.5%, 3%, and 5% discount rates.

The ALJ concluded that the preponderance of the evidence demonstrates that both the 3% and 5% discount rates are recognized as consumption rates of discount, and it is reasonable to apply the 3% and 5% discount rates to the SCC.[254]

The Judge further concluded that the 2.5% discount rate 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.[255] ALJ Conclusion 18 pointed to the multigenerational scope of CO_2 impacts:

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[252] Ex. 100, Schedule 2 of Polasky Direct, IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, at 17-18.

[253] Ex. 100, Schedule 2 of Polasky Direct, IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, at 23.

[254] ALJ Report, Conclusion 14.

[255] ALJ Report, Conclusion 18.

18. The Administrative Law Judge concludes 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.

The Judge also concluded that the proposal advanced by GRE/MP/OTP and MLIG to use a 7% discount rate should not be included in the range of discount rates. The ALJ reasoned that a 7% discount rate would be a "cost-of-control" approach, which is contrary to the Commission's required damage-cost approach.[256]

Some parties raised opposing views related to the discount rate used by the IWG. For this section, staff will refer to three (and reference the party who raised it): the consumption rate of interest, uncertainty, and the Ramsey Rule.

Opposing Views

A. Real Rate of Return to Private Capital (MLIG)

A lengthy portion of MLIG's Exceptions responds to the Judge's Conclusion that a 7% discount rate should not be used to estimate the SCC.

First of all, MLIG did not believe the ALJ accurately portrayed its position on discount rates. Specifically, MLIG recommended that "Findings of Fact 182 and 184 should be corrected and Conclusions 16 through 18 are not supported by the record, are erroneous, and should be rejected."[257]

ALJ Findings of Fact 182 reads:

182. The IWG presented the FSCC valued at three different discount rates: 2.5, 3, and 5 percent. The Utilities and MLIG agreed that it was reasonable for the IWG to base its discount rates on the "consumption rate of interest" and supported the 3 and 5 percent discount rates. The "consumption rate of interest," according to the Utilities and MLIG, is the same as what OMB calls the "social rate of time preference," with both terms in contrast to the "opportunity cost of capital." The Utilities and MLIG agreed that the consumption rate of interest was appropriate for the IWG to use because the IAMs model damages in "consumption-equivalent" units. Therefore, it was sensible to utilize the consumption rate of interest to discount damages to their present value.

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[256] ALJ Report, Conclusion 17.
[257] MLIG Exceptions, at 49.

MLIG argued this is an incomplete representation of its position. In its Exceptions, MLIG added to the end of Finding of Fact 182, "But because the FSCC has different consumer purposes than the large-industry electric utility purpose of Minn. Stat. § 216B.2422, the Utilities and MLIG also argued that a 5 percent discount rate should not be the upper bound used for the SCC, and that the upper bound should be set at 7 percent."[258]

In short, MLIG recommends the Commission adopt one of two options on discount rates: the FSCC could use discount rates of 3, 5, and 7, but MLIG emphasizes that a 3% discount rate is appropriate *only if* the 5% and 7% discount rates are adopted as well. In the alternative, the Commission could apply a usage-averaged discount rate. A usage-averaged discount rate would be based on the 3% consumption rate of interest identified by the IWG *and* the 7% average before-tax real rate of return to private capital in the U.S. Economy. Since two-thirds of Minnesota's electricity consumption comes from large industry and small, medium, and large companies, and about one-third of Minnesota's electric consumption is by households, multiplying the usage rate by each interest rate (3%*0.333 + 7%*0.667) would yield a discount rate of 5.66%.

The modified form of MLIG's proposed ALJ Finding of Fact 184 reads:

> The Utilities and MLIG objected that the FSCC fails to account for the opportunity costs of utility resource investments in its discounting. If the IWG accounted for the pre-tax market rate returns as provided for by OMB Circulars A-4 and A-94, applicable to private capital investments and opportunity costs of utility resource investments, it would include discount rates higher than 5 percent, which would lower the FSCC. The IWG's discount rates have overstated the applicable cost by only using consumer rates of interest. The Utilities and MLIG showed by a preponderance of the evidence that OMB's mandatory modeling discount rate of 7 percent should be a discount rate used in this proceeding and Minn. Stat. § 216B.2422, as it is in other aspects of Minnesota resource planning.

Staff shows MLIG's objection in redline form, below, to note the language, "mandatory modeling discount rate of 7 percent," which reflects the difference in how the ALJ and MLIG interpreted the nature of OMB Circular A-4:

> The Utilities and MLIG showed ~~hinted~~ by a preponderance of the evidence that the OMB's ~~suggested~~ mandatory modeling discount rate of 7 percent…[259]

MLIG also recommended the Commission strike ALJ Conclusion 16, which concluded that OMB A-4 was advisory rather than mandatory in nature:

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[258] MLIG Exceptions, at 97-98.
[259] MLIG Exceptions, at 74.

16. The Administrative Law Judge concludes that the preponderance of the evidence demonstrated that the OMB Circular A-4 does not require the IWG to use the seven percent discount rate to calculate the FSCC, because the Circular A-4 is advisory and not mandatory in nature. The Administrative Law Judge concludes that the OMB participated in the IWG's development of the FSCC and there was no evidence that the OMB objected to the IWG's choice not to use a seven percent discount rate in calculating the FSCC.

MLIG stated in its Exceptions, "MLIG has at all times been clear that a discount rate of 7% is appropriate when a regulation will affect private sector capital spending, as recognized by the federal Office of Management and Budget."[260]

> ### i.　　　Responses

The IWG addressed the nature of Circular A-4 in its 2010 *Technical Support Document*:

> 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. As previously mentioned, the 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.[261]

Then, the IWG elaborated on Circular A-4 in its 2015 *Response to Comments*:

> Circular A-4 is a living document, which may be updated as appropriate to reflect new developments and unforeseen issues. 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 the TSDs and in Section 5 of this document. Briefly, 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.[262]

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[260] MLIG Exceptions at 48.

[261] Ex. 100, Schedule 2 of Polasky Direct, IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, at 17-18.

[262] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis, at 36.

The Agencies argued that MLIG's 5.66 % discount rate "was not supported by any witness' testimony, nor was the basis for the proposal disclosed during discovery, and as such, witnesses had no opportunity to assess the merits of the proposal and critique or endorse such a discount rate, nor was any opportunity afforded for any expert witness to evaluate the methodology underlying the proposed new discount rate."[263]

Generally, though, the Agencies argued that claiming that discount rates close or equal to that of investor–owned utilities' overall rate of return is illogical unless the GDP is made up of primarily utility consumption, which it is not. The Agencies believe MLIG is conflating monetized CO_2 damage values with the potential rate impact due to the use of the damage values.

Additionally, the Agencies argued, "the three alternative discount rates for the federal SCC, 2.5, 3.0 and 5.0 percent, reflect reasonable judgments under both descriptive and prescriptive approaches to determining an appropriate rate of discount. Dr. Hanemann testified that it was appropriate for the IWG to use these three values because they are consistent with the values used in the existing literature on the economics of climate change and of GHG mitigation. Dr. Hanemann knew of no values higher than 5.5 percent being used in the existing literature on the economics of climate change." [264]

CEO's responses largely focused on the multigenerational question and discount rates generally accepted by peer-reviewed economists:

> The question raised by the discount rate, in this context, is how much weight do we as a society place on the reduced consumption of future generations. MLIG has offered no compelling argument that the discount rate used to calculate the present value of utility investments should answer that question.[265]
> …
>
> MLIG states that the IWG's inclusion of a 2.5 percent discount rate is "problematic" because it leads to a higher externality value. But MLIG fails to point to any evidence, beyond the opinions of its hired expert, that supports its position to exclude a 2.5 percent discount rate value. It simply sets out some arguments for higher discount rates while ignoring arguments for the lower discount rates. Drs. Polasky and Hanemann explained these arguments in their testimonies.
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> That MLIG's position is not consistent with the preponderance of the evidence is probably best shown in the literature by Peabody's witness Dr. Tol who himself conducted a meta-analysis of climate change studies. Dr. Tol summarized the discount rates used in studies on the social cost of carbon through 2006 and found that only two papers out of thirty-nine used a discount rate above 5 percent. In

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[263] Agencies Reply Brief, at 7-8.
[264] Agencies Reply Brief, at
[265] CEO Reply Brief, at 3.

contrast, he found that 10 studies used a discount rate below 3 percent. And among those, six studies used a discount rate of 1 percent or less.[266]

B. *Uncertainty (Utilities)*

In examining the quantitative sensitivity of the assumptions as they interact in the modeling, Dr. Smith observed that a primary source of the differences in cost estimates was due to the share of damages that are accrued post-2100. Among other findings, Dr. Smith concluded:

> These results show the interaction of the model horizon with the discount rate in determining the SCC value. The impact is very large both in percentage and dollar terms if the discount rate is relatively low, and becomes less important if discount rates are as high as 7% (the high end of the OMB's recommended range). In other words, there would be minimal speculative content to SCC estimates using 7% discount rates, but there is substantial speculative content in SCC estimates using discount rates of 5% or lower, if they also have a modeling horizon beyond 2100. For example, if a 5% discount rate is employed, about one-quarter of the IWG's SCC estimates' value can be viewed as coming from highly speculative assumptions, whereas for discount rates of 3% the portion of the value coming from the highly speculative assumptions rises to about one-half.[267]

Dr. Smith argued that a problem with using lower discount rates is that it not only produces much higher SCC estimates, but of these damages (according to the modeling results), more than half accrue when there is inherently more uncertainty. Using a higher discount rate, therefore, is one way to minimize what Dr. Smith refers to as "speculative values."

i.   *Responses*

Dr. Polasky, in his Rebuttal, acknowledged the considerable uncertainty in future climate impacts, but drew the exact opposite conclusion. Dr. Polasky stated, "Given the considerable uncertainty about future economic growth especially under climate change, a strong argument for discount rates lower than 2.5 percent can be made."[268] He also quoted OMB's Regulatory Impact Assessment to support lower discount rates:

> Special considerations arise when comparing benefits and costs across generations. Although most people demonstrate time preference in their own consumption behavior, it may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. Future citizens who are affected by such choices cannot take part in making them, and today's society must act with due consideration of their

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[266] CEO Reply Brief, at 8.
[267] Ex. 302, Smith Direct, Exhibit 2 –Expert Report - CO_2 Environmental Cost Values Phase, at 76.
[268] Ex. 101, Polasky Rebuttal, at 21-22.

interests. Many people have argued for a principle of intergenerational neutrality, which would mean that those in the present generation would not treat those in later generations as worthy of less concern. Discounting the welfare of future generations at 7 percent or even 3 percent could create serious ethical problems.[269]

C. The Ramsey Rule (Peabody)

Peabody argued that the FSCC is unreliable because the discount rates are arbitrary, but have significant impacts. Peabody's witness, Dr. Tol, who developed the FUND model, stated the Ramsey rule is a more appropriate choice for the IWG to use to develop discount rates. According to the Ramsey rule, the discount rate should vary with economic growth, rising as economic growth increases and falling as economic growth slows.

Dr. Tol explained that the underlying logic of the Ramsey rule "makes sense because it relates the money discount rate to parameters underlying the 'time value' of money—i.e., the reasons that receiving money today is preferred over receiving it in the future."[270]

i.   Responses

The Agencies opposed using the Ramsey Rule, and the Agencies' opposing arguments are summarized as ALJ Findings of Fact 206-211. In particular, Finding of Fact 206 says:

206. The Agencies described the assumptions underlying the marginal utility factor that arises with Ramsey Rule discounting as applied in DICE's optimization mode, and why they believe the assumptions are not reasonable in the context of calculating the FSCC:

- The assumption 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.

- The assumption that the individual has constant preferences and constant expectations regarding what gives him well-being throughout the course of his lifetime.

- The assumption that everything the individual cares about can be boiled down to one item – the amount of money that he has – and all impacts of climate change can be reduced to the equivalent of a change in the money that he has.

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[269] Ex. 101, Polasky Rebuttal, at 24.
[270] Ex. 238, Tol Rebuttal Ex. 2, at 4.

ALJ Conclusion 15 explained why the Ramsey Rule should not be used in this case:

> 15. The Administrative Law Judge concludes that Peabody, and the Utilities and MLIG failed to demonstrate by a preponderance of the evidence that a Ramsey rule discount rate that adjusts over time is reasonable to use in calculating the SCC. That approach is not appropriate because it is based on the concept that climate policy can be viewed through the metaphor of a single, infinitely-lived individual rather than the changing views of societies as they evolve over generations. The Administrative Law Judge concludes that the Ramsey rule fails to take into account the idea that priorities and preferences of people and societies will change over an extended period of time and does not address issues of equity between generations. Furthermore, the Administrative Law Judge concludes the Ramsey rule is not appropriate in this proceeding because it begins with a higher discount rate which declines with time. In addition to the intergenerational nature of the FSCC damage calculation, due to the uncertainties associated with the possibility of catastrophic damages from a "tipping point" event which may occur at an unknown time, and the understatement of impacts in the IAMs' damage functions, the Administrative Law Judge concludes that an approach that is designed to begin with a higher discount rate and gradually declines is neither reasonable nor the best approach to for the purpose of calculating an SCC.

In the IWG's 2015 *Response to Comments*, the IWG also addressed the Ramsey framework:

> *(3) A Ramsey framework should be used to determine the discount rates*
>
> Some commenters supported use of a Ramsey framework for determining discount rates and noted that the original developers of the IAMs used by the IWG routinely use a Ramsey framework in their own applications of their models. A Ramsey framework, derived from a representative agent who maximizes the sum of discounted utility under specific assumptions, relates the consumption discount rate to the elasticity of the marginal utility of consumption, the growth rate of per capita consumption, and the pure rate of time preference. Some commenters also stated that the socioeconomic scenarios used to calculate the SCC imply growth rates of per capita consumption that change over time, so under the Ramsey framework the discount rates also should change endogenously over time based on the economic growth rates assumed in the underlying socio-economic scenarios.
>
> *Response*
>
> 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.

The IWG considered this framework explicitly in exploring the implications of setting the [pure rate of time preference] at or near zero to give equal weight to the welfare of all future generations. As explained above, this analysis was part of the basis for selecting the lower end of the 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 (Arrow et al., 2012). 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, but did consider the Ramsey literature in deriving the range of 2.5 to 5 percent for use in estimating the SCC. The IWG will continue to evaluate new research on the Ramsey framework and its applicability to SCC estimation and seek external expert advice on issues related to discounting in the context of climate change.[271]

D. *Absence of Consensus on Discount Rate (Xcel)*

Xcel's approach reflected the absence of consensus on what the "best" discount rate is or should be. Xcel's proposed SCC used the Federal SCC modeling output data to develop a range from the 25th and 75th percentiles taken of the distribution of 450,000 SCC estimates for a given emission year. Xcel's range equally weights the SCC values for each of the three discount rates at the low and high ends of the range. In other words, Xcel retained for its proposal all three discount rates (2.5, 3, and 5 percent) used by the IWG.[272]

Xcel's witness, Mr. Martin, described the discount rate as "an inherently subjective and normative policy decision about how to weight present consumption against future consumption, and in this case the welfare of the present generation against the welfare of future generations."[273] Mr. Martin's chosen approach, therefore, was "not to substitute

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[271] Ex. 101, Schedule 1 of Polasky Rebuttal, at 24-25.
[272] Xcel Initial Brief, at 20.
[273] Ex. 602, Martin Surrebuttal, at 20.

[Xcel's] judgment for the IWG's, either by recommending rates below 2.5 percent or above 5 percent, or by discarding any of the three discount rates used by the IWG."[274]

Referring again to Xcel's criterion approach, staff includes below an excerpted version of Table 1 of Xcel's Initial Brief, which is Xcel's Matrix for comparing party proposals.   As explained in the Introduction, Xcel's Matrix provided a concise representation of its view of how well each party's recommendation met Xcel's criteria. Green boxes indicate a criterion is met, and red boxes indicate a criterion is largely not met.

Table 1. Matrix Comparing all Parties' Proposals to Company's Criteria[7]

Criterion	Dr. Hanemann	Dr. Polasky	Dr. Smith	Dr. Gayer	Dr. Mendelsohn	Company
Reflects absence of consensus on discount rate	green	green	red	green	red	green

As shown above, Xcel believes its proposal for a reasonable discount rate, along with Dr. Hanemann's (Agencies), Dr. Polasky's (CEO), and Dr. Gayer (MLIGH), meets Xcel's criteria.[275]

According to Mr. Martin, Dr. Mendelsohn uses a single declining rate, which is inconsistent with the IWG's contention that multiple rates should be used to reflect the lack of consensus.[276] And, Mr. Martin concluded that Dr. Smith's recommendation to discard the 2.5% discount rate was subjective. Responding to Dr. Smith's claim that there is no evidentiary basis for a 2.5% discount rate, Mr. Martin noted, "While there may be no firm evidentiary basis for a 2.5 percent discount rate, there is also no evidentiary basis to conclude that future generations would not prefer this discount rate, so dropping it reflects an implicit subjective judgment without empirical basis."[277]

i.   Responses

CEO, in its Initial Brief, summarized its position and cited other witnesses drawing the same conclusion that it would be inappropriate for the Commission to average the discount rates:

> The IWG chose to apply multiple discount rates to each model in order to provide those applying the SCC with information from all three discount rates. Averaging

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[274] Ex. 602, Martin Surrebuttal, at 21.

[275] As a reminder, Xcel's criteria for evaluating the FSCC were: reasonably accounting for uncertainty; reflecting the absence of consensus on discount rate; using statistically sound methods; applying a reasonable tolerance of risk; minimizing subjective judgments; using a practicable range; and applying a methodology that is transparent, replicable, and updateable.

[276] Ex. 601, Martin Rebuttal, at 41.

[277] Ex. 601, Martin Rebuttal, at 41.

data from three separate discount rates prevents the Commission from comparing the SCC at different discount rates and obscures the discount rates' strong effect on the SCC.[278] As Dr. Polasky pointed out in his direct testimony, "[b]ecause climate change impacts go so far into the future, what one assumes about the discount rate matters hugely."[279] Furthermore, "[a]veraging the results across the three discount rates has no theoretical basis [because] we are not considering the entire range of possible discount rates, nor are we applying any probability distribution to the likelihood of any rate being the 'true' social discount rate."[280] In spite of other disagreements, Drs. Hanemann, Smith, Mendelsohn, and Wecker all echoed this criticism.[281] Dr. Wecker also emphasized that reducing such complicated data will "suppress rather than present decision-makers with information."[282] Xcel's averaging data across different discount rates is not consistent with scientific understanding of discounting.[283]

E. Staff Discussion

The Commission can decide that one particular discount rate is appropriate (including if that rate is an averaged discount rate) or whether a range of discount rates would be appropriate. Xcel proposed an average, and GRE/MP/OTP proposed two discount rates, 3% and 5%.

As with all issues in this case where there are multiple alternatives, adopting more options means additional sensitivities that will be required in resource plan proceedings. Xcel's criterion to use a practicable range means, in part, that the Commission could take into account the number of sensitivities run and considered in IRP proceedings. As such, it might be preferable to hold most assumptions constant while testing others to yield a true range.

Xcel's approach averages the discount rates. This allows the percentiles to determine the upper and lower bounds of CO_2 externality costs. GRE/MP/OTP, alternatively, holds constant the time horizon, tonne, and geographic scope, and allows the discount rates (3%/5%) to determine the range. The ALJ recommended three discount rates, which Xcel claimed is not a true range. Proponents of the FSCC likewise recommended three discount rates, but with an additional scenario to represent high-damage outcomes.

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[278] Ex. 101, Polasky Rebuttal, at 43.
[279] Ex. 100, Polasky Direct, at 11.
[280] Ex. 101, Polasky Rebuttal, at 43.
[281] Ex. 802 at 39; ex. 303 at 3-6; ex. 217 at 9; ex. 242 sched. 2 at lines 338-40.
[282] Ex. 242 sched. 2 at lines 190-92.
[283] CEO Initial Brief, at 27-28.

If the Commission prefers to incorporate a high and low bound, meaning only two sets of estimates, it could either adopt Xcel's percentile approach or use the discount rate as the changing variable as GRE/MP/OTP recommends.[284]

Several parties criticized Xcel's approach to average the discount rates, because this approach, some claimed, is inconsistent with the scientific understanding of discounting. Staff takes no position on this, but notes that OMB Circular A-4 also appears to use a form of averaged discounting for the private rate of return (7% discount rate) and the social rate of time preference (3%).

According to OMB Circular A-4:

> The 7 percent rate is an estimate of the **average** before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital. It **approximates** the opportunity cost of capital, and it is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector.[285] (Emphasis added.)

And for the 3% discount rate, OMB stated:

> When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate. The alternative most often used is sometimes called the "social rate of time preference." This simply means the rate at which "society" discounts future consumption flows to their present value. If we take the rate that the **average** saver uses to discount future consumption as our measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a **fair approximation**. Over the last thirty years, this rate has **averaged around 3 percent** in real terms on a pre-tax basis.[286] (Emphasis added.)

In addition, IWG explained in its 2010 Technical Support Document

> [B]oth the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the **average real return from Treasury notes** over the longest time period available. … A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments

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[284] Peabody Energy recommends a $0 cost value; however, Peabody provides alternatives that are lower/upper bound ranges.

[285] Ex. 417, OMB Circular A-4, at 33.

[286] Ex. 417, OMB Circular A-4, at 33.

(approximately 7 percent) for taxes yields a real rate of roughly 5 percent.[287] (Emphasis added.)

Again, staff does not intend to dispute the conclusions of several economists in this proceeding who explained the limitations or theoretical flaws of averaging discount rates. Rather, staff's observation is that it seems the IWG applied an averaging method adopted from OMB Circular A-4. And, OMB Circular A-4's 3% discount rate and 5% discount rate appear to use an averaging method to some degree.

Xcel's average would be within the range of discount rates supported by FSCC proponents. Secondly, the discount rate is, according to many, an issue with no clear consensus even among prominent economists. It is very clear why some disagreed with Xcel's approach, but it is less clear why the number Xcel ultimately used is so outlandish.

If the Commission decides it is reasonable to use Xcel's percentiles approach, the Commission could further ask Xcel if it could easily re-calculate its proposal based on a single discount rate, such as OMB's 3% discount rate, or another discount rate it determines to be more reasonable.

ALJ Conclusions Section VII: Geographic Scope

In its July 2015 *Response to Comments*, the IWG addressed the use of global versus domestic SCC estimates. According to the IWG, "the IWG determined that a global measure of SCC is appropriate in this context because emissions of most greenhouse gases contribute to damages around the world and the world's economies are now highly interconnected."[288]

A. ALJ Report

On geographic scope, the ALJ concluded in her report:

> 36. The Administrative Law Judge concludes that the preponderance of the evidence in this docket demonstrates that CO_2 emissions emitted in one location on the Earth mix with GHGs emitted from all other locations on the planet, with each GHG molecule contributing to climate change experienced everywhere. In addition, in the first Externalities proceeding the Minnesota Court of Appeals held that, "[r]egardless of its emission point, CO_2 is believed to contribute to global warming, which in turn adversely impacts the global environment."

> 37. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that limiting damages to the

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[287] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 20.
[288] Ex. 101, Schedule 1 of Polasky Rebuttal, at 31.

United States or Minnesota will capture all of the damage caused by CO_2 emissions released from electric power generating facilities within Minnesota.

38. The Administrative Law Judge concludes that MLIG improperly framed the calculation of the environmental cost value of CO_2 as a question of economic standing by stating the question in terms of who pays the costs of the policy and who receives the benefits.

39. The Administrative Law Judge concludes that Minn. Stat. § 216B.2442, subd. 3, and the Commission's requirement that the parties use a damage-cost analysis compel that the question of the geographic scope of damages be viewed in terms of the source of the CO_2 emissions and all their damaging impacts, wherever they are experienced. Therefore, the Administrative Law Judge concludes that this proceeding requires a global scope for damages.

B. Party Positions

Agencies

According to the Agencies, "GHGs emitted at a particular location on the Earth mixes in the atmosphere with GHGs emitted from all other locations on Earth. A molecule of emitted GHG contributes to damages from climate change experienced everywhere around the globe, regardless of where it is emitted. The impacts on human well-being play out on a global scale."[289]

CEO

CEO's position is that there is no real dispute that CO_2 is a global pollutant and "that the emission of CO_2 in Minnesota will lead to damages well outside of Minnesota [and] the U.S."[290,291]   Therefore, the preponderance of the evidence points towards global, rather than domestic, external costs. Witnesses who proposed values which exclude non-U.S. damages is also contrary to Commission precedent, as Minnesota's current values for CO_2 recognize that CO_2 is a global pollutant and are based on an assessment of worldwide damages. As Dr. Polasky explained, "[i]f every state, province, or other political territory only considered the damages of their own CO_2 emissions within their own political boundaries then there would be virtually no correcting for externalities."[292]

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[289] Agencies, Amended Initial Brief, at 59.
[290] Ex. 101, Polasky Rebuttal, at 25.
[291] CEO Initial Brief, at 33.
[292] Ex. 101, Polasky Rebuttal, at 26.

GRE/MP/OTP

Initially, GRE/MP/OTP also supported a geographic scope adjustment; however, in its Exceptions, GRE/MP/OTP did *not* object to the ALJ's Conclusions on geographic scope. Rather, GRE/MP/OTP's Exceptions focused on the precedent set by Judge Klein's 1996 ALJ report and the Commission's order in the prior externalities case, in which the Commission established the CO_2 values on a global geographic scope.

GRE/MP/OTP's witness, Dr. Smith, argued that the basic tenets of benefit-cost analysis require consideration of whose willingness to pay should count. According to Dr. Smith:

> Given that Minnesota's environmental cost values policy imposes potential costs on generators in Minnesota and near Minnesota, and the costs from such actions will then be passed to electricity customers residing only within Minnesota, economic standing should only be assigned to Minnesotans. The standard prescription in [benefit-cost analysis] practice thus would be to sum benefits only across Minnesotans.[293]

Dr. Smith employed an IAM-based approach for calculating domestic (U.S.) SCC estimates. Dr. Smith did not develop a Minnesota-specific damage estimate because "none of the IAMs can produce one at present."[294]

With regard to calculating U.S. SCC estimates, Dr. Smith was not able to use DICE, since DICE is a global model with no regional distinction. Lines of code were added to FUND's model so that it would report the U.S. damages. The standard version of PAGE reports the SCC for each of its regions so no changes were required. For further details on Dr. Smith's modeling adjustments are included in her Expert Report, attached as Exhibit 2 of Smith Direct.

MLIG

Perhaps the most succinct way to summarize MLIG's position on geographic scope is to state verbatim its Exception to ALJ Conclusion 39, whereby MLIG offered the following modification:

> The question of a worldwide geographic scope is complex in the absence of reciprocity and was not addressed in detail in the original 1996 proceedings. Reciprocity plays a role in the quantity of the value to be assigned to the environmental cost value of CO_2 and the absence of reciprocity on both a national and international level means that a global geographic damages scope leads to an overstatement of damages caused by Minnesota-produced CO_2. Addressing global greenhouse gas emissions in a meaningful way requires all major emitting nations to reduce their emissions significantly, not just the U.S. emitters. Importantly, this

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[293] Ex. 302, Exhibit 2 of Smith Direct (Expert Report), at 95.
[294] Ex. 302, Exhibit 2 of Smith Direct (Expert Report), at 99.

fact leads to exactly the opposite conclusion about inclusion of global benefits in the SCC value from what the IWG concluded. The IAMs compute a high $/ton value for a ton of U.S. emission not because the U.S.'s emissions are causing such high damages, but rather the SCC estimate is driven upwards by the effect of all of the other nations' uncontrolled CO_2 emissions. Otherwise stated, if no other nation emitted greenhouse gasses, then the SCC estimate would be entirely due to U.S. emissions; however, that SCC estimate would be lower than what the IWG has computed. The ALJ accordingly concludes that unless and until there is a national and international reciprocal system in force, the calculation of the environmental cost value of CO_2 should be made on a local, *i.e.*, Minnesota, damages assessment.[295]

For purposes of estimating the SCC, the monetary impacts of CO_2 emissions are a function of global GDP and the carbon intensity of economic output.[296] Dr. Gayer, MLIG's witness, considered two approaches for calculating Minnesota or U.S. damages as a share of global GDP: (1) a GDP-scaling approach (2) or one that relied on IAMs. Dr. Gayer observed, "None of the integrated assessment models used by the IWG allow for a state-specific estimation of the SCC, but an estimate based on scaling the global benefit to Minnesota's share of global GDP is feasible."[297]

Dr. Gayer concluded, "given the inability of the models to estimate state effects, the magnitude of the differences cannot be predicted reliably." [298] As such, using a GDP-scaling approach, and assuming an estimated benefit to Minnesota as less than 0.4 percent of the estimated global benefit, adjusting IWG's global estimates to fit a Minnesota-specific SCC would amount to about $0.37 per metric ton of CO_2 (2010 damage value in 2007 dollars).[299]

Peabody

Peabody argued, "A warmer, wetter, CO_2-enriched world would be a clear gain for Minnesota agriculture. Ecological models suggest that Minnesota forests would become more productive and have more standing biomass as a result of near term climate change. A slightly warmer winter is likely to be beneficial as well and would offset possible damage from a slightly warmer summer."[300] According to Dr. Mendelsohn, if the FSCC were used, the U.S. would pay the full cost of emission reductions, but 95% of the benefits would go to other countries. Therefore, Dr. Mendelsohn estimated the American share of the SCC, which he referred to as the "American Cost of Carbon", that assumed 5% of the global SCC damages.

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[295] MLIG Exceptions, at 109-110.
[296] Ex. 100, Schedule 1 of Polasky Direct, IWG Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, at 6.
[297] Ex. 400, Appendix 2 (Gayer Expert Report) of Gayer Direct, at 16.
[298] Ex. 400, Appendix 2 (Gayer Expert Report) of Gayer Direct, at 16-17.
[299] Ex. 400, Appendix 2 (Gayer Expert Report) of Gayer Direct, at 17.
[300] Ex. 214, Mendelsohn Direct, at 4.

Xcel

Xcel summarized its position on geographic scope on page 26 of its Initial Brief:

> On the one hand, Xcel Energy agrees that using the SCC would likely overestimate the benefits of emission reductions in Minnesota, because the SCC values are calculated based on global damages, even though any reductions in Minnesota's emissions are likely to have little effect on global damages. The likelihood of emissions leakage in an interconnected electricity system would further diminish any effect on net damages.

> On the other hand, CO_2 is a global pollutant, and was treated as such in the original Externalities Docket.

C. Staff Discussion

Commission Precedent

There are several precedents to which the Commission could refer when contemplating the most appropriate geographic scope. First, in the prior environmental externalities proceeding, Judge Klein reasoned in his ALJ Report to the Commission:

> The Administrative Law Judge agrees with the public testimony from Willmar cited earlier to the effect that the real resolution of the global warming problem must come from a global emissions reduction effort, or at the very least, a national effort. One state, especially a state like Minnesota, can not make much of a difference. In fact, even if Minnesota's utilities stopped emitting any carbon dioxide, the global problem would be virtually unaffected by our act, *except* as our action, and similar actions of others in this country and abroad, cause national governments to take the kind of actions that *will* make a difference.[301]

Notably, in the above excerpt, Judge Klein also addressed whether Minnesota could, in his words, "make much of a difference" is material to the geographic scope question. Acknowledging that one state may not make much of a difference, it was ALJ Klein's view that "the global warming problem" demands a global geographic scope.

Second, the Commission stated in its 1997 order setting environmental externalities values:

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[301] Ex. 305, *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Ch. 356, Section 3*, Findings of Fact, Conclusions, Recommendation and Memorandum at 10, Docket No. E-999/CI-93-583 (Mar. 22, 1996), at "Discussion".

7.d. The Commission's Decision Regarding CO_2

Parties further objected that it would be "impracticable" for Minnesota to adopt CO_2 values because CO_2 (and any associated global warming) could not be addressed with any appreciable impact by Minnesota alone. It is true that CO_2 emissions in Minnesota (approximately 33 million tons per year) constitutes approximately 0.1 percent of global CO_2 emissions (approximately 60 billion tons per year). The objectors' argument, however, does not really challenge the practicability (feasibility) of setting CO_2 values, but instead questions the wisdom of doing so in view of what they view as the inconsequential impact of such an effort. Their argument that nothing should be done because nothing "significant" (in the eyes of the objectors) can be done is a political argument not appropriately before the Commission. The legislature has made the appropriate political decision that the Commission should value CO_2 to the extent that this is feasible and, after rejecting some proposed ranges for CO_2, the Commission has done so.[302]

Ultimately, the Commission's January 3, 1997 Order agreed with Judge Klein, and the Commission based its CO_2 values on a global geographic scope:

4. General Focus on Damage Occurring in Minnesota

With the exception of the values adopted for CO_2, which causes damages globally rather than regionally or locally, the Commission has quantified the costs of environmental damage occurring in Minnesota. This is consistent with the approach recommended by the Department and found reasonable by the Commission that the Commission focus on the effects of byproducts that cause the most significant costs. With respect to CO_2, this means assessing damage globally; for all other pollutants for which values are established in this Order, it means quantifying the damage they cause in Minnesota.[303]

The Commission's 1997 decision establishing final values was affirmed by the Minnesota Court of Appeals.[304,305]

Geographic Scope and Its Impact on the Final Values

The geographic scope is among the most impactful assumptions in terms of the variation in the potential range of values. According to Dr. Smith, "Restricting the damages to the U.S. reduces

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[302] Ex. 306, Commission Order, *ORDER ESTABLISHING ENVIRONMENTAL COST VALUES*, Docket No. E-999/CI-93-583, January 3, 1997, at 26.

[303] Ex. 306, *In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota 1993, Chapter 356, Section 3*, Order Establishing Environmental Cost Values MPUC Docket 93-583, January 3, 1997, at 15.

[304] ALJ Report, Finding of Fact 2.

[305] *In re Quantification of Envtl Costs*, 578 N.W.2d 794 (Minn. Ct. App. 1998), *review denied* (Minn. Aug. 18, 1998).

the SCC by 81% to 84% from its value when global damages are considered."[306] This is shown in Table 15 of Dr. Smith's Expert Report:

Table 15: 2020 SCC for Global and U.S. Regional Scopes for Discount Rates of 3% and 5% (2007$/tonne of CO_2)[147]

2020 SCC Values (2007$ or % change)	Average SCC or %:	$44	$12	$7	$2	16%	19%
Incremental Ton		Last	Last	Last	Last	Last	Last
Regional Scope		Global	Global	U.S.	U.S.	U.S./Global	U.S./Global
Discount Rate		3%	5%	3%	5%	3%	5%
Horizon		2300	2300	2300	2300	2300	2300

This can also be illustrated by other examples provided in Table 4 of Dr. Smith's Summary of SCC Estimates (Smith Direct). For example, under the 2100 time horizon, 3% discount rate, 2140 time horizon, average tonne scenario, the change from a Global to U.S. scope yields the following (in $2014/net tonne):

Discount Rate	Time Horizon	*Scope*	Which Tonne	2020 SCC Value (2014$/net tonne)
3%	2100	*Global*	Average	$20.97
3%	2100	*U.S.*	Average	$3.91

Source: Table 4A, Direct Testimony of Dr. Anne Smith (Ex. 307)

At a 5% discount rate, 2100 time horizon, average tonne scenario, the change from a Global to U.S. scope yields the following (in $2014/net tonne):

Discount Rate	Time Horizon	*Scope*	Which Tonne	2020 SCC Value (2014$/net tonne)
5%	2100	*Global*	Average	$8.75
5%	2100	*U.S.*	Average	$1.80

Source: Table 4A, Direct Testimony of Dr. Anne Smith (Ex. 307)

Apportioning Damages by Physical Impacts versus Economic Impacts

There are at least two distinct views of geographic scope: modeling the physical damage in a specific scope and estimating the financial obligation of a society. For instance, Drs. Mendelsohn and Smith manipulated the IAMs to limit the SCC calculated to U.S.-only *physical*

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[306] Ex. 302, Exhibit 2 of Smith Direct (Expert Report), at 98.

damages. Dr. Gayer proposed a GDP-scaling method to provide U.S. and Minnesota *economic* damages, whereby the IWG's estimates were adjusted by a percentage of the global value.[307]

Physical Impacts

Due to the complex nature of and interactions within the climate system, evaluating the physical impacts of climate change on a localized scale could indeed bring into question any usefulness of the IAMs to calculate damages. In part, this is because IAMs contain an aggregated damage function linking global increases in temperature to multiple types of impacts in order to create a monetary value. As Dr. Smith noted, she did not develop a Minnesota-specific damage estimate because there are no damage functions at the state level.

According to Dr. Smith's Expert Report:

> A study of the IAM damage functions, however, finds that they are simplified formulas that largely circumvent a key attribute of the damage function approach. In large part, the models do not use "dose-response" relationships between climate outcomes and physical measures of resource changes that can then be assigned monetary values, but instead calculate loss of societal value directly from temperature change levels. … To the extent that aggregated damage functions are employed by an IAM, it becomes very difficult to know exactly *what* types of damages are even included in a particular SCC estimate.[308]

Dr. Hanemann did not agree with Dr. Smith's contention that the IAM damage functions have no empirical basis because they do not include dose-response functions. According to Dr. Hanemann's Rebuttal:

> Dose-response functions are typically formulated for narrowly defined outcomes, whether health outcomes or otherwise. They apply to particular outcomes – say, malaria rather than waterborne diseases in general – and they are calibrated to specific conditions. I am not aware that dose-response functions exist for the multiplicity of outcomes of impacts likely to be associated with climate change on the spatial and temporal scales required.[309]

The IAMs used to calculate physical damages in economic terms are simplified representations of a complex system, and that is what the Commission directed in its October 2014 Order requesting parties use "reduced form" modeling to compute damages. But if the purpose for localizing the physical damages is because dose response relationships are necessary, then perhaps the most applicable evidence might be from Dr. Reich, whose testimony discussed localized physical impacts specific to Minnesota. Still, according to Dr. Reich, even specific,

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[307] Ex. 400, Gayer Direct, at 10.
[308] Ex. 302, Smith Direct, Exhibit 2 –Expert Report, at 23.
[309] Ex. 801, Hanemann Rebuttal, at 39.

disaggregated Minnesota impacts would be difficult to translate into monetary terms with any great confidence, yet there is enough confidence to say the impacts are indeed damaging:

> I don't believe that we, the scientific community, has sufficient scientific understanding to accurately predict whether, and by how much, MN crop production will increase or decrease with climate change. My opinion is that the risks have much more downside potential than the benefits have upside potential. However, there is certainly is no evidence to support the notion that MN agriculture will generally benefit from rising CO_2 and associated climate change in the next several decades.[310]

But even Dr. Reich's studies of plant growth survival and experimental climate manipulations, which indicate deleterious effects of climate change in Minnesota, still require a global geographic scope, because these impacts depend on CO_2 concentrations of emissions that are globally-mixed.

Furthermore, as Drs. Dessler and Abraham explained, the behavior of CO_2 and its interactions with the rest of the earth system is far more complex than look at one state or one country as source and sink. For example, in a climate model or in a climate system, a significant amount CO_2 emissions can be absorbed into the ocean, thereby yielding no apparent impact on atmospheric CO_2 under short-term timescales. If considering CO_2 emissions cumulatively and over the long-term, it could be far too restrictive, limited, and inaccurate to view CO_2 in the context of one isolated areae.

To present this in graphical form, one could refer to how IPCC runs its Earth System Models. In Box 6.4, Figure 1 (Chapter 6) of AR5, IPCC provides a simplified schematic representation of how Earth System Models can provide a predictive link between CO_2 emissions, future CO_2 concentrations, and climate.[311]

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[310] Ex. 107, Reich Rebuttal, at 14.
[311] Ex. 405, IPCC Fifth Assessment at 516-517.
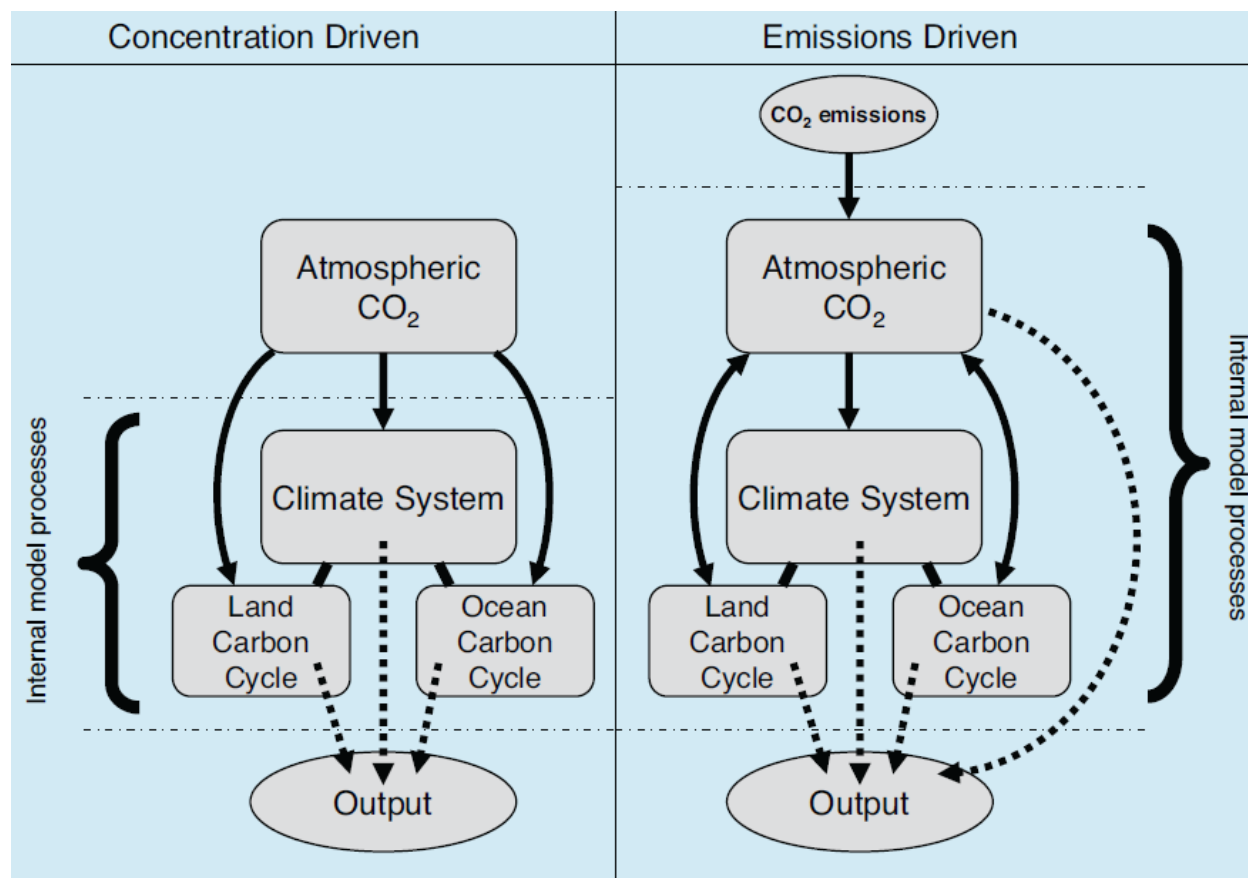
Earth System Models do not treat an emission as merely the interaction between a molecule of emitted carbon dioxide and the atmosphere, but as a function of multiple feedbacks and interrelationships within the climate system, including land and ocean carbon cycles.

Economic Impacts

If a local geographic scope is ill-suited for IAMs or not reflective of the Earth system in general, a local geographic scope could still be used if the means for doing so is, as Dr. Gayer proposed, using adjustment factors based on GDP share.

The IWG's global geographic scope ran the IAMs to calculate the social impact of a marginal unit of CO_2 emissions on global GDP. Dr. Gayer raised policy and economic efficiency concerns regarding such an approach, namely that it would be imprudent to attribute the damage costs to a single actor, such as one country or one state, when those damages have global origins. It would seem, though, that adopting a GDP-scaling approach could be a straightforward, post-model adjustment that (1) could still translate global climate change into global GDP, (2) possibly avoid re-running the IAMs, but (3) apply adjustment factors to reflect Minnesota or U.S. damages. In other words, a GDP-scaling approach could still be consistent with the underlying physical sciences driving the estimates. According to Xcel:

In case the Commission chooses to establish CO_2 environmental values based on other than global damages, the range we propose could easily be adjusted by applying an adjustment factor based on the GDP of the chosen jurisdiction as a proportion of global GDP.[312]

Of course, this might muddle the definition of the geographic scope, but presumably, one can consider global damages while adjusting the change in GDP using a localized geographic scope. As staff interprets MLIG's argument, MLIG seems to be saying is that, to the extent there is a "true SCC," and if that SCC is expressed in terms of global GDP, an efficient societal outcome would mean that every "society" contributes its respective share of global GDP. In this case, if a "society" means the State of Minnesota or the U.S., it would be reasonable to adjust the true SCC by the Minnesota or national share of global GDP. While some will certainly disagree, one could argue that this would not abandon a global perspective completely, because it could still accommodate all physical science assumptions before adjustments are made to global GDP.

ALJ Conclusions Section VI: Time Horizon

A. ALJ Report

The ALJ recommended the Commission shorten the time horizon by 100 years, from 2300 to 2200. The ALJ also made the following Conclusions on modeling time horizon.

> 30. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that a ton of CO_2 released into the atmosphere will not be fully absorbed into the land or the oceans for a minimum of two hundred years. The Administrative Law Judge finds that it will be hundreds of years before that ton will be fully absorbed.

> 31. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that CO_2 will continue to have a cumulative impact on the climate for as long as it remains in the atmosphere.

> 32. The Administrative Law Judge concludes that the CEOs and Agencies failed to demonstrate that the IWG's prediction of damages from the year 2100 to the year 2300 meet the same standards of reliability as the IWG's predictions of damages from the present to the year 2100. The IWG used the peer-reviewed EMF-22 emissions scenarios, which were constructed through the year 2100. The IWG extrapolated the EMF inputs to the year 2300 based on limited data, without the benefit of peer review.

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[312] Xcel Initial Brief, at 27.

33. The Administrative Law Judge concludes the Utilities and MLIG demonstrated by a preponderance of the evidence that approximately 50 percent of the FSCC estimates at a three percent rate are in the post-2100 era.

34. The Administrative Law Judge concludes that the Agencies and the CEOs failed to demonstrate by a preponderance of the evidence that a modeling time horizon extending to the year 2300 is reasonable. An additional two-hundred years will add increased numbers of cost values at lower interest rates and accelerating rates of damages with the passage of time and increased temperature. Therefore, the Administrative Law Judge finds that an extrapolation extending two-hundred years beyond the year that the EMF-22 scenarios were constructed to end is a degree of uncertainty that is not reasonably supported by adequate evidence.

35. However, weighing the importance of accounting for the CO_2 that will remain in the atmosphere beyond the year 2100, and the understated nature of the FSCC, the Administrative Law Judge concludes that it is reasonable to implement the IWG's extrapolation for 100 years, to the year 2200. While the evidentiary underpinning is no greater for this extrapolation than it would be to extend the model to the year 2300, this approach lessens the danger of multiplication of errors within the extrapolation while providing a response to the strong evidence of damage from CO_2.

The ALJ included a Memorandum to her Report following the Recommendations section, and one of the areas the Judge discussed was the time horizon. Staff includes the ALJ's discussion in full, from pages 129-130 of her report.

The Commission is faced with a decision regarding the time horizon which requires a balancing of evidentiary and policy considerations. The evidence is clear that carbon remains in the atmosphere, cumulates, and will continue to affect the climate for hundreds of years to come. The dilemma facing the Administrative Law Judge, and the Commission, is a certainty that damages will continue to occur after 2100, coupled with a significant drop-off in the reliability of how to predict those damages after 2100. Predicting future damages is not at all certain, even based on the peer-reviewed EMF-22 scenarios designed to project to the year 2100. The IWG's extrapolation beyond that time frame with the scenarios is more tenuous. Yet, the certainty that damages are there remains.

The best evidence supports recalculating the damages to the year 2100. On the other hand, there is a strong argument that, knowing the damages continue, it is reasonable to include damages until the year 2200. This compromise position would account for the ongoing damages yet limit, to some extent, the compounding effect of continuing the calculation for another 100 years. The Agencies' and the CEOs' experts did not perceive the level of speculation between the EMF-22 projections from the present until 2100 and from 2100 until 2300 to

be significantly different in terms of reliability. While the Administrative Law Judge cannot credit the projections for the two periods equally in an evidentiary sense, neither can she completely discount the latter. Therefore, the Administrative Law Judge recommends recalculating the FSCC based on IAMs with inputs through the year 2200.

B. Party Positions

MLIG

One of MLIG's chief arguments favoring a shorter time horizon is that it reflects a more reasonable and commonly used practice in policy analysis. Staff refers the Commission to pages 12-13 of Dr. Gayer's Surrebuttal, which discussed weighing uncertainty under various timescales and accounting for it in economic forecasts.

MLIG also argued there is no evidentiary underpinning for the IWG's extrapolation of the EMF-22 scenarios, and therefore the FSCC values should be recalculated to reflect a shortened time horizon extending to the year 2100.

GRE/MP/OTP

According to GRE/MP/OTP's Exceptions:

> Because the record establishes that damage estimates beyond 2100 are based on extrapolation, it follows that damages beyond 2100 can be neither quantified nor supported by sufficient evidence in a manner required by the environmental cost stature. Thus, we object to Conclusion 35, and we urge the Commission to use a time horizon of 2100.[313]

GRE/MP/OTP noted that the Commission's current CO_2 environmental cost values for Minnesota were based on estimates of loss in GDP due to projected temperature changes through the year 2100, and there is no evidentiary basis in this record for the Commission to change the currently used time horizon.

According to GRE/MP/OTP witness, Dr. Smith:

> In response to a likely argument that a 300-year time horizon is necessary because a portion of the climate impacts of emissions today may linger for far longer than 100 years, one should consider the vast degree of extrapolation and speculation that this then places on the IAM damage functions, especially considering the

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[313] GRE/MP/OTP Exceptions, at 17.

effect of the nonlinear (e.g., quadratic) damage functions contained in the IAMs.[314]

CEO

Dr. Polasky disagreed with Dr. Smith, arguing in his Rebuttal:

> Properly estimating the marginal damages associated with a unit of emission of CO_2 requires accounting for the impact of that unit as far into the future as it is likely to remain in the atmosphere and cause damages. A unit of CO_2 and the associated warming effect persists for many years, with some estimates of residence time in the atmosphere lasting up to two hundred years. It would be inappropriate to arbitrarily exclude any future time period where damages will likely occur. At some point, both because of low probability of remaining in the atmosphere and discounting, future impacts become negligible. The IWG determined that the year 2300 was the appropriate time horizon required to capture all pertinent impacts associated with CO_2 emissions. Of course it is impossible to predict with great accuracy what will happen out to 2300, just as it is impossible to predict with great accuracy what will happen out to 2140, to 2100, or even to 2050.[315]

CEO's Exceptions detailed, at length, why the time horizon should not be truncated. In part, CEO argued:

> The record demonstrates, and the ALJ concluded, "that a ton of CO_2 released into the atmosphere will not be fully absorbed into the land or the oceans for a minimum of two hundred years. . . . [and] that it will be hundreds of years before that ton will be fully absorbed." The Agencies' expert reiterated that CO_2 is a particularly long-lived greenhouse gas: "Some GHGs are short-lived while others remain in the atmosphere for hundreds or thousands of years. The warming impacts of ozone or contrails last only days or months. Those of methane last for about 20 years. Those of CO_2 persist for hundreds of years."16 In other words, CO_2 emitted in 2100 persists in the atmosphere contributing to warming until at least 2300; and damages caused by that CO_2 persist long after that. The IWG Technical Supporting Documents (TSD) demonstrate that damages attributable to an emitted ton continue on even after that ton has left the atmosphere. As one example, the 2013 TSD explained why the DICE model would continue to demonstrate increasing damages even after modeled CO2 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

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[314] Ex. 302, Smith Direct, Exhibit 2, Expert Report, at 29.
[315] Ex. 101, Polasky Rebuttal, at 15.

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.[316]

Agencies

The Agencies also dedicated a substantial portion of its Exceptions on time horizon. The Agencies' remarks mostly refuted the ALJ's premise that 2300 creates excessive uncertainty in the SCC estimates. The Agencies contended that, while there is greater uncertainty about the assumption of GDP in 2300, the damages are represented as the same percentage of whatever the GDP happens to be. Therefore, there is not necessarily more uncertainty about the damage as a percentage of GDP in 2300 relative to 2100. In addition, there is no factual basis for the assertion that economists can forecast the state of the economy in 2100 or 2200 more reliably than they can forecast it in 2300.

The Agencies offer the following reasons for retaining a modeling horizon of 2300. First, there is no factual basis for the assertion that economists can forecast the state of the economy in 2100 or 2200 more reliably than they can forecast it in 2300. While the state of the economy in 2200 and 2300 are both uncertain, and 2300 is further in the future than 2200,

Xcel

Xcel argued it would not be feasible to adjust its proposal to a shorter modeling horizon, since this would have required acquiring, re-coding, and re-running the IAMs.

CEO agreed with Xcel, and in its Exceptions explained:

> The first of the proposed changes is to recalculate the SCC with a shorter timeline, ending the modeling at the year 2200 instead of 2300. A 2200 time horizon was considered by the IWG and rejected as unreasonable. Recalculating all of the SCC values in order to incorporate this change will likely place a huge burden on Minnesota agencies' resources, a burden repeated each time the values need to be calculated, verified, or updated. Also, the evidence in the record suggests that this change has a small effect on the ultimate values—removing this century of modeled results does not significantly change the SCC numbers relative to their current levels. As a result, this high-cost and small-effect change in time horizon should be rejected by the Commission, and the Commission should instead adopt the SCC values as calculated by the IWG.[317]

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[316] CEO Exceptions, at 7-8.
[317] CEO Exceptions, at 3-4.

C. Staff Discussion

The primary dispute between those recommending a longer-time horizon versus those recommending a shorter one is about CO_2 persistence versus uncertainty. For this issue, it is really the Commission's choice about whether it decides the SCC estimates should be aligned with the lifetime of CO_2 damages, or whether the IWG's extrapolations were unreasonable.

The lifetime of CO_2 emissions will clearly persist beyond 2100, and in fact, IPCC reported that "about 15 to 40% of emitted CO_2 will remain in the atmosphere longer than 1,000 years."[318] With that in mind, staff's discussion will focus on the IWG extrapolations.

Atmospheric CO_2 concentrations

In setting the social cost of carbon, IWG noted in its 2015 *Response to Comments* that "At the time the 2013 SCC update was released, the most authoritative statement about [equilibrium climate sensitivity] appeared in the IPCC's AR4."[319] The IWG therefore applied a probability distribution for this parameter mirroring the range of estimates used by the IPCC.

Previous sections of this briefing paper discussed how the IPCC arrived at *likely* ranges for increases to global mean surface temperature; in doing so, IPCC's aim was to "communicate the uncertainty, confidence and degree of consensus prevailing in the scientific literature."[320]

IPCC's four Representative Concentration Pathways were run up to the end of the 21st century, although IPCC cited studies that investigated longer-term climate change implications, whereby RCPs were extended beyond 2100. Nevertheless, IPCC determined, "Beyond 2100, the number of CMIP5 simulations is insufficient to estimate a *likely* range."[321]

The IWG extrapolated the estimates out to 2300, which required "assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100."[322] Thus, the argument about CO_2 persistence is obviously valid, yet it is not as though no uncertainty exists with respect to the cumulative emissions, CO_2 concentration, and radiative forcing in the 2100-2300 timeframe, which is important because this timeframe constitutes a large share of the present value of damages that will ultimately be considered in resource plan proceedings. Dr. Smith's Replication Analysis, for example, found that more than half of the damages are accrued in the post-2100 timeframe.

Referring to Figure 6 of Mr. Martin's Direct, below, it is no surprise why: As shown by the graphical representation of IWG's extrapolations of atmospheric CO_2 concentrations,

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[318] Ex. 405, IPCC Fifth Assessment, at 469.
[319] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 12.
[320] Ex. 405, IPCC Fifth Assessment, at 142.
[321] Ex. 405, IPCC Fifth Assessment, at 1058.
[322] Ex. 100, Schedule 2 of Polasky Direct, IWG Technical Support Document, at 43.

atmospheric CO_2 can reach levels close to or above 2,000 ppm under some scenarios in the 23rd century, which is approximately five times current levels and seven times pre-industrial levels.

Figure 6
Change in Atmospheric CO_2 Concentrations (Top Figure, in Parts per Million), Total CO_2 and Non-CO_2 Radiative Forcing (Middle Figure, in Watts/m^2), and Average Global Temperature (Bottom Figure, in Degrees Celsius Above Pre-Industrial) Across the Three IAMs[32]
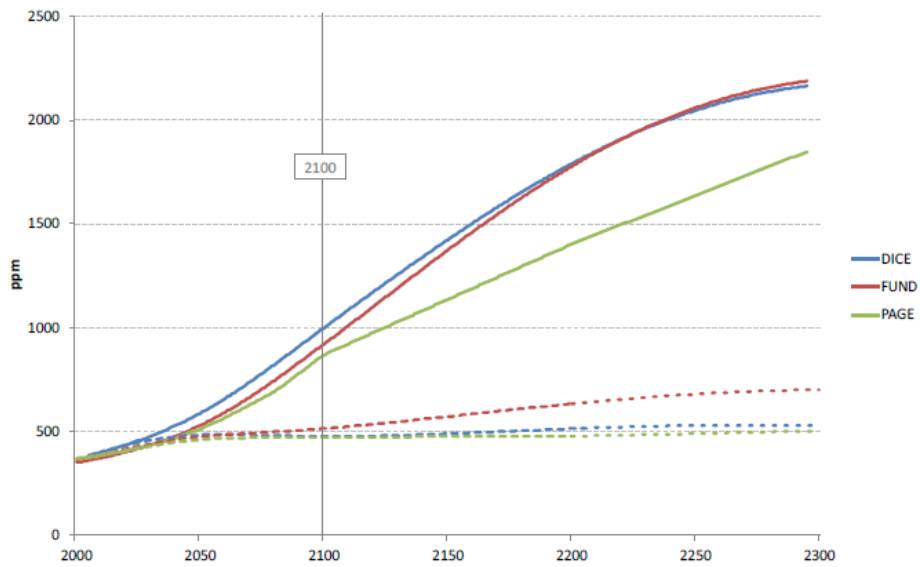
The middle graph of Mr. Martin's Figure 6 shows CO_2 and non-CO_2 radiative forcing (in W/m^2). As shown by the y-axis, by 2300, the upper bound (MERGE Optimistic) has a radiative forcing value of about 12 W/m^2 and the lower bound (550 ppm) has a radiative forcing value between 4-6 W/m^2.
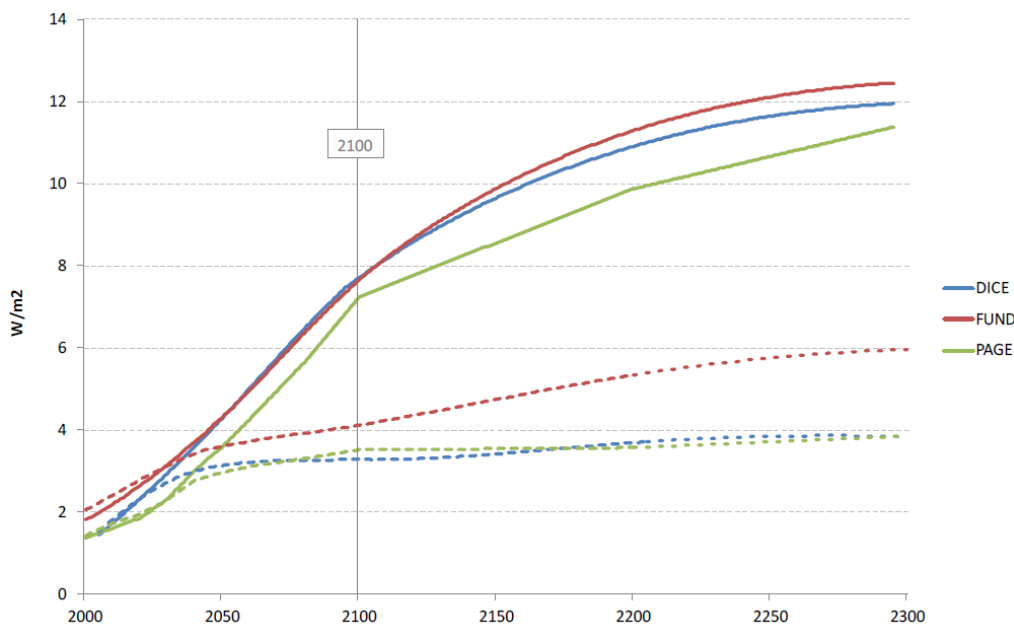
According to IPCC's Fourth Assessment, IPCC reported that with unmitigated CO_2 emissions, a tipping point could be reached whereby "effective adaptation is not possible, or will only be available at very high social, environmental and economic costs."[323]   ALJ Conclusion 43 addresses tipping point catastrophies:

> 43. The Administrative Law Judge concludes that the Agencies and CEOs demonstrated by a preponderance of the evidence that, given the increased scientific certainty of the link between CO_2 emissions and climate change, uncertainties such as the potential danger of a "tipping point" catastrophe reasonably require an initially high SCC until more is known about such uncertainties.

Dr. Hanemann explained the how an uncertain threshold for a tipping point can raise the SCC value and that valuing climate impacts is not even the major area of uncertainty but that "these climate outcomes are unprecedented in human history."[324]

Atmospheric CO_2 concentration (and its associated tipping point uncertainty) is one example of why the time horizon is among the most important areas of this proceeding. On the one hand, the Agencies explained how projected climate change outcomes, including concentrations nonexistent in human history, could affect the FSCC. On the other, one may actually see the practicability in exercising caution when considering IWG's extrapolations of atmospheric CO_2 concentrations to ~2,000 ppm levels, as counterintuitive as that may seem, if these extrapolations go beyond the current scientific consensus of projected climate change.

Referring back to Mr. Martin's Figure 6, at least at the upper bound, atmospheric CO_2 levels can reach 2000 ppm and radiative forcing values reach about 12 W/m^2. The four Representative Concentration Pathways (RCPs) IPCC considered in AR5 used radiative forcings of 2.6, 4.5, 6.0, and 8.5 W/m^2 by the year 2100. These forcing levels were translated into concentrations, and, according to IPCC, "Most of the CMIP5 and Earth System Model simulations were performed with prescribed CO_2 concentrations reaching 421 ppm (RCP2.6), 538 ppm (RCP4.5), 670 ppm (RCP6.0), and 936 ppm (RCP8.5) by the year 2100."[325]

Mr. Martin's Figure 6, if accurate, means that the IWG's atmospheric CO_2 concentrations, by 2300 and at the upper bound, are roughly double the CO_2 concentration evaluated in RCP8.5 (in ppm), with a roughly 50% higher radiative forcing value.

The IPCC did include in AR5 scientific literature of longer-term climate modeling, in which its RCPs were extended until 2300. These are formally named Extended Concentration Pathways (ECPs). However, in its characterization of the ECPs, the IPCC explained they "use simple

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[323] Ex. 267, IPCC Fourth Assessment, at 65.
[324] Ex, 802, Hanemann Surrebuttal, at 44.
[325] Ex. 405, IPCC Fifth Assessment, at 29.

assumptions about GHG and aerosol emissions and concentrations beyond 2100 (such as stabilization or steady decline) and were designed as hypothetical 'what-if' scenarios, not as an outcome of an IAM assuming socioeconomic considerations beyond 2100."[326]

The ongoing investigation of the earth systems' response to longer-term (post-2100) anthropogenic perturbations may, or probably will, facilitate deeper understandings of climate change under very long time horizons, but it is a legitimate question to ask what level of scientific understanding or consensus these timescales have. Moreover, the Commission might find that such extrapolations stray too far from the threshold question posed in this proceeding, which is the best estimate of CO_2 emissions' impact to society for use in resource planning decisions. In other words, the Commission might find that "hypothetical 'what-if' scenarios," as IPCC puts it, may go beyond a reasonable boundary of a robust sensitivity analysis for a fifteen-year resource plan filed every two years.

The choice of the time horizon also could affect the Commission's consideration of tipping point uncertainty. For example, IPCC stated in its Fifth Assessment (with parenthetical citations removed for readability):

> Related to multiple climate states, and hysteresis, is the concept of irreversibility in the climate system. In some cases where multiple states and irreversibility combine, bifurcations or 'tipping points' can been reached. In these situations, it is difficult if not impossible for the climate system to revert to its previous state, and the change is termed irreversible over some timescale and forcing range. A small number of studies using simplified models find evidence for global-scale 'tipping points'; however, there is no evidence for global-scale tipping points in any of the most comprehensive models evaluated to date in studies of climate evolution in the 21st century. There is evidence for threshold behaviour in certain aspects of the climate system, such as ocean circulation and ice sheets, on multi-centennial-to-millennial timescales. There are also arguments for the existence of regional tipping points, most notably in the Arctic, although aspects of this are contested.[327]

This is not to suggest the IPCC did not investigate long-term timescales; it did, and at great length, particularly in Chapter 12 of AR5. And merely because IPCC established a *likely* range of temperature increase only through 2100 does not necessarily mean IPCC implied policymakers should do the same. In fact, the opposite is true, and ultimately IPCC noted, "The choice of time horizon is a value judgement because it depends on the relative weight assigned to effects at different times."[328]

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[326] Ex. 405, IPCC Fifth Assessment, at 1047.
[327] Ex. 405, IPCC Fifth Assessment, at 129.
[328] Ex. 405, IPCC Fifth Assessment, at 712.

Parties in this proceeding argued opposing sides of the question of whether IWG's extrapolations were reasonable and appropriate. IWG defended its choice to extrapolate beyond 2100 because it argued it applied the most recent and available scientific information it had available at the time of developing the SCC, including the IPCC's *likely* ranges. The questionable choice, it seems, is whether IWG unreasonably deviated from the sources of its information, namely EMF-22, by going beyond 2100. IWG responded to this criticism in its 2015 *Response to Comments*:

> The IWG also agrees that the trajectory of socioeconomic-emission scenarios beyond 2100 is uncertain. However, as the 2010 TSD notes, because of the long atmospheric lifetime of CO_2, using too short a time horizon could miss a significant fraction of damages under certain assumptions about the growth of marginal damages. Therefore, the IWG ran each model through 2300. The IWG will continue to follow and evaluate the scientific literature on long-term scenario development.[329]

The IWG determined—and the Commission can determine—that a multi-generational perspective beyond 2100 is reasonable, in part due to the long-lived nature of CO_2 emissions. The ALJ concurred with that view, although to a more limited extent that the IWG.

As CEO observed in its Exceptions, the IAMs in their original forms had varied time horizons, too, and in some cases the IWG actually *shortened* the time horizon during the IAM standardization process, not lengthened it. According to CEO:

> The IAMs used by the IWG had varying default time horizons—for PAGE it was 2200, but for DICE it was 2595, and for FUND it was the year 3000.[330] Using a time horizon of 2300 was already a compromise position taken by the IWG—and it was reasonable because after 2300 the discount rate effectively reduces the increase in damages to a negligible value. But shortening the time horizon even further omits damages that are certain to occur.[331]

CEO raises an important point here. In ALJ Conclusion 6, the Judge concluded that "the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that the IWG's use of the DICE, PAGE, and FUND models to calculate the FSCC is a damage-cost approach consistent with the Commission's Notice and Order for Hearing in this docket." In ALJ Conclusion 8, the Judge concluded that "the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that it was reasonable for them to rely on an environmental cost valuation for CO_2 based on the use of the DICE, PAGE and FUND models." According to Dr. Hanemann, the IAMs used by the IWG in estimating the SCC are the three main such models in the literature. So, if the IAMs are widely-used models that are generally considered to be

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[329] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG 2015 Response to Comments, at 29.
[330] ALJ Finding of Fact 110.
[331] CEO Exceptions, at 10.

credible, and if the ALJ concluded they are reasonable to use for this proceeding, why did *IWG* err by actually shortening some horizons during the standardization process?

To revisit the Judge's Memorandum in her Report, the ALJ noted:

> The best evidence supports recalculating the damages to the year 2100. On the other hand, there is a strong argument that, knowing the damages continue, it is reasonable to include damages until the year 2200. **This compromise position** would account for the ongoing damages yet limit, to some extent, the compounding effect of continuing the calculation for another 100 years. (Emphasis added.)

According to the ALJ, time horizon is a policy decision for the Commission to make. Naturally, all parties disagree with the ALJ's recommendation because it reflects a "compromise position." However, as stated above, CEO noted that IWG's time horizon was in fact also a "compromise position" to begin with.

ALJ Conclusions Section III: 95ᵗʰ Percentile at 3% Discount Rate Scenario

There are at least three ways the Commission could determine the 95ᵗʰ percentile at 3% discount rate scenario is reasonable to include among the SCC estimates. First, the Commission could follow the Judge's findings and conclusions and adopt her recommendation not to include the 95ᵗʰ percentile values. Second, the Commission could decide it is good public policy to consider the effects of catastrophic climate change. Third, the Commission could determine that, for reasons explained by witnesses such as Dr. Rom and Dr. Hanemann, the SCC is too low and does not sufficiently account for all damages attributable to CO_2 emissions, and therefore a more reasonable SCC estimate would actually reflect higher values.

A. ALJ Report

The ALJ recommended the Commission "exclude the value derived from the 95th percentile at a 3 percent discount rate value from the range of values."[332] Even though the Judge did not recommend the Commission include the 95ᵗʰ percentile in the range of SCC estimates, the Judge nonetheless concluded:

> 12. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the IAMs damage functions do not account for a significant number of important environmental impacts which will occur as a result of climate change.

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[332] Id, Recommendation 1.a) at 124.

13. The Administrative Law Judge concludes that, based on unreported and underreported health and environmental impacts, along with the IWG's acknowledgement that the FSCC is not based on the most current research, the preponderance of the evidence demonstrates that the FSCC understates the full environmental cost of CO_2.

20. The Administrative Law Judge concludes that the CEOs and the Agencies demonstrated by a preponderance of the evidence that the FSCC likely understates damages and that the risk of a "tipping point" is not well-represented within the scope of the 2.5, 3.0 and 5.0 percent rate of discount.

21. Nonetheless, the Administrative Law Judge concludes that the CEOs and the Agencies failed to demonstrate, by a preponderance of the evidence, that the 95th percentile value at a three percent discount is a reasonable means of representing the high side of the FSCC distribution. The Agencies and the CEOs failed to demonstrate a reasonable basis for choosing the 95th percentile at three percent to represent the uncertainties regarding understated damages and a potential "tipping point." The 95th percentile value provided a larger damages number but was not supported by specific evidence or reasoning to demonstrate that the number is a meaningful estimate of the uncertainties it represents.

B. Party Positions

High-Damage/Low-Probability Events

Dr. Polasky explained why the consideration of all possible outcomes, especially those at the high end of the range, are appropriate and necessary:

> The issues involved in establishing a value for the SCC are similar to the issues involved in the way we price home insurance. They both involve uncertainty about what damages might occur in the future. If we could be certain there would be no damages to our house over the next year, the value of home insurance would be zero. But the value of insurance is greater than zero because there is some, perhaps small, probability that a damage-causing event will happen (e.g., severe storm, fire). Suppose there is a 5 percent chance of such an event occurring. That means there is a 95 percent chance that no such event will occur. In other words, 95 times out of 100, the possible future cost of damage to our home is $0.0. Five times out of 100, however, the cost of those damages could be quite large. If we calculate the median of expected damages over the coming year, it is zero. In fact, the range from the 25th to the 75th percentile outcomes would also be zero. This is true regardless of how high the cost is in the five times out of 100 that our home will suffer some damage.

The mean, in contrast, gives us a much better understanding of the actual risk to our home and the reason for which we would buy insurance. The mean incorporates information about the damages from the 5 percent chance of a damage-causing event, and is a positive value that will vary depending on the amount of damage we might suffer. The mean, rather than the median, is the basis for the price for insurance. This is the exact same concept that should be used when considering the expected damages from climate change, and this is exactly how the IWG calculated the SCC.[333]

Some refuted this comparison to pricing home insurance. Dr. Gayer argued that this confuses uncertainty and risk. The home insurance example envisions a scenario where there is a 5% risk of damage. In other words, risk is the probability of an event occurring, whereas uncertainty is the degree of imprecision in the estimate of risk.[334] Mr. Martin contended that the home insurance example significantly differs from the problem of establishing a value for the SCC. The damages in the home insurance example for each year are either zero or extremely high; in contrast, the modeling performed by the IWG suggests the correct SCC value lies on a continuum and may be between zero (or slightly negative) and very high numbers.[335]

Xcel noted it would be impractical to consider very high and very low values in resource planning. Thus, Xcel's proposal identified a range within the FSCC estimates that, it claimed, appropriately balances uncertainty, risk tolerance, and practicability."[336] Xcel explained:

> Unsupportably high or diametrically opposed (low/negative and very high) values would tend to create a tension that is difficult to reconcile between the Commission's consideration of the PVRR (Present Value of Revenue Requirements, reflecting the actual cost to utility customers) ranking of resource plan alternatives and the PVSC (i.e., the PVRR plus the value of estimated damages) ranking of resource plan alternatives. In our view, if the PVRR and PVSC rankings are entirely dichotomous and non-overlapping, the results fail on the practicability requirement because they could point to resource plan alternatives that do not overlap in a given docket.[337]

Some supported adopting the 95th percentile scenario for public policy reasons. For example, Dr. Hanemann raised the following question in his Rebuttal:

> **Q. Do policymakers and regulators need to consider possibly catastrophic outcomes resulting from climate change?**

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[333] Ex. 101, Polasky Rebuttal, at 38-39.
[334] Ex. 401, Gayer Surrebuttal, at 13-17.
[335] Ex. 602, Martin Surrebuttal, at 18.
[336] Xcel Exceptions to ALJ Report, at 7.
[337] Xcel Exceptions to ALJ Report, at 7.

A. In my view, the answer is yes. The justification for this answer is well expressed by Pindyck (2013a), as follows:

> Why do we need to worry about large temperature increases and their impact? Because even if a large temperature outcome has low probability, if the economic impact of that change is very large, it can push up the SCC considerably. As discussed in Pindyck (2013c), the problem is that the possibility of a catastrophic outcome is an essential driver of the SCC.[338]

On the other hand, some considered it to be good public policy not to adopt very high damage estimates if they have little to be reasonable basis. These arguments contended that incorporating high-damage, low-probability outcomes worsens the problem of considering a flawed analysis in the first place. In Dr. Smith's Direct testimony, she warned against using IAMs for *any* SCC estimate. On page 17 of Dr. Smith's Direct, Dr. Smith questioned the reasonableness of using *any* SCC estimate, even under the framing assumptions she proposed:

> In the course of my analyses using the IAMs to prepare my testimony and recommendations for this proceeding, it became apparent to me that the sensitivity of the IAMs to unverified and non-scientific assumptions made by modelers, as well as by model users, throws into question the reasonableness of using any SCC value that the IAMs may produce.[339]

Peabody and MLIG agreed and cited an article that stated IAMs have "crucial flaws" and are "close to useless."[340] MLIG urged the Commission to avoid increasing the environmental cost of CO_2 for no benefit, especially if it would jeopardize the State's economy.[341]

The SCC Estimates Are Unreasonably Low

In IWG's 2015 *Response to Comments*, it stated, "the 95th percentile of the pooled distribution using a 3 percent discount rate, is included to represent higher-than-expected economic impacts from climate change further out in the tail of the SCC distribution."[342] IWG further explained:

> Based on the current scientific understanding of climate change and its impacts, and on the limitations of the IAMs in quantifying and monetizing the full array of potential catastrophic and non-catastrophic damages, the IWG concluded that the distribution of SCC estimates may be biased downwards. Since then, the peer-

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[338] Ex. 801, Hanemann Rebuttal, at 64.
[339] Ex. 301, Smith Direct, at 17.
[340] Citations from Pindyck, Robert S., "Climate Change Policy: What Do Models Tell Us?" (2013a) *Journal of Economic Literature* 51(3), 860-872 at 870.
[341] MLIG Initial Brief, at 53-54
[342] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 25-26.

reviewed literature has continued to support this conclusion. For example, the IPCC Fifth Assessment report observed that SCC estimates continue to omit various impacts that would likely increase damages. The 95th percentile estimate was included in the recommended range for regulatory impact analysis to address these concerns.[343]

Dr. Hanemann's Direct discusses several features of each IAM used to calculate the FSCC. With regard to catastrophic outcomes, Dr. Hanemann explained economic impact of a climate catastrophe is not modeled separately in DICE or FUND. In PAGE it is represented by a damage function which kicks in with a positive probability when the increase in global average annual temperature exceeds 3°C.[344] In Dr. Hanemann's Rebuttal testimony, he concluded that IAM damage functions "are likely to understate the damage associated with catastrophically large degrees of warming," which in turn would "lead the IWG's estimates to understate the true value of the SCC."[345]

The Doctors for a Healthy Environment likewise recommended that the Commission should use the SCC as a conservative estimate of the environmental costs of CO_2.[346]

Dr. Polasky argued that the IAMs, as used by the IWG, are intentionally conservative in their estimates:

> The three IAMs used by the IWG are quite conservative in their representation of the potentially catastrophic outcomes from a fundamental shift in the climate. For instance, Martin Weitzman suggests that estimates of damages in IAMs should be equivalent to 50 percent of GDP from 6 degrees Celsius of temperature increase. By contrast, the damages in the three IAMs from 6 degree temperature increases are all less than 10 percent of GDP. By not altering the damage function in the IAMs, the IWG chose to accept this cautious representation of catastrophic outcomes. The position not to change the damage functions reflects the IWG's desire to not want to alter the original models, but this decision is conservative and lowers the estimate of the SCC.[347]

If climate change reduces the growth rate of GDP, then the damages are long-lasting because each successive year GDP is further behind the baseline without climate impacts. How IAMs model the effect on economic growth from climate change and the probability of catastrophic climate change can greatly increase the SCC.

Dr. Polasky's also identified several categories of possible damages from climate change that the federal SCC does not include:

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[343] Ex. 101, Schedule 1, IWG Response to Comments, at 27.
[344] Ex. 800, Hanemann Direct, at 42.
[345] Ex. 801, Hanemann Rebuttal, at 66.
[346] Doctors for a Healthy Environment, Initial Brief, at 4.
[347] Ex. 100, Polasky Direct, at 19.

The IWG acknowledges that the federal SCC does not include damages from ocean acidification and species loss.[348] Van den Bergh and Botzen[349] analyze estimates of the SCC from many sources and determine that important omitted categories of damages include large biodiversity losses, impacts on long-term economic growth, increased political instability, increased migration, extreme weather events, and irreversible climate change. Peter Howard has also examined the categories of damages that are left out of IAMs and estimates that in the U.S. alone the damages from an increase in wild fires could be $23 billion annually by 2050.

CEO noted these conclusions and argued in its Exceptions that the ALJ's Conclusion that the FSCC is an underestimate in many respects does not logically square with her Conclusion not to recommend the 95th percentile values:

Despite agreeing that the SCC is artificially low, despite understanding the purpose of the 95th percentile values, and despite the evidence supporting the need for its inclusion in order to account for the "long tail" of the distribution, the ALJ concluded that CEOs and the Agencies failed to prove that the IWG's 95th percentile value was a reasonable expression of the high side of SCC damages. This runs counter to the evidence in the record as well as the logic behind the SCC and why the IWG chose to have a low-probability/high-damage value in the first place. Based on these findings and the ALJ's correct reading of the law to encourage conservative values, it is within the Commission's authority to adopt all four SCC values as a reasonable estimate of the damage costs attributable to CO_2 pollution. There is no credible evidence in the record to support removing one of the values.[350]

Mr. Martin stated in his Rebuttal that "the IAMs' incomplete modeling of catastrophic damages makes it possible that the SCC is underestimated,"[351] even though Mr. Martin also provided reasons the SCC could be overestimated.

C. Staff Discussion

95th Percentile and Climate Sensitivity

Naturally, treating climate sensitivity probabilistically results in a vast spread of low temperature outcomes with lower projections of damages and high temperature outcomes

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[348] Ex. 100, Schedule 2 of Polasky Direct, at 29.

[349] Van den Bergh, J.C.J.M & W.J.W Botzen, 2014. A lower bound to the social cost of CO2 emissions. *Nature Climate Change*, 4, 253-58.

[350] CEO Exceptions to ALJ Report, at 18.

[351] Ex. 601, Martin Rebuttal, at 17.

with higher projections of damages. Along the Roe & Baker distribution IWG used for climate sensitivity, the climate sensitivity value at the 95th percentile is 7.14°C. According to the IWG, the 95th percentile scenario is based on climate sensitivity parameters consistent with IPCC Assessments and the scientific literature. IWG stated in its 2010 *Technical Support Document*:

> [T]he calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95th percentiles of the three other calibrated distributions (5.2-6.0 °C).[352]

When considering the reasonableness of the 95th percentile estimates, the Commission could first determine whether ECS values at that point along the distribution have a reasonable scientific basis. According to IWG, there have been studies that concluded ECS values higher than 7°C are justifiable. The IWG further stated that it was IPCC's judgment that "values substantially higher than 4.5°C still cannot be excluded." However, there is a difference between whether a value exists within the realm of possibility versus whether it should be used for policy and economic analysis.

For instance, a fuller context of what IPCC reported about higher ECS values was that the "equilibrium climate sensitivity … is *very unlikely* greater than 6°C (*medium confidence*)."[353] In IPCC's treatment of uncertainty, *very unlikely* means a 10% or less probability. Thus, the issue facing the Commission involves treatment of uncertainty and tolerance for risk.

There is significant debate among the parties about how to treat unlikely outcomes, and with respect to whether there is a reasonable scientific basis for a 7.14°C ECS, there is not necessarily a "yes or no" answer, because the question of whether it is reasonable is a matter of the preferred degree of confidence or certainty.

95th Percentile and the IAMs

The three IAMs used to calculate the SCC consider "catastrophic" outcomes very differently. FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increase under higher temperature conditions. PAGE models catastrophic impacts in a probabilistic framework.[354] As one might expect, then, the different treatments of catastrophic damages yield substantially different 95th percentiles, and this is shown in the right-most column of Table 3 of the IWG's 2010 *Technical Support Document*,

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[352] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 14.
[353] Ex. 405, IPCC Fifth Assessment, at 16.
[354] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 31.

below. Table 3 also includes the four discount rate scenarios across the five EMF-22 socioeconomic trajectories; staff notes the high variance across the three IAMs for the 95th percentile scenario.

Table 3: Disaggregated Social Cost of CO_2 Values by Model, Socio-Economic Trajectory, and Discount Rate for 2010 (in 2007 dollars)

Model	Discount rate: Scenario	5% Avg	3% Avg	2.5% Avg	3% 95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

When considering the reasonableness of the 95th percentile estimates, the Commission could next determine whether the IWG reasonably incorporated higher-than-expected damages derived from the IAMs.

95th Percentile and Time Horizons

There is a practicability issue regarding the 95th percentile scenario and its relationship to any possible adjustments the Commission might make. Mr. Martin explained in his Direct testimony how the IWG used the IAMs, and it is important to consider this in the context of developing, possibly, a new 95th percentile under a truncated time horizon:

> The IWG assumed a probability distribution for equilibrium climate sensitivity, and then ran the IAMs in Monte Carlo mode – 10,000 times for each of the fifteen scenarios (three IAMs * five socioeconomic/emissions scenarios) – with the models making random draws from the distribution for the equilibrium climate

sensitivity parameter. As a result, the SCC value for a given emissions year and discount rate results from aggregating 150,000 model results (three IAMs * five socioeconomic/emissions scenarios * 10,000 model runs), and presenting either the simple average (arithmetic mean) or 95th percentile of those 150,000 results.[355]

Why this is important can be further explained by referring to Xcel's Exceptions. With regard to the ALJ's proposed adjustment of the modeling horizon from the year 2300 to 2200, Xcel noted:

> Adjustment of the values would entail acquiring the IAMs; adjusting their internal code to eliminate damages after 2200 (but otherwise following the Interagency Working Group's (IWG) methodology); re-running the IAMs; and recalculating the average across IAM results at each of the three discount rates.[356]

In other words, making this one adjustment—reducing the modeling time horizon from 2300 to 2200—would eliminate the last 100 years of estimated damages, and there would be a new distribution, which means a new (but unknown) 95th percentile.

The Commission might contemplate that the necessity to assess catastrophic outcomes is partially dependent on the time horizon it chooses. This is because, as previously explained, time horizon plays a significant role in whether global tipping points are more or less probable, or more or less severe. Consider Dr. Polasky's testimony, where he states, "marginal damages tend to rise with higher concentrations of GHGs in the atmosphere. The damages from going from 2 to 4 degree increase in temperature are greater than the damages from going from 0 to 2 degree increase in temperature."[357] This is why damage estimates for each subsequent emissions year grow higher.

Next, consider the third figure from Figure 6 of Mr. Martin's Direct, below, showing the temperature increase through 2300 across DICE, FUND and PAGE under the highest emissions scenario, MERGE Optimistic (solid lines), and the lowest emissions scenario, 550 ppm average (dotted lines).

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[355] Ex. 600, Martin Direct, at 18
[356] Xcel Exceptions, at
[357] Ex. 101, Polasky Rebuttal, at 10.
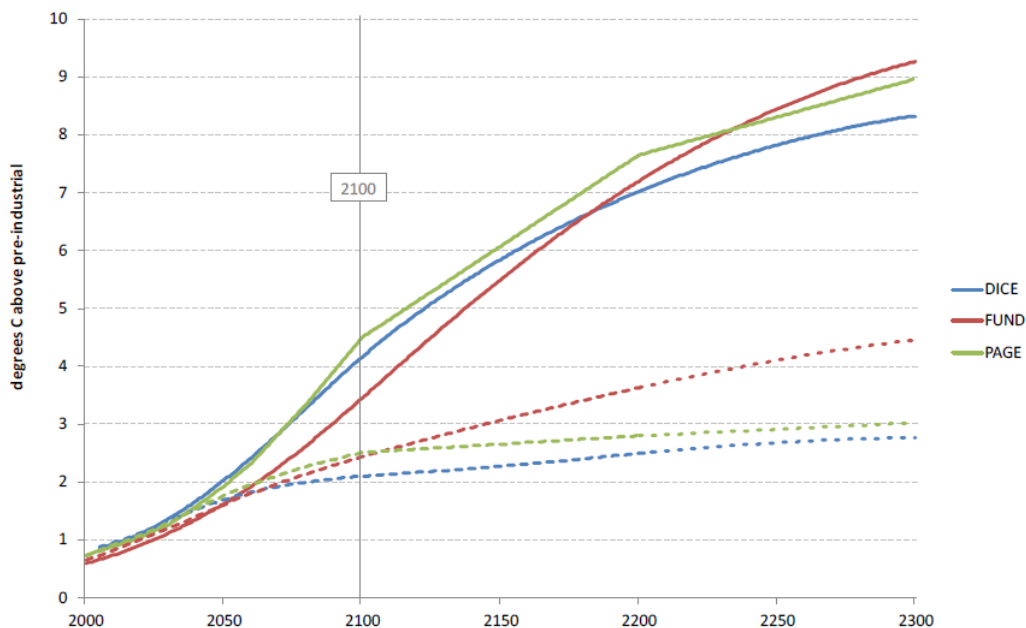
As shown, with each subsequent century, the temperature increase at the upper bound is roughly 3.5-4.5 degrees by 2100, 7-8 degrees by 2200, and 8-9.5 degrees by 2300. One can expect the marginal damages to be substantially higher in the post-2100 time period and the probability of global tipping points to be lower pre-2100.

Another time-dependent variable is sea level rise (which is also a geographic scope issue). Dr. Hanemann explained in his Direct testimony how changes in sea levels were considered in each IAM:

> In the case of sea level rise, the damage is modeled as a function of the rise in global mean sea level, which, in each model, is projected as a function of temperature and lagged temperature. In DICE the global damage is expressed as a quadratic function of the rise in mean sea level. In PAGE and FUND with their regional spatial resolutions, factors such as regional coastal length or topography are used in the calibration of the regional sea level rise damage function. In PAGE, the function is a power function of projected global sea level rise. In FUND, a more elaborate formula is employed.[358]

The IWG also addressed sea level rise in its 2015 *Response to Comments*, and IWG at least implied that the IAMs understate the economic impacts from sea level rise. If true, this may further support claims made by several parties in this proceeding that the FSCC is a conservative estimate:

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[358] Ex. 800, Hanemann Direct, at 41-42.

Regarding the criticisms by commenters of the sea level rise projections in DICE, the IWG recognizes that sea level rise projections are also an area of ongoing research. One key issue involves projections of melt from the Greenland and West Antarctic ice sheets. The IPCC AR5 report notes there is a possibility of sea level rise "substantially above" their best estimate of a likely range because of uncertainties regarding the response of the Antarctic ice sheet (AR5 Working Group 1, Chapter 13).[359]

…

[W]e agree that that the models' functional forms may not adequately capture potentially discontinuous "tipping point" behavior in Earth systems. In fact, large-scale earth system feedback effects (e.g., Arctic sea ice loss, melting permafrost, large scale forest dieback, changing ocean circulation patterns) are not modeled at all in one IAM, and are imperfectly captured in the others.[360]

Sea levels are particularly important to the 95th Percentile/Time Horizon issue, and this can be partially explained by referring to Figure 13.13 of IPCC's Fifth Assessment. Figure 13.13, shown below, illustrates changes in sea levels in 2100 and beyond, grouped into three categories according to greenhouse gas concentrations (>700 ppm, 500–700 ppm, and <500 ppm).   The light red-shaded bars show the likely range for the 21st century total sea level projection in the year 2100, and the dark red bars show the ice sheet model's total sea level change from 1) thermal expansion, 2) glaciers, 3) Greenland, and 4) Antarctica in years 2100, 2200, 2300, 2400, and 2500.[361]

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[359] Ex. 101, Schedule 1 of Polasky Rebuttal, at 14.
[360] Ex. 101, Schedule 1 of Polasky Rebuttal, at 15.
[361] Ex. 405, IPCC Fifth Assessment, at 1188.
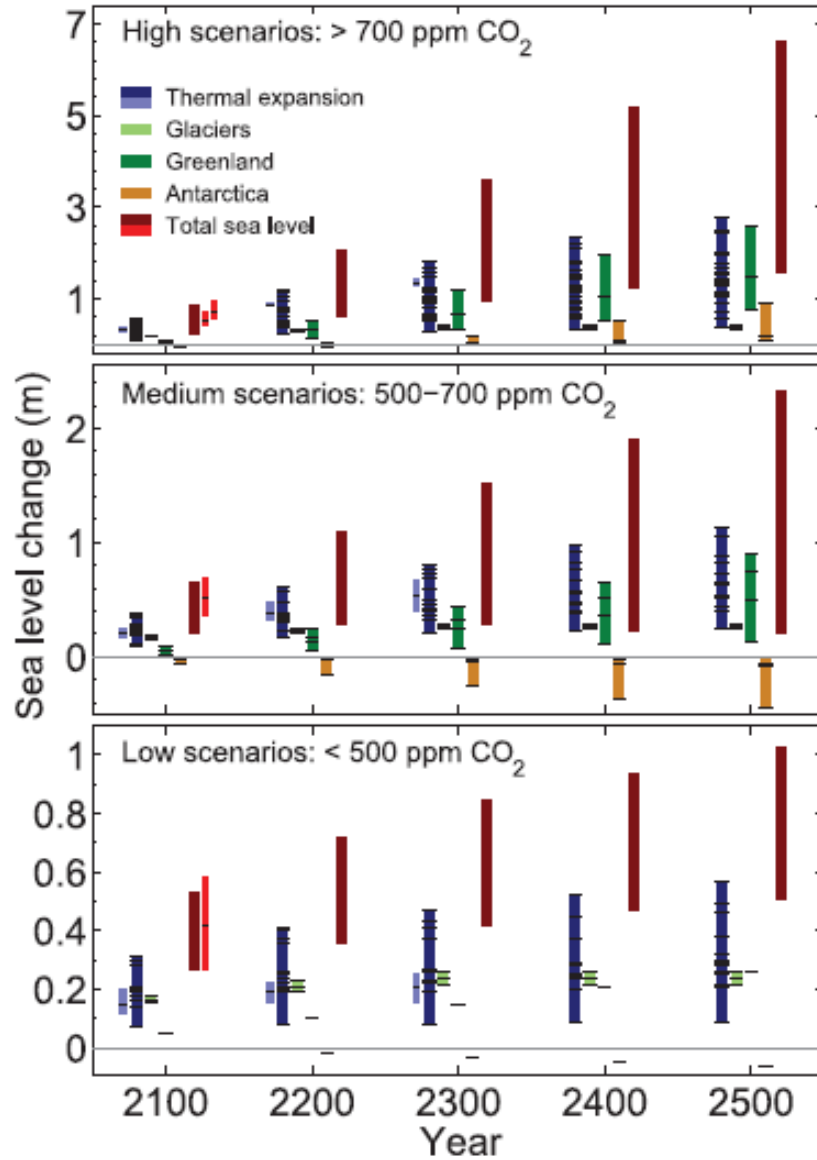
As shown, under all circumstances, as time goes on and as GHG concentrations increase, sea levels are projected to increase substantially over time, and the magnitude of sea level rise is much greater with each subsequent century and under each GHG concentration level, as indicated by the y-axis. At least two questions arise from these results:

1. What is the $/ton magnitude of sea level rise, as it pertains to the SCC estimates, in the pre-2100 timescale relative to the post-2100 timescale? and
2. In Dr. Smith's assessment of U.S. damages, how are the three IAMs' different damage functions for global mean seal level rise taken into account?

Sea level change is just one example in which there could be completely opposing views on the 95th percentile. In one way, an argument could be made that very significant damages extrapolated out to 2300 should not be incorporated into present day utility investment

decisions, particularly if the geographic scope is confined to the State of Minnesota, where obviously has no coastline.

On the other hand, if the time horizon is modeled out to 2300 and a global geographic scope is considered, one could argue the IAMs vastly underestimate the impacts of, for example, sea level rise, particularly considering the magnitudes indicated by Figure 13.13 above. Xcel argued that a 2300 time horizon is appropriate, but the 95th percentile scenario is not, in part because the IWG did not appropriately consider technological change and adaptation. However, this is a general statement lacking specifics, and Xcel did not explain how societies could adapt to or technology could improve to cushion the economic damages incurred by a sea level rise on the order of 3-4 meters (about 10-13 feet), or more if the IWG's extrapolations of CO_2 concentration levels are considered.

Overall, there are several issues to consider pertaining to adopting the 95th scenario, including:
- Is there a reasonable scientific basis to justify incorporating a 95th percentile scenario?
- Did the IAMs reasonably incorporate the variance of 95th percentile estimates across the three IAMs?
- Does the Commission have the record before it to adopt 95th percentile estimates if the Commission adopts a modified form of the FSCC?
- If the time horizon is truncated, by 100 or 200 years, is the justification for a 95th percentile equally supportable or less supportable?

Shrinking the Range (Xcel Proposal)

One of Xcel's reasons for opposing the 95th percentile is due to its view that "the CO_2 damage cost range adopted in this proceeding should not be so wide that the low and high ends point to diametrically opposite resource plans."[362] CEO addressed Xcel's claim as follows:

> The purpose of running different sensitivities is to understand how planning must change depending on assumptions. Indeed, it would seem to be very useful to understand that if the Commission wants to avoid catastrophic damages from climate change, a utility's future resource mix must look different than if we assume climate change will not be damaging, or if we assume that we can invest enough capital today to simply pay off those damages later rather than avoiding them.[363]

Several parties argued that a fundamental limitation of the IAMs is that they do not consider many health-related or non-market impacts of climate change. If correct, not only does this provide some support for adopting a value reflecting "higher-than-expected" damages, but it explains why diametrically opposite resource plans should not only be expected but are important. For instance, if one's primary concern is to avoid catastrophic outcomes, *and* the

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[362] Xcel Initial Brief, at 19.
[363] CEO Reply Exceptions, at 15.

IAMs do not represent a "true" cost of climate change, *and* these underestimates yield expansion plans roughly in line with plans that do not account for externalities, then what purpose would a new range actually serve?

It could be worth noting that Xcel used the following CO_2 values in the sensitivity analysis for its most recent, 2016 IRP:
- No CO_2 value (the Present Value Revenue Requirement metric);
- High/low range of the Commission's current CO_2 externality values;
- A cost of compliance range of $9-34 per ton of CO_2, (set in the Commission's CO_2 Values Docket), with a base case mid-point of $21.50/ton; and
- The federal social cost of carbon at the 3% discount rate.

These vastly different assumptions, along with various prices for fuel, capital costs, and so on, naturally produced resource plans that painted quite different pictures of Xcel's future generation landscape. While Xcel claims that diametrically opposite resource plans is a problem, one could say that, at the very least, it would not be something that is new to resource planning. Maybe creating diametrically opposite plans is not particularly useful or insightful in every instance, but CEO's point is that to neglect a possibly reasonable estimate simply because it produces a rather different plan is unreasonable. In a way, a diametrically opposite plan could be quite revealing.

Xcel raises a fair point, though, in that a primary objective of capacity expansion modeling is to extract the maximum value out of the sensitivity analysis. For example, a common measurement in resource planning is natural gas price volatility and ratepayers' exposure to this volatility, which is tested by incorporating a reasonable range of fuel price assumptions. At the risk of false equivalence, considering there is always a balance in limiting to some extent the number of sensitivities run while having a robust sensitivity analysis, it could be preferable to test smaller increments of natural gas prices in a range that tracks the market historically. Less might be learned by including a wider, low-probability range in larger increments. With this being said, natural gas price volatility and the right tail of the CO_2 externality distribution may not be an apples-to-apples comparison, in part because the Commission might be most concerned with catastrophic outcomes.

Thus, perhaps a more useful way of looking at the 95th percentile is, first, whether the estimates have a sound evidentiary basis and, second, whether the value of considering the 95th percentile estimates outweighs the benefits of discarding them. Of course, if the 95th percentile estimates are not supportable by the record evidence in the first place, then the application question is somewhat of a moot point. However, if the 95th percentile estimates are supportable, then the Commission may question why discarding supportable values is a reasonable thing to do.

The Commission could alternatively determine that Xcel's proposal did not necessarily ignore catastrophic outcomes. Perhaps there is a psychological hurdle in that the term "95th percentile" has become interchangeably used with the terms "catastrophic" or "high-damage."

But no single percentile has a discernable, distinguishable relationship to the physical world; in other words, who can really conceptualize a discernable difference between the planet under the 95th percentile versus the planet under the 94th percentile?

Xcel simply disagreed with the nonsymmetrical percentile approach IWG employed, and Xcel attempted to create symmetrical percentiles and manage uncertainty and risk by shrinking the range *at both ends*. Along the Roe & Baker distribution, the median (50th percentile) ECS was 3.0°C and the 90th percentile was 5.86°C. Xcel's upper bound percentile is roughly the 74th percentile of the IWG's 450,000 data points in any given emissions year.[364] With growing atmospheric CO_2 concentrations and higher radiative forcing through 2300, which is Xcel's time horizon, and with associated ECS values somewhere in-between 3.0°C-5.86°C for Xcel's upper bound percentile, actually imagining the planet by 2300 under these circumstances makes it is hard to believe that catastrophic outcomes will not occur to some degree.

Finally, there is a question about whether incorporating the 95th percentile means the Commission would not consider a "true range." And, in the Discount Rates section of this briefing paper, staff discussed parties' concerns about whether using too many discount rates might abandon the "true range" required by the IRP statute. While staff believes parties made fair points about the true range, staff does not believe this constrains the Commission's ability to consider a separate scenario for catastrophic outcomes. Those values are reflective of a deliberate and separate policy choice. In fact, the Commission could consider them as separate categories: it could adopt the high/low range and separately adopt the 95th percentile scenario.

It is common to run policy scenarios in resource planning, with examples being the Minnesota Greenhouse Gas Goal scenario and the 50%/75% replacement energy from renewables scenario. In addition, as noted in the Introduction, utilities generally model a mid-point of the CO_2 price as a base case, high/low values for externalities, and high/low values for CO_2 regulatory costs, so it is not as though resource plans rigidly adhere to the upper/lower bound analysis anyway. To determine in this docket that high-damage outcomes should be excluded might prevent, or at least make difficult to justify, the Commission from considering high-damage outcomes in future resource plans.

IAMs and "low-probability" outcomes

GRE/MP/OTP, MLIG, Peabody, and Xcel all agreed that IAM-derived values, regardless of the percentile, have questionable credibility. Peabody and MLIG suggested the IAMs are "close to useless,"[365] and the IAMs themselves are so flawed that they throw "into question the reasonableness of using any social cost of carbon value that the IAMs may produce."[366] GRE/MP/OTP suggested the FSCC could be improved by using different framing assumptions,

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[364] According to page 63 of Martin Direct, the actual percentage varies slightly by emission year, and were as follows: 2010: 74.82 percent; 2020: 75.14 percent; 2030: 74.58 percent; 2040: 74.00 percent; 2050: 73.46 percent.
[365] MLIG, Reply Brief, at 30.
[366] MLIG Exceptions, at 15.

but its witness, Dr. Smith, testified that even the alternative framing assumptions do not allow the IAMs to produce reliable SCC estimates.[367]

With this is mind, staff struggled to reconcile the view that IAMs produce useless estimates, yet, according to those same parties, there are more likely values than others. MLIG, for example, criticized Xcel's proposal for excluding the "most likely damage numbers,"[368] but if there is little or no foundation for any data point, it begs the question what "more likely" or "less likely" actually means. In this way, if the Commission desires a value that represents catastrophic outcomes, yet agrees to an extent that the probability distribution should be taken with a grain of salt, the Commission might actually conclude that the 95th percentile is the best available estimate to support this policy goal.

Further justification is that one IAM did not consider catastrophic climate change at all, and some argued that the IAMs failed to capture many adverse consequences of climate change. Nevertheless, IWG chose not to change with the IAMs as authored by their developers.

ALJ Conclusions Sections IX and X: Uncertainty, Adaptation, and Mitigation

As noted in the Introduction, uncertainty, adaptation, and mitigation are concepts naturally embedded in all other concepts discussed throughout the record; therefore, it is up to the Commission whether to address uncertainty, adaptation, and mitigation directly, or indirectly within other issues.

A. ALJ Report

ALJ Conclusions 41-46 make the following determinations regarding uncertainty, adaptation, and mitigation:

IX. Uncertainty

41. The Administrative Law Judge concludes that the preponderance of the evidence shows that the task of predicting the SCC is highly uncertain, because it is an exercise in predicting impacts of CO_2 emissions many years into the future. The process involves forecasting such uncertainties as changing temperatures, global GDP far into the future, and the possible occurrence of a "tipping point" event leading to irreversible, catastrophic damages.

42. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates the IWG partially accounts for uncertainty in the FSCC by using three IAMs, five different socioeconomic emissions projections and

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[367] Ex. 300, Smith Direct, at 17.
[368] MLIG Initial Brief, at 65-66.

probability distributions for the ECS values, as well as a number of parameters in the FUND and PAGE IAMs.

43. The Administrative Law Judge concludes that the Agencies and CEOs demonstrated by a preponderance of the evidence that, given the increased scientific certainty of the link between CO_2 emissions and climate change, uncertainties such as the potential danger of a "tipping point" catastrophe reasonably require an initially high SCC until more is known about such uncertainties.

X. Adaptation and Mitigation

44. The Administrative Law Judge concludes that the Agencies and CEOs demonstrated by a preponderance of the evidence that the IWG adequately accounted for adaptation and mitigation in the FSCC. No other party demonstrated by a preponderance of the evidence that it is reasonable to account for adaptation or mitigation to any extent beyond that included in the FSCC. There was no specific evidence presented regarding the efficacy of any specific mode of adaptation or mitigation.

45. The Administrative Law Judge concludes that approaching the damage calculation to achieve an "optimal mitigation level" such as Peabody recommended is not consistent with the cost-damage approach required by the Commission.

B. *Party Responses*

Uncertainty

There are many different views regarding how the Commission should address uncertainty. Dr. Polasky (CEO), for example, submits the following:

> Uncertainty in assessing the social cost of carbon cannot be avoided. It is not valid to say that because uncertainty is large that attempts to deal with it are excessively speculative. It is also not valid to conclude that the proper response to large uncertainty is to just ignore it ... The use of multiple models, each of which also incorporates elements of uncertainty and a range of discount factors, clearly shows there is uncertainty about the SCC ... While we cannot know damages from CO_2 emissions with absolute certainty, assuming that damages are zero simply because they are uncertain is surely the wrong answer and surely would be an illegitimate and unscientific approach.[369]

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[369] Polasky Rebuttal, at 6 and 7.

Dr. Gurney (MLIG) stated in his Surrebuttal, "Although I agree [with Dr. Polasky] that uncertainty in and of itself does not justify inaction, I emphasize that the uncertainty of any prediction approaches infinity as time increases indefinitely. This is why we don't use economic models that forecast the distant future."[370]

GRE/MP/OTP also suggested an indirect approach—that is, to address uncertainty through various parameters used to estimate the SCC, such as time horizon:

> Given our lack of knowledge of future economic conditions and the impact of temperature increases of more than three degrees on the economy, there is an inherent difficulty in predicting far-future impacts from carbon dioxide emissions and that difficulty and the resulting uncertainty is particularly great after 2100 and 2140.[371]

Dr. Smith did not comment on the ECS but raised the issue of whether high values of the range should be considered, and to what extent. According to Dr. Smith:

> IAMs may provide useful computational efficiency, but the IWG has used them in a way that is out of line with any realistic view of how actual climate change, if it turns out to be consistent with pessimistic views, will be addressed by society.[372]

Regarding climate policy action, the IWG stated in its 2015 *Response to Comments*:

> the IWG aimed to select scenarios that span most of the plausible range of outcomes for the socioeconomic variables. Given the level of uncertainty in these trajectories, the IWG felt that it was appropriate to consider a trajectory with significant global mitigation, assuming that this is a distinct possibility even in the absence of U.S. actions. Because there were five scenarios, and each received equal weighting, the stabilization scenario received 20% of the total probability weight.[373]

Adaptation and Mitigation

Some parties argued that the IWG failed to appropriately account for adaptation. According to Peabody Energy:

> Damages calculations reach these irrational levels because they are untethered to reality: the IAMs assume there will be essentially no mitigation of CO_2 emissions and that humans will not adapt to higher temperatures. In addition, the IAMs fail

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[370] Ex. 401, Gayer Surrebuttal, at 12.
[371] Reply Brief, at 13.
[372] Ex. Smith Report, at 30.
[373] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 19.

to properly account for a basic fact of biology: CO_2 is plant food that has beneficial impacts as well as potentially adverse ones.[374]

According to Dr. Smith:

> Any attempt to value damages associated with more than about 4°C that does not account for human reactions starting to take effect before that occurs is unrealistic.

Peabody also argued that the response the the FSCC itself was unaccounted for, contending, "the IWG incorrectly assumed that the implementation of the FSCC would have no impact on emissions rates in the vast majority of scenarios."[375]

Mr. Martin argued that the IWG ignored technological progress:

> the IAMs take the Stanford Energy Modeling Forum scenarios as exogenous, front-end inputs and do not account for the possibility that future societies, in response to the impacts of climate change, are likely to develop new technologies with lower CO_2 intensity than was initially assumed.[376]

According to IWG's 2010 *Technical Support Document*, however, IWG stated, "For purposes of estimating the SCC, carbon dioxide emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress."[377] Figure A7 from the IWG's TSD shows how it accounted for CO_2 intensity:

Figure A7. Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090-2100 is maintained through 2300.)
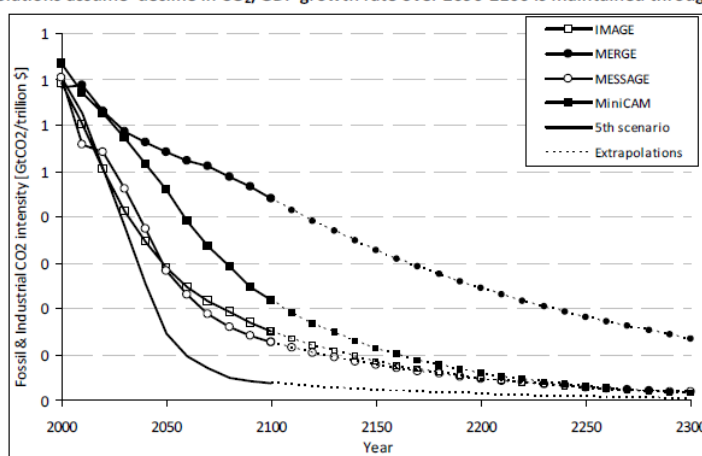
Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

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[374] Peabody Initial Brief, at 63.
[375] Peabody Initial Brief, at 64.
[376] Ex. 600, Martin Direct, at 34.
[377] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 6.

The IWG also addressed technological improved directly:

> Maintaining the decline in the 2090-2100 carbon intensity growth rate (i.e., CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario.[378]

Mr. Martin also summarized in Figure 5 of his Direct the differences among the five Stanford Energy Modeling Forum scenarios (EMF-22) and, in the third graph of Figure 5,[379] showed the variation in emissions results through 2100 among the five scenarios:
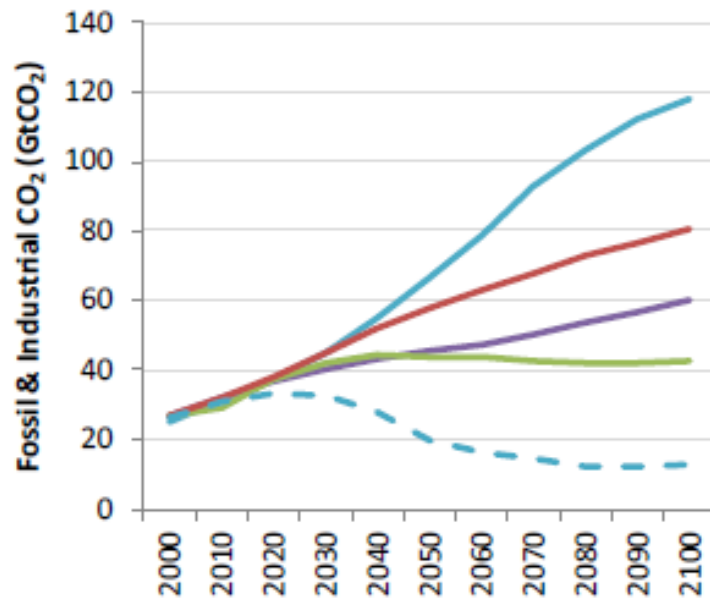

The IWG's extrapolations for CO_2 intensity through 2300, however, shown in Figure A4 of IWG's 2010 *Technical Support Document*, show that CO_2 emissions level off then decline under all five scenarios:

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[378] Ex. 100, Schedule 2 of Polasky Direct, IWG 2010 Technical Support Document, at 44.
[379] Ex. 600, Martin Direct, at 33.

Figure A4. Global Fossil and Industrial CO₂ Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO₂ intensity (CO₂/GDP) over 2090-2100 is maintained through 2300.)
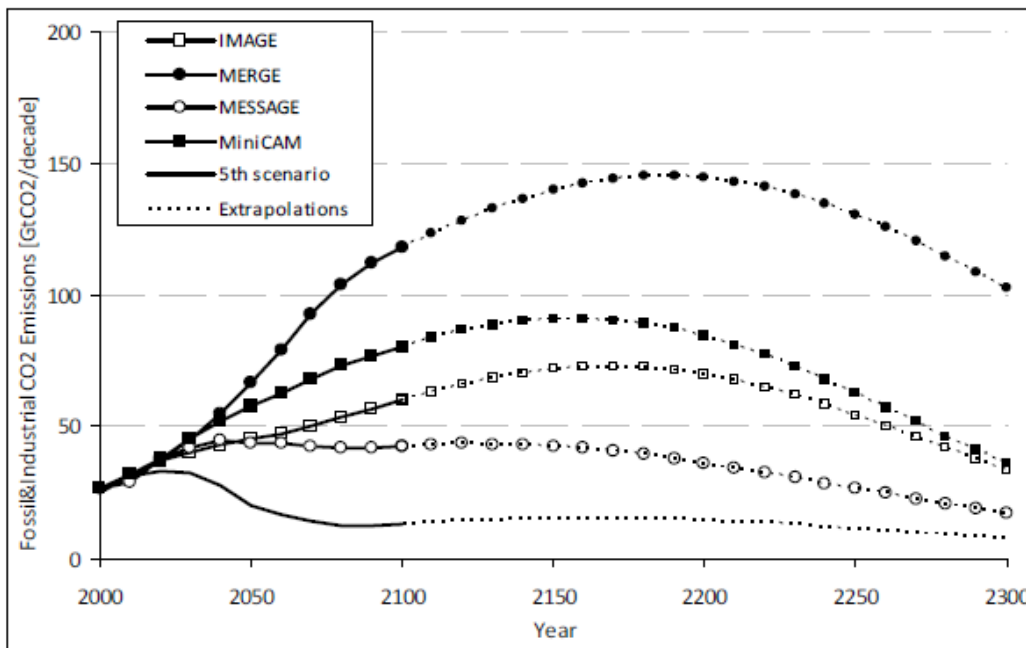
Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

C. Staff Discussion

Perspectives on how to address uncertainty were obviously quite different depending on the party and whether the physical sciences or economic aspects of this proceeding were in question. For example, whether the IPCC's range for ECS values is reasonable is a separate (although not mutually exclusive) question than whether the IWG employed a reasonable ECS probability distribution through the 2300 time horizon.

Some parties made arguments about uncertainty more broadly, arguing that uncertainty may be so great that any SCC estimate is essentially meaningless. Others argued that, while uncertainty is indeed significant, the appropriate response is not to conclude there is no social impact at all—in other words, uncertainty is not an adequate excuse for inaction.

In any case, it appears there is universal agreement among the parties that uncertainty is critical for projecting both future climate impacts and the costs (or benefits) of those impacts. The relevance for the Commission's decision is, among other things, (1) whether and to what extent IAMs are an acceptable basis for accounting for uncertainty, adaptation, and mitigation, (2) if IAMs are capable, whether the IWG employed the best available methodology to account for uncertainty, adaptation, and mitigation, and (3) if IAMs are not capable, what alternative tool is superior.

Uncertainty

To inform the decision-making process, it may first be helpful to discuss what concepts like uncertainty and adaptation mean in this context. Regarding uncertainty, on the physical sciences side, uncertainty could refer to the likelihood of increases to global mean surface temperature, which IPCC expresses probabilistically based on observational data, paleoclimate data, multi-model analyses, and so on.

On the economics side, damages are expressed in monetary terms, in this case as a change to global GDP. One area of uncertainty within this monetary expression is the uncertainty in GDP forecasts generally and the impact of CO_2 emissions on global GDP specifically. As Dr. Smith noted, "the IAM's damage functions are based on some limited empirical evidence and reasoning about the current shares of GDP associated with certain sectors (e.g. agriculture, energy, etc.) and how much those particular sectors (given today's technologies) would be impacted by a temperature increase … As centuries pass, not only will GDP grow, but the contributions of different resources and sectors to that GDP will change."[380]

There is also localized uncertainty regarding the SCC's ultimate effect to Minnesota ratepayers and the State's economy. MLIG emphasized that, since energy costs range from 25- 30% of its members' overall cost of production it is imperative to mitigate the uncertainty which could unduly affect its operating costs. CBEC supported the FSCC to send appropriate signals for businesses to internalize the costs of CO_2, and therefore facilitate investment in technologies that will maximize social and economic value in Minnesota.

Adaptation

Regarding adaptation, one could view this as human beings' ability to adapt, whether areas of the economy will be able to adapt, and/or whether and to what extent higher CO_2 concentrations might result in changes to the climate system that are out of human control. As it relates to the IAMs, some examples from the ALJ Report include:

- Finding of Fact 90: …"DICE implicitly allows for some adaptation to global warming. The agricultural impact studies the model relies upon allow for farmers to adjust land uses. The health impact studies assume improvements in healthcare over time…"

- Finding of Fact 94: … "PAGE explicitly attempts to model adaptation to global warming. Economic impacts occur when temperatures increase by more than 2°C in developed countries, and by any amount of temperature increase in undeveloped countries. Non-economic impacts occur when temperatures increase by any amount. Adaptation is assumed to reduce damages significantly – 25% of non-economic impacts, and higher percentages for economic impacts."

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[380] Ex. 302, Smith Expert Report, at 74.

- Finding of Fact 98: "FUND does not incorporate the possibility of catastrophic events but it does implicitly and explicitly allow for adaptation. Both agricultural and forestry impacts are reduced by adaptation explicitly…"

- Finding of Fact 148: "PAGE also added an explicit treatment of sea level rise damages, updated adaptation assumptions, and a revised treatment of potential abrupt damages. The more recent version of PAGE is less optimistic about the extent to which adaptation can reduce damages…"

With respect to arguments that the IWG failed to properly account for how humans will react to climate change, such arguments could be interpreted as more philosophical in nature, since it predicts human beings' and governments' willingness to tolerate warming and respond to certain levels of warming accordingly. For instance, Dr. Smith argued that IWG made "the unrealistic assumption that humanity will passively accept significant, sustained temperature increases over a long time period, and do nothing to respond with future technologies."[381] First, emissions decline over time, and so does CO_2 intensity. Second, passive acceptance implies that warming is entirely within the control of governmental action, and the timing of CO_2 abatement is an important factor to consider. According to IPCC's Fourth Assessment, "Unmitigated climate change would, in the long term, be *likely* to exceed the capacity of natural, managed and human systems to adapt."[382] IPCC continued:

> Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower [stabilization] levels. Delayed emissions reductions significantly constrain the opportunities to achieve lower [stabilization] levels and increase the risk of more severe climate change impacts.[383]

It is also not exactly clear how or when technological progress will actually resolve the threats posed. Dr. Smith argued that IWG failed to include "geoengineering to either remove carbon from the atmosphere, or to create atmospheric changes that will have a countervailing cooling effect." [384] In addition, "countries could heavily subsidize carbon sequestration activities such as planting trees and protecting existing forests," or "a few countries could embark on geoengineering to reduce the radiative forcing of the sun's energy."[385] It is certainly possibly that these technologies could make advancements, but whether the Commission believes there is sufficient record evidence to support these adjustments is another matter.

Mitigation

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[381] Ex. 300, Smith Direct, at 35.
[382] Ex. 267, IPCC Fourth Assessment, at 65.
[383] Ex. 237, IPCC Fourth Assessment, Climate Change Summary (2007), at 73.
[384] Ex. 300, Smith Direct, at 73.
[385] Ex. 300, Smith Direct, at 117.

Much of GRE/MP/OTP's criticism of the IWG's SCC estimates is that GRE/MP/OTP claimed IWG underestimated the policy response to increasing temperatures. According to Dr. Smith:

> The three IAMs find the global mean temperature would increase by 2.9 to 5 degrees from pre-industrial levels except for the 5th scenario, which is an odd scenario. It is possible that governments would not respond to such increases in temperatures in any meaningful way. But given the concern over a 1° to 2 °C increase in temperature, it seems likely that countries would begin to take significant action if the average global mean temperature were to start approaching an increase anywhere near 3 °C.

First, IPCC's *likely* range, represented a 66% or greater probability, contemplated a temperature increase of up to 4.5°C in that probability. Second, in making this claim, GRE/MP/OTP appear to have disregarded both historical observations of temperature increases and expected projections of warming that will occur as a result of CO_2 already emitted—i.e., future warming that is outside the control of governmental action.

For example, IPCC stated in its Fifth Assessment that the "globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to 2012.[386] Further, IPCC reported that "CO_2-induced warming is projected to remain approximately constant for many centuries following a complete cessation of emissions."[387] In other words, some amount of additional warming is expected to occur even if emissions are ceased immediately. Dr. Dessler discussed this in his distinctions of equilibrium versus transient states. IPCC determined that "if concentration of greenhouse gases were held constant at present day level, the Earth surface would still continue to warm by about 0.6°C over the 21st century relative to the year 2000."[388]

Regarding the 2°C limit to which GRE/MP/OTP refers, IPCC considered this threshold. According to Figure 6.40 of IPCC's Fifth Assessment, shown below, IPCC assumed an immediate emissions cessation in 2050. In this scenarios, a 1°C- 2°C increase could only likely occur following 1) an instantaneous cessation of CO_2 emissions in year 2050 (red line), 2) a one-time removal of the excess of atmospheric CO_2 over pre-industrial levels (blue line), and 3) removal of this excess of atmospheric CO_2 followed by continued removal of all the CO_2 that degasses from the ocean (green line).[389]

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[386] Ex. 405, IPCC Fifth Assessment at 5.
[387] Ex. 405, IPCC Fifth Assessment, at 103.
[388] Ex. 405, IPCC Fifth Assessment, at 1106.
[389] Ex. 405, IPCC Fifth Assessment, at 548.
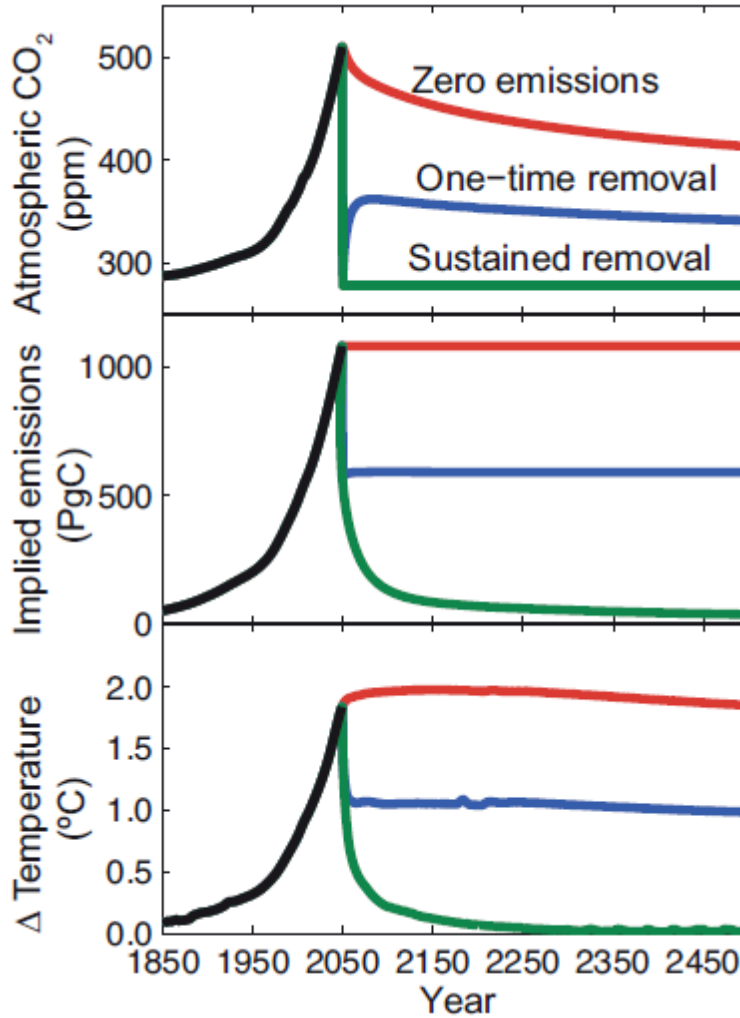
Ultimately, the majority of IWG's scenarios expect CO$_2$ emissions to continue to rise, albeit at a lower rate over time. The IWG did include a stabilization scenario, which was given an equal probability to other scenarios considered. The reasonableness of the extrapolations is a valid concern, but the claim that IWG overstated temperature in the next century is not backed by the IPCC Assessment Reports.

ALJ Conclusions Section XIII: Xcel Proposal

It is important to highlight the fact that, despite its many criticisms of the IWG's FSCC, Xcel had no objection to several components of the IWG methodology, including:[390]
- the choice of DICE, FUND and PAGE as the three IAMs to use to estimate damages;
- the standardization of input parameters to facilitate a model inter-comparison exercise;

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[390] Xcel Reply Brief, at 3.

- the conversion of DICE into a simulation model; the use of standardized population, economic growth and emissions inputs from the Stanford Energy Modeling Forum-22 (EMF-22) exercise;
- the choice to treat equilibrium climate sensitivity as an uncertain parameter by making random draws from a probability distribution;
- the use of a Monte Carlo approach in which each model is run 10,000 times per emission year, discount rate and EMF-22 scenario;
- the standardization of discount rates across IAMs; and
- the choice of 2.5%, 3% and 5% discount rates.

According to Xcel, its proposal "is built from the IAM outputs as run by the IWG," but Xcel belied adjustments were necessarily, particularly because of Xcel's position that the SCC was developed for a "significantly different purpose of state-level Commission decisions."[391]

Thus, Xcel began with the Federal SCC modeling output data as a starting point, then defined an initial range from the 25th percentile at 5% discount rate to the 75th percentile at 2.5% discount rate, taken of the distribution of 450,000 SCC estimates for a given emission year.

The result was an initial range from $2.48 at the 5% discount rate to $67.08 at the 2.5% discount rate ($2014 per short ton). Xcel then weighted the SCC values for each of the three discount rates at the low and high ends of the initial range. This resulted in a $12.13 to $41.40 per ton range, which corresponds with the 36th and 74th percentiles of the IAMs' distribution of 450,000 SCC estimates for emission year 2020.[392]

The figure below, included as Figure 9 of Mr. Martin's Direct testimony and ALJ Finding of Fact 401, shows the probability distribution curve for the FSCC, with the red dotted lines, labeled "Proposed Bounds," presenting Xcel's proposed range of $12.33 to $41.80 per short ton.

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[391] Xcel Reply Brief, at 3-4.
[392] Xcel Initial Brief, at 10.

2020 Combined SCC Distribution ($2014/short ton)
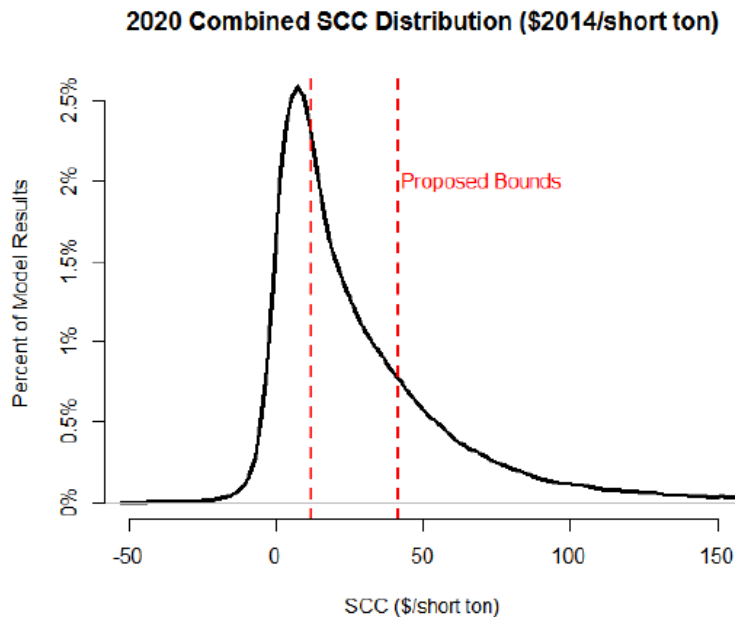
The x-axis shows the social cost of carbon, and the y-axis shows the percent of modeling results. Values on each side of the red dotted lines represents SCC estimates excluded from consideration. Due to the non-normal shape of the SCC probability distribution, lower-value SCC predictions to the left have a greater probability of occurring than the higher damage estimates included on the right side.[393]

Xcel's general approach was to develop a CO_2 cost range based several criteria that could, among other things, address uncertainty, balance risk, minimize subjectivity, and yield a practicable range. In addition, Xcel's proposal would be more transparent and it is replicable and updatable. Xcel emphasized repeatedly that it accounted for values at both ends of range without giving preference to either bound. In fact, Xcel's proposal "retained significantly more than half of all values for the combined discount rate distribution of 450,000 values per emission year."[394]

Throughout this briefing paper staff has frequently referenced the tails of the SCC distribution, specifically the long right tail representing higher-than-expected economic impacts from climate change. Xcel urged the Commission to avoid adopting low-probability estimates at the low end of the SCC results, as well as low-probability estimates at the high end of the SCC results. Thus, one reason for the percentiles approach was to reflect appropriate risk tolerance and yield a practicable range.

A. ALJ Report

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[393] Ex. 600, Martin Direct, at 64.
[394] Xcel Reply Brief, at 13.

Some relevant ALJ Conclusions regarding Xcel's proposal include Conclusions 49-51 on pages 122 and 123 of the ALJ Report, and are as follows:

XIII.   Xcel Proposal

49.   The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that its proposal to calculate the upper and lower SCC values at the 25th and 75th percentiles of the IWG data distribution was reasonable. The Administrative Law Judge concludes that, by choosing the 25th and 75th percentiles, Xcel centered its SCC range around the 50th percentile, which is the median of the distribution. By choosing to center its range around the median value, Xcel unreasonably excluded information about the magnitude, as well as the likelihood of significant damages, as reflected in the higher end tails of the distribution. These high damage outcomes are of great concern and it would be unreasonable to ignore them.

50.   The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that it had a reasonable basis on which to average the three FSCC discount rate values at the upper and lower ends of its range of values to establish its final SCC range of cost values. Xcel presented no evidence of theoretical, practical or scholarly support for its idea that averaging the values of the three discount rates for each end of its distribution range is an appropriate way in which to account for the controversy among the parties regarding a proper discount rate in this proceeding.

51. The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that the FSCC does not offer a range of values. The FSCC chooses one cost based on an average of the values on the distribution scale, then creates a range of values from the single cost by offering that value at three different discount rates, and adding the 95th percentile as a fourth high-end value.

B. *Xcel Exceptions*

Responding to ALJ Conclusions 49-51 (on the Xcel proposal), Xcel made the following objections in its Exceptions:

- Xcel Exception to ALJ Conclusion 49: ALJ Conclusion 49 above states that Xcel "unreasonably excluded information about the magnitude" of damages, and it would be "unreasonable to ignore" high damage estimate. Xcel responded, "It is incorrect to state that selecting the 25th percentile and 75th percentile as bookends of our initial range excluded information about the magnitude and likelihood of significant damages

at the higher end of the distribution, or ignored the high damage outcomes."[395] Xcel emphasized that the SCC estimates have a non-normal distribution, and the highest-damage but lowest-probability values pulls the mean up. Xcel chose to use a percentile-based approach that still included high damages but focused on the most likely values on the probability distribution.

- Xcel Exception to ALJ Conclusion 50: The ALJ concluded that Xcel failed to demonstrate that averaging the discount rates is superior to the IWG's methodology to discount damages at 2.5%, and 3%, and 5%. According to Xcel, "equally weighting the SCC values at each discount rate is an appropriate way to remain agnostic on a question that is fundamentally normative, subjective, and unresolved among economists, ethicists and others at this time."[396] Adopting more values by using several discount rates is, in Xcel's view, inconsistent with the traditional low/high range approach to environmental externalities.

- Xcel Exception to ALJ Conclusion 51: Xcel has maintained throughout the proceeding that the FSCC values are single point estimates and do not constitute a range, and the ALJ did not agree with Xcel in this regard. According to Xcel, "the ALJ recommends adopting three of the FSCC values, but does not discuss how these values could be applied as a 'range.'"[397]

Xcel includes a redline version of all of its proposed changes to the ALJ Report as Attachment A of its Exceptions, which are also included in the Decision Options section.

C. Party Replies to Xcel Exceptions

CEO's primary concern with Xcel's proposal, and the Company's Exceptions to the ALJ Report is that "Xcel continues to ignore why it is important to include the high-damage low-probability estimates in the CO_2 damage value and how the SCC incorporates these estimates while Xcel's range does not."[398] Because of the long right tail of the SCC distribution, treating the high-damage side of the distribution equally to the low-damage side has the effect of ignoring the potential for catastrophic damages and thereby unreasonably lowering the SCC value. According to CEO:

> The distribution of potential climate-change outcomes is not a normal distribution. As Xcel describes, the distribution is "a skewed, non-normal distribution with a long right tail of high cost damage estimates." The long right tail is a graphic depiction of the fact that damages from climate change—as predicted by the models—could be extremely high. The left side of the distribution

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[395] Xcel Exceptions, at 16.
[396] Xcel Exceptions, at 17.
[397] Xcel Exceptions, at 19.
[398] CEO Reply Exceptions, at 2-3.

does not have a "long tail." This is because we know that there will be some damages from climate change. The question is how to account for the long tail. Xcel chopped off 25 percent of the high damage values, which were spread out over the long tail, and 25 percent of the low damage values, which were clustered at the left side of the distribution. The Interagency Working Group (IWG), in contrast, took the average of all of the values within the distribution.[399]

The Agencies agreed with the ALJ's conclusion that it was unreasonable to use the median (50th percentile) instead of the average (mean) values. Because the distribution is a skewed, non-normal distribution, basing the range on the median unreasonably excludes information about the magnitude and likelihood of significant damages.

MLIG argued that, despite Xcel's aim to minimize subjective judgements, MLIG claimed Xcel's proposal makes its own subjective assumption that the discount rates of 2.5%, 3%, and 5% should be given equal probability. According to MLIG, agreeing with Dr. Smith's testimony, different discount rates should be reported separately.

In addition, MLIG argued that the Commission should take into account the frequency of values along the probability distribution. For example, among the 450,000 IWG values considered by Xcel for inclusion, "the most frequent damage number in the entire set of 450,000 values was approximately \$5 or \$6" (\$2014/short ton).[400]

D. Staff Discussion

Even though the ALJ devotes a section of her Conclusions solely to the Xcel proposal, the Staff Discussion for this section will include the GRE/MP/OTP alternative as well. The utilities are ultimately the entities who will need to incorporate the SCC range into their proposed resource plans, and all four utilities who participated in this proceeding have undoubtedly considered the mechanics and feasibility of various approaches. Thus, staff believes it makes sense to compare the utilities' proposals side-by-side.

GRE/MP/OTP's and Xcel's Range of Estimates

Xcel's proposed range of SCC estimates is \$12.13-\$41.40 per ***short*** ton for emissions in 2020 (in \$2014).

The GRE/MP/OTP alternative is \$7.87 to \$18.85 per ***metric*** ton emitted in 2020 (in \$2007).[401] This assumes a 2100 time horizon, average tons, 3% and 5% discount rates, and a global scope of emissions.

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[399] CEO Reply Exceptions, at 3.
[400] MLIG Reply Exceptions, at 26-27.
[401] As noted in the Introduction of this briefing paper, the current Minnesota environmental cost values are stated in \$/short ton, while the IWG's SCC values (and all other estimates that are derived from runs of the IAMs that the

Table 4A of Exhibit 307 shows Dr. Smith's SCC estimates under different framing assumptions. (Table 4A is also included as Attachment A of this briefing paper.) Below, staff has grouped together the GRE/MP/OTP range of $7.87 to $18.85, which it suggests in the alternative of its recommendation to keep the current CO_2 externality values. Staff included an additional two rows showing the tons in terms of the last ton as the marginal ton.

Scenario	# changes from base	Discount Rate	Time Horizon	Geographic Scope	Which Tonne	2020 SCC Value ($2007/net tonne)	2020 SCC Value (2014$/net tonne)
38.	3	5%	2100	Global	Average	$7.87	$8.75
35.	2	3%	2100	Global	Average	$18.85	$20.97
6.	2	5%	2100	Global	Last	$9.03	$10.05
3.	1	3%	2100	Global	Last	$22.14	$24.63

Of note, Scenarios 38 and 35 represent the lower and upper bound, respectively, of GRE/MP/OTP's recommended alternative, and Scenarios 6 and 3 represent the lower and upper bound, respectively, of the GRE/MP/OTP alternative with an adjustment made to account for the Last ton approach. As discussed in the Marginal Ton section of this briefing paper, ALJ Conclusion 29 determined that "counting the last ton of CO_2 emitted as the marginal ton is reasonable and the best approach to calculate damages."[402]

By comparison, Xcel presented its values in $2014. To do the same with GRE/MP/OTP, the Commission should refer to the right-most column of the table. This range, when expressed in average tons, is $8.75-$20.97 per metric ton. With the last ton as the marginal unit, the range in $2014 would be $10.05-$24.63 per metric ton.

What is noteworthy about the two ranges is that, while Xcel's range is higher, both are fairly comparable to CO_2 values used in resource planning currently. As noted in the Introduction, a common practice utilities use when modeling CO_2 is to incorporate the externality values until the values set in the CO_2 Values Docket go into effect. The most recent Commission order in the CO_2 Values Docket set the range at $9-$34 per ton, which has remained constant over the past several iterations, although the first year for applying the values was delayed in the most recent Commission order.[403]

IWG used) are in $/metric ton, i.e., "$/tonne." Short tons can be converted into metric tons by multiplying the number of short tons by 0.907184.

[402] ALJ Report, Conclusion 29.

[403] Docket No. E-999/CI-07-1199, Order Establishing 2016 and 2017 Estimate of Future Carbon Dioxide Regulation Costs, August 5, 2016.

In addition, another common practice for utilities (and the Department) is to use the mid-point of the range, $21.50 per ton, into the base case. In light of these facts, to the extent the Commission is concerned about shocks to the sensitivity analysis, it should be noted that neither Xcel's nor GRE/MP/OTP's ranges deviate extremely far from the status quo, if the status quo means regulatory costs. Moreover, and to repeat previous statements about IRP evaluation, resource plans also contemplate a No Externalities case, and the Commission's decision considers many other factors than environmental costs.

Distinguishing Characteristics, Advantages and Disadvantages

The notable differences between the Xcel Proposal and GRE/MP/OTP Alternative include:

Issue	Xcel	GRE/MP/OTP
Time Horizon	2300	2100
Which ton?	Last	Average
Discount Rate	Average of 2.5, 3, 5%	3%, 5%
Geographic Scope	Global	Global
Percentiles	Final range between 36-74%	Full distribution

If the Commission prefers elements of the GRE/MP/OTP alternative but agrees with the ALJ to use the last ton as the marginal ton, there are estimates provided (Scenarios 6 and 3 from Dr. Smith Table 4A) to easily make this change. Notably, on time horizon, Dr. Smith did not run a 2200 scenario. Below is a table that includes (1) Xcel's range and (2) Dr. Smith's results using a 2300 time horizon, **last ton**, 3% and 5% discount rates, and global geographic scope.

	Low / Scenario 4	High / Scenario 0	Ton
Xcel	$12.13	$41.40	Short ton
GRE/MP/MP	$13.39	$46.88	Metric ton

Next, staff will discuss some advantages and disadvantages of the two proposals.

GRE/MP/OTP

One advantage GRE/MP/OTP claims its proposal has relative to other proposed values is its consistency with the Commission's prior order setting what are the current externality values. According to GRE/MP/OTP:

> [I]f if the Commission is inclined to rely on the FSCC to update the CO_2 ECV, the preponderance of the evidence clearly establishes that a modified version of the FSCC, consistent with the economic framing assumptions that have previously been used by the Commission, is a better alternative. More specifically, the evidence supports a recommendation that the Commission adopt a modified

version of the FSCC to determine the CO_2 ECV incorporating the following economic framing assumptions:

1) A time horizon extending to the year 2100;
2) Use of an average cost approach to calculate marginal ton;
3) 3.0 percent and 5.0 percent discount rates; and
4) Global damages.

One of the most compelling facts established in this proceeding is that the primary difference between the measure used by the Commission to establish the current CO_2 values and the measure used by the IWG is the economic framing assumptions, rather than any significant advancement in scientific understanding.[404]

Perhaps the feature of GRE/MP/OTP's proposal that was most scrutinized was which tonne. Critiques to this assumption were provided in the Marginal Ton section, and staff does not repeat those here.

Xcel

One advantage Xcel claims its proposal has over other proposals is its updateability. According to Mr. Martin's Rebuttal:

> We were able to obtain the new dataset from the IWG in a matter of days, and updating our summary statistics and recommended range was a simple matter of re-running the same code. This should not be taken as a Company recommendation that the Commission adopt any IWG update regardless of changes in the methodology or values; it merely illustrates the relative ease of doing so in this case, and in cases where the IWG makes routine updates.[405]

According to Mr. Martin's Rebuttal, "Dr. Smith's approach involves acquiring, re-coding and re-running the IAMs. It is transparent, since she describes clearly how she did this, but would require significant effort to replicate and update compared to the Company's approach, which requires no new modeling."[406]

However, Dr. Smith responded to Mr. Martin in her Surrebuttal testimony, stating:

> Mr. Martin claims that his approach is easy to update and my approach is not. At the same time, although he agrees it would be nice to consider alternative framing assumptions such as I have recommended, he acknowledges that his approach is

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[404] GRE/MP/OTP Exceptions, at 4.
[405] Ex. 601, Martin Rebuttal, at 6.
[406] Ex. 601, Martin Rebuttal, at 29.

too inflexible to apply such alternative assumptions. Mr. Martin is greatly exaggerating the difficulty of performing an update using my approach.

If the IWG were to release an update using three updated models, I believe that any organization with access to computers that can run Excel and its @Risk add-on, Matlab, and C#, that employs research analysts who are comfortable running computer programs and managing data files of outputs, and that has copies of my expert report and work papers, would be able to perform a complete update using the sets of alternative framing assumptions that I have recommended. [407]

Staff defers to those who did the modeling to comment on the updateability of each proposal, but it does seem that GRE/MP/OTP's whole objective going into this proceeding was so the Commission could have transparent, updateable information. Moreover, Dr. Smith was very detailed in her testimony and Expert Report, so how she arrived at her result is far from a black-box. In any case, what may seem as a confusion at this point should not be difficult to resolve during Oral Argument. Moreover, the Commission has the option to select from any of Dr. Smith's 48 scenarios she developed and presented in Table 4A of Exhibit 307, which would not require re-coding and re-running the IAMs.

Another of the advantages Xcel claims its proposal has is that it uses IWG's modeling as a reasonable and best available starting point, but aligns it to be more applicable with traditional Minnesota IRP proceedings. And, considering there are modeling uncertainties that may result in underestimates and overestimates, Xcel believes its proposal accounts for both possibilities.

Perhaps the feature of Xcel's proposal most scrutinized was its selection of the truncated range. Dr. Polasky responded to the percentiles as such:

Martin has chosen two arbitrary endpoints (25th and 75th percentiles) and then averaged across discount rates. I think both of these choices are inappropriate. … The mean provides us with a single measure of expected value of damages from this distribution. It is true that no single measure will capture all of the information in the probability distribution. It is also true that no two numbers, such as a high and a low value for range can do so either. In general, having more measures (such as a measure of mean, variance, and skewness) will give more information about the probability distribution.[408]

According to Mr. Martin, the mean of the probability distribution "is greatly influenced by outliers," and as such, the "median is a more robust measure of central tendency for a non-normal probability distribution, because it represents the midpoint – with 50 percent of values below and 50 percent of values above – and is not influenced by outliers."[409]

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[407] Ex. 304, Smith Surrebuttal, at 35-36.
[408] Ex. 101, Polasky Rebuttal, at 40.
[409] Ex. 600, Martin Direct, at 27-28.

In response, Dr. Hanemann noted:

> In my view, "outlier" is the wrong term … What we have here [is] a continuum of observations with increasingly large values. In this case, it is not that there are outlier values of the SCC. It is that the distribution of SCC values is skewed with a long right tail. … [T]he much larger damage estimates that Mr. Martin is characterizing as outliers as part of the SCC damage calculation are within the accepted distribution of a population of SCC estimates exhibiting positive skewness.[410]

ALJ Conclusions Section VII: Leakage

A. ALJ Report

Below, staff provides a condensed version of the ALJ Report addressing the concept of leakage, first providing her Findings of Fact and then her Conclusions and Recommendation.

> 287. The Utilities and MLIG explained that leakage occurs when reduced CO_2 emissions in one jurisdiction are replaced by increased CO_2 emissions in another jurisdiction. "Leakage is the extent to which policy-driven decreases in carbon emissions are offset by resulting increases in other jurisdictions."

> 288. The Utilities and MLIG pointed out that Minnesota's electrical grid is interconnected to electricity systems in other states that may not impose equivalent costs on carbon emissions. As a result, the Utilities and MLIG reasoned, the use of an SCC in resource planning in Minnesota will result in fewer CO_2 emissions in Minnesota but additional CO_2 emissions elsewhere to meet electrical demand.

> 290. The Utilities and MLIG supported the consideration of leakage when using CO_2 environmental cost values. However, they would not take leakage directly into account in calculating the SCC. Instead, they would apply SCC values to a net total ton of CO_2 emissions, after applying a calculated leakage amount in each particular resource planning situation.

> 295. The Utilities and MLIG urged the Administrative Law Judge to recommend that the Commission adopt an estimate of the SCC net of leakage in this proceeding and that the Commission conduct a leakage study "as part of any application of the CO_2 environmental cost values that result from this proceeding."

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[410] Ex. 801, Hanemann Rebuttal, at 67-68.

301. The Agencies asserted that leakage should not be considered when applying a SCC value. The Agencies reasoned that, because the Commission regulates utilities that operate in Minnesota and does not have jurisdiction in other states or countries, the Commission has no responsibility for the aggregated level of emissions resulting from other jurisdictions' action or inaction. The Agencies found no reason for the Commission to modify its assessment of an environmental cost based on what may or may not happen in other jurisdictions.

302. The CEOs explained that leakage does not affect the CO_2 values adopted by the Commission and did not support the consideration of leakage when calculating the FSCC values.

303. The CEOs explained that leakage is a policy issue that can be addressed through other Commission actions and agreed with the IWG's response to leakage questions. The IWG is concerned with leakage, but not as leakage affects the calculation of damages. The FSCC is an estimate of the marginal benefit of a net one- ton reduction in CO_2 emissions. The IWG explained that "[t]he FSCC estimates are multiplied by estimates of net GHG emissions changes to calculate the value of benefits associated with a policy action in a given year." The CEOs concluded that the FSCC assigns a damage cost to emissions. The CEOs reasoned that the FSCC number assigned to the damages from a ton of carbon is not a function of leakage.

304. Xcel also noted that the IWG recommends that any estimate of leakage be applied to emission reductions and not to the SCC itself. Xcel agreed with MLIG and the Utilities that the Commission could consider leakage in another proceeding because leakage is outside the scope of this proceeding, which is intended to determine damage cost values.

305. Xcel disagreed with the Agencies' argument that the Commission should not account for leakage when applying its CO_2 cost range because the Commission lacks jurisdiction over utilities outside of Minnesota. Additionally, Xcel noted, the benefit of avoided climate damages may be overestimated if it ignores the possibility of leakage. In order to derive the value of climate damages avoided by Commission action, Xcel supported the Commission making a case by-case estimate of leakage in a separate proceeding to derive an adjustment factor that would be multiplied by emission reductions in Minnesota, and then by Xcel's proposed CO_2 environmental cost range.

The ALJ concluded:

40. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that calculating leakage of increased CO_2 emissions is not properly a part of this proceeding.

However, the ALJ went on to recommend to the Commission:

The Administrative Law Judge respectfully recommends 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, as suggested by Xcel in this proceeding.

B. Party Positions and Staff Discussion

Staff does not agree with the ALJ that the Commission should address leakage in a generic docket, nor does staff agree with parties who contend that leakage should be an adjustment that must be accounted for (or netted out) within the environmental cost values set by the Commission.

In GRE/MP/OTP's Exceptions to the ALJ Report, it states:

There is no dispute that leakage occurs and reduces the efficacy of CO_2 reductions in emissions from Minnesota.[411]

GRE/MP/OTP make a very strong claim but offers no quantified evidence to substantiate it (that staff could locate), at least to a degree to claim leakage is indisputable. GRE/MP/OTP's own witness stated that leakage is "very likely to occur,"[412] but she did not say it indisputably occurs or, importantly, offer any evidence specific to Minnesota generation decisions to substantiate this likelihood. In other words, the degree to which externality values, by themselves, reduce the efficacy CO_2 emissions in Minnesota is an unsupported general statement as it pertains to Minnesota resource plans.

Staff draws this conclusion because GRE/MP/OTP could have been able to demonstrate that CO_2 emissions have increased elsewhere as a result of Minnesota's environmental externalities, but it did not. Dr. Smith discussed in her Expert Report *how* to account for leakage, and she explained that "a detailed generation planning model of the Minnesota electric system and the power pools that connect to Minnesota can be run with and without a specific change in generation resources in Minnesota."[413] This merely presents a way to validate a claim, but Dr. Smith did not perform this analysis. Thus, the hypothesis jumped to the conclusion without the analysis.

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[411] GRE/MP/OTP Exceptions, at 19.
[412] Ex. Direct, Dr. Anne Smith, p. 28.
[413] Ex. 302, Smith Direct, Exhibit 2 –Expert Report, at 102.

Environmental cost values have been applied in Minnesota IRP proceedings for the past two decades; if leakage has unquestionably and indisputably occurred *and* reduced the efficacy of Minnesota's CO_2 reductions, GRE/MP/OTP should have been able to present conclusive evidence, citing specific examples. Since GRE/MP/OTP has a methodology, proposed by its witness, it is incumbent upon it to perform such an exercise—that is, to simulate the Minnesota electric system and the connected power pools from a generation planning model under a range of CO_2 values.

As a practical concern, resource planning is (typically) not location-specific, and new resource options are not modelled in a particular jurisdiction. Even if it were, GRE/MP/OTP make an implicit assumptions that replacement or ramped up generation is always from carbon-emitting resources. However, the Clean Energy Business Coalition noted, "renewable energy has been a significant portion of new generating capacity added to the grid in the United States," adding further, "From 2012-2014, renewables made up 50% of all electric capacity added to the grid."[414] CBEC also noted that "wind and solar resources will displace more expensive energy sources on the wholesale market."[415]

On page 44 of MLIG's Exceptions, MLIG states:

> MLIG and the Utilities Group had sought an expression of the environmental cost value of CO_2 in net tons to account for leakage. The amount of leakage can then be determined in each docket in which it is an issue, on an appropriate case-by-case basis. **By expressing the environmental-cost value of CO_2 in net tons, and requiring the utilities to advise the Commission in each affected docket as to anticipated leakage**, the Commission can achieve all objectives, without the speculation that the ALJ's recommendation would bring about. (Emphasis added.)

Utilities can freely account for leakage in their own respective resource plans without a Commission requirement to do so, and certainly without a generic docket to investigate a complex issue that will undoubtedly apply differently to each utility. ALJ Conclusion 40 determined that "calculating leakage of increased CO_2 emissions is not properly a part of this proceeding," which leaves two options to resolve leakage: either the Commission can open generic docket, or a utility can estimate it in an individual resource plan.

To be clear, staff does not mean to imply that leakage should be ignored entirely; instead, staff is unsure why "anticipated leakage" should be taken as a given and why leakage should have any bearing on the incremental impact of the SCC in the first place. In other words, does the marginal societal benefit of an avoided CO_2 emission change regardless of emissions that may follow elsewhere? Xcel addressed this question as follows:

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[414] CBEC Reply Brief, at 7.
[415] CBEC Reply Brief, at 5.

the Commission should not address leakage in this proceeding. This proceeding attempts to estimate damages per ton of CO_2 emitted or avoided, not estimate the number of net tons emitted or avoided …[416]

The Agencies disagreed that leakage is relevant to this proceeding on the basis of jurisdictional authority:

> Dr. Hanemann and the Agencies disagree that leakage should be considered when applying an SCC value. Dr. Hanemann explained that the Commission regulates only utilities in Minnesota and does not regulate utilities in other states or other countries. The level of GHG emissions in other states is not the responsibility of the Commission. Further, the Commission has no responsibility for the aggregate level of emissions in the U.S.
>
> Consequently, what other states do -- or fail to do -- to control emissions is outside the jurisdiction of the Minnesota Commission. While the Commission is free to consider the actions of other jurisdictions in its decisions regarding the application of externality values, there is no reason to modify its assessment of externality cost ranges based on what may or may not happen in other jurisdictions. The marginal damages resulting from an incremental ton of emissions is not affected by application decisions.[417]

Those who supported the net tonne calculation (i.e. accounting for leakage) did not address the fact that the Commission has established CO_2 currently. Again, staff found it difficult to embrace the colossal concerns some had about CO_2 externalities when there was no discussion about the historical effect of these values. Dr. Gayer, for example, argued strongly that "Minnesota must take seriously the problem of leakage, especially if it follows Dr. Polasky's advice to price CO_2 much higher than neighboring states do."[418] However, Dr. Gayer's proposal would substantially reduce the CO_2 values that Minnesota utilities currently use. Whether his argument it that there is a threshold price where leakage becomes relevant is not explained. Furthermore, witnesses also did not explain how reducing the externality values from where they are currently could improve the efficacy of Minnesota's CO_2 reductions.

According to MP/GRE/OTP, it would be "a failure by the Commission" not "to properly account for leakage."[419] According to MP/GRE/OTP witness, Dr. Smith, "Leakage could be nearly 100% in the case of reductions in emissions from electricity generation in a single state that is interconnected with power from other states that are not imposing comparable policies."[420]

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[416] Xcel Reply Brief, at 21.
[417] Agencies Amended Initial Brief, at 130.
[418] Ex. 401, Gayer Surrebuttal, at 9.
[419] GRE/MP/OTP, Initial Brief, at 40.
[420] Ex. 302, Exhibit 2 of Smith Direct (Expert Report), at 9.

The IRP statute requires that the utility provide in each resource plan a "narrative identifying and describing the costs, opportunities, and technical barriers to the utility continuing to make progress on its system toward achieving the state greenhouse gas emission reduction goals established in section 216H.02, subdivision 1" (the Greenhouse Gas Reduction Goal). Utilities are free to qualify in their resource plans that the CO_2 reductions they claim will actually be of no benefit to the State, and that the emissions reductions they expect will indisputably be offset elsewhere, possibly as much as 100%.

With regard to opening a generic docket, quite frankly, one might imagine that doing so could quickly devolve into a series of politically-driven, industry-driven, and advocacy-driven narratives and generalities concerning the advantages or limitations of one resource or another. With a collection of arguments with little to no applicability to actual resource plans, the Commission might be left picking up the pieces at the back end. To seriously consider opening a generic docket on leakage, it should first be discussed, with specific detail, what facts may be considered, how a leakage adjustment might be updated over time, and how it could be calculated such that it could reasonably apply to all utilities filing IRPs.

ALJ Conclusions Section XI: Use of FSCC Outside of Federal Regulatory Setting

A. ALJ Report

According to ALJ Finding of Fact 336,

> 336. Several parties criticized the use of the FSCC as a state tool for resource planning, arguing that it was developed by the IWG so that federal agencies could include relevant cost-benefit analyses for proposed GHG emissions regulation in their Regulatory Impact Analyses as required by Executive Order 12866.[421]

The ALJ disagreed with these arguments, however, stating in Conclusion 46:

> 46. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the IWG has not taken a position regarding whether it is appropriate for a state to adopt the FSCC for purposes such as those outlined in Minn. Stat. § 216B.2422, subd. 3. The Administrative Law Judge concludes that the FSCC could provide the Commission with the information it requires to implement Minn. Stat. § 216B.2422, subd.3. There was no evidence offered in this proceeding to demonstrate that the IWG's FSCC values are different than they would have been had the IWG developed an SCC specifically for the purpose of complying with Minn. Stat. § 216B.2422, subd.3.

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[421] Ex. 302, AES-D-2 at 32 (Smith Direct); Ex. 601 at 20 (Martin Rebuttal); Ex. 400, Att. 2 at 6 (Gayer Direct).

In the Memorandum of the ALJ Report, on pages 130-131, the Judge discussed the appropriateness of using of the FSCC outside of a federal regulatory setting:

> The dispute over whether the FSCC is properly used for resource planning and certificate of need proceedings when it was designed to be used for cost-benefit analyses in federal rulemaking proceedings is, at its heart, a question about process. The real difference between how the FSCC is used as originally intended and how it would be used if adopted by the Commission in this proceeding is essentially the difference between internal agency policy and a requirement that functions like an agency rule. The FSCC was designed for agencies to internally to evaluate their own rules, not to apply to outside parties. Environmental cost values, pursuant to Minn. Stat. § 216B.2422, subd. 3, are numbers which regulated parties are required to use as part of proceedings in which they are required to participate. Those numbers will affect how the parties are treated in resource planning and certificate of need proceedings. In that sense, the Commission's choice of numbers as a result of this proceeding resembles rulemaking.

> The legislature could have required the Commission to establish the environmental cost values through formal rulemaking proceedings, but it did not. However, the Commission found that a contested case proceeding was necessary to fully develop the record, to provide interested parties with differing points of view the opportunity to present evidence and argument, to allow for public input and to allow an Administrative Law Judge to synthesize the evidence, arguments and input in the form of this Report. The Commission did not rubber stamp the FSCC. The comprehensive and vigorous nature of these proceedings provided for a thorough review of the FSCC. Therefore, while the FSCC was originally developed for a different purpose through a process with less input from the public and regulated parties than is usual in Minnesota, those criticisms have been cured through this proceeding.

B. Party Positions

According to Xcel, "all Parties acknowledge that the SCC was originally developed to be used in regulatory impact analyses and the IWG has not recommended its use in state-level decision-making."[422] The Commission might wish to seek clarification on this argument, since Xcel speaks on behalf of all parties, many of whom endorse and recommend adoption of the FSCC in this case.

Additionally, Xcel claimed the IWG's position is that the FSCC should not be used for state-level proceedings. CEO argued in its Reply Brief that Xcel misleadingly characterized IWG's position, stating:

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[422] Xcel Energy, Initial Brief, at 13.

Xcel alleges, misleadingly, that "the IWG has not recommended the [Federal SCC estimates'] use in state-level decision-making."[423] What the IWG actually said is that it "has not addressed the use of the SCC estimates outside the regulatory context, such as in NEPA analysis, state level decision making, and 'pricing' carbon in the marketplace."[424] The IWG goes on to explain that the Council on Environmental Quality has endorsed the use of the Federal SCC in project-specific environmental review. In any case, the IWG has neither recommended nor discouraged the use of the Federal SCC in state regulatory proceedings. The most credible voices in this case, however, see no reason why the values should not be adopted for use by the Commission in resource planning.[425,426,427]

Part 5: Other Issues

Burden of Proof

A. ALJ Report

This case is somewhat unique in that it is a Commission investigation, although it was re-opened after CEO filed a petition contending that the Commission's environmental cost values were no longer supported by scientific evidence.[428]

Before evidentiary hearings began in this case, the ALJ issued an order on March 27, 2015 addressing the evidentiary burdens of proof (OAH Burdens of Proof Order). The ALJ set forth the following parameters for the evidentiary burdens of proof, which are also included in the ALJ Report, Findings of Fact 10.a.-h. Staff does not repeat those findings here.

ALJ Conclusion 3 also addresses burdens of proof:

> 3. The Administrative Law Judge concludes that the following burdens of proof apply in this proceeding:
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>> a. A party or parties proposing that the Commission adopt a new environmental cost value for CO_2, including the Federal Social Cost of Carbon, bears the burden of showing by a preponderance of the evidence

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[423] Xcel Energy, Initial Brief, at 14.
[424] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 41.
[425] Ex. 101, Schedule 1 of Polasky Rebuttal, IWG Response to Comments, at 33.
[426] CEO Reply Brief, at 12-13.
[427] Ex. 801, Hanemann Rebuttal at 16-17.
[428] Commission Order Reopening Investigation, February 10, 2014.

that the value being proposed is reasonable and the best available measure of the environmental cost of CO_2.

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

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

Only MLIG took exception to the Judge's Conclusion; MLIG proposed the Commission strike ALJ Conclusion 3.b.

Parties argued back-and-forth about burdens of proof generally in Exceptions and Reply Exceptions. For example:

- **GRE/MP/OTP** (Exceptions): [P]roponents of the adoption of the FSCC must present evidence demonstrating that it is more probable than not that the FSCC is reasonable and the best available measure of the CO_2 [environmental cost value]. They cannot meet this burden unless they satisfy the "practicability of quantification" standard the Commission has determined to be required by the statute. They must do more than convince the Commission the damages they propose to include in the costs exist; they must demonstrate, based upon a preponderance of the evidence, that the costs of the damages are sufficiently certain that they may be practicably quantified.[429]

- **MLIG** (Exceptions): [T]he ALJ erroneously imposed a burden of proof on FSCC opponents to show that climate change did not exist, instead of considering witness testimony that the FSCC models do not adequately account for current data regarding actual current CO_2 levels and that the current reality is different from that predicted by the models, which "run hot," such that the data and the record invalidate a number of important assumptions within the FSCC, such as the equilibrium climate sensitivity ("ECS").[430]
  …

  The MLIG takes exception to paragraph 3 of the Order Regarding Burdens of Proof dated March 27, 2015 that requires that "[a] party or parties proposing that the Commission retain any environmental cost value as currently assigned by the Commission bears the burden of showing, by a preponderance of the evidence, that the current value is

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[429] Utilities Exceptions, at 7-8.
[430] MLIG Exceptions, at 3.

reasonable and the best available measure to determine the applicable environmental cost." Imposing a burden of proof on a party seeking to establish a new value is in accord with Minn. R. 1400.7300, Subp. 5. Seeking to impose a burden of proof on a party who simply rejects values newly proposed by others, which then leaves the status quo ante is contrary to law. See Minn. R. 1400.7300, Subp. 5.[431]

- **Agencies** [Reply to Exceptions, in response to MLIG]: The MLIG Exceptions complained that the ALJ's "Order Regarding Burdens of Proof" dated March 27, 2015 did not properly allocate the burden of proof. (MLIG Exceptions at 12-14.)The MLIG argued without citation to authority, that the burden of proof should have been on the parties that advocate adoption of the FSCC, not on parties advocating for retention of the cost of carbon set in the 1990's proceeding.

  As an initial matter, the Agencies observe that, in making its argument, the MLIG overlooked the Commission's October 15, 2014 Order, where the Commission, in referring this matter for a contested case proceeding, confirmed that scientific advances in the past 20 years called for a reconsideration of the damage costs of CO_2 emissions. In its October 15, 2014 Order, the Commission acknowledged that "[i]t would be premature at this stage to adopt the federal SCC values for CO_2 as the Agencies recommend." It went on to say that "…in light of the record so far, the Commission will ask the Administrative Law Judge to determine whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO_2 and, if not, what measure is better supported by the evidence." In this Order, the Commission thus established that any party who wished to put forth a value that "is better supported by the evidence" than the FSCC could attempt to do so. The Commission specifically did not state that the values established in the 1990's proceeding remained presumptively the "best available measure to determine the environmental cost of CO_2."[432]

  The MLIG did not object to the Commission's October 15, 2014 Order. It did not seek reconsideration by the Commission, as it could have done under the Minn. R. 7829.300023 if it believed that the values set in the 1990's proceeding should be treated as presumptively the "best available measure." Nor did it seek certification to the Commission of the ALJ's Order Regarding Burdens of Proof, as it could have done under Minn. Rule 1400.7600, if it believed the ALJ had improperly construed the Commission's October 15, 2014 Order.

- **CEO** [Reply to Exceptions, in response to MLIG]: MLIG suggests that the ALJ erred in concluding that CEOs and the Agencies have met the burden of proof because our academic experts testified as to the process used by the IWG rather than creating our own process. This misunderstands the purpose of this proceeding. The Commission

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[431] MLIG Exceptions, at 12-13.
[432] Agencies Reply to Exceptions, at 11-12.

specifically asked parties to address whether the SCC was reasonable and the best available measure of the damage cost value for CO_2. The Commission did not ask parties to perform their own "damage-cost modeling work. The ALJ properly relied on the record in this proceeding to make her findings and reach her conclusions.[433]

- ***Xcel*** [Reply to Exceptions]: We highlighted that under the ALJ's Burden of Proof Order, proponents of the FSCC bear the burden to demonstrate that the FSCC is reasonable and best available; part of this burden is demonstrating that the FSCC, which was designed for federal regulatory impact analysis, is reasonable for use under Minn. Stat. §216B.2422, subd. 3. This burden is not met by merely showing that the IWG has not specifically recommended against using the FSCC for Minn. Stat. §216B.2422 – a question the IWG has never been asked – or speculating that the IWG might have done nothing differently if asked to develop a range for Minn. Stat. §216B.2422. The IWG in fact explicitly stated that it has not recommended use of the FSCC for state level decision making. Thus, proponents of the FSCC executive summary values in this respect failed to meet their burden of proof.[434]

Re-calculation of the SCC

If Xcel is correct, if the Commission adopts the ALJ Report without modifications, the Commission will need to decide how to re-calculate the SCC estimates. In fact, for any decision that Commission makes that modifies the IWG's FSCC, it may be helpful to discuss if it would require a re-calculation, and if so, how that will work logistically.

It could also be helpful to ask Xcel how adjustments could practically be incorporated into its proposal. For example, regarding the first, last, or average ton approach, Mr. Martin explained:

> If the Commission felt the average-ton approach was more appropriate, the Commission could no longer rely on simple statistical treatment of the IAM results as the Company has proposed, but would have to conduct new modeling. So while I agree with the rationale for this alternative, it would be difficult to replicate and update.[435]

Xcel had a similar explanation for truncating the time horizon. However, there could be some adjustments that are easier than others, and the Commission may wish to delineate which adjustments would be problematic and which could be done with relative ease.

Extrapolations

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[433] CEO Reply to Exceptions, at 16-17.
[434] Xcel Reply to Exceptions, at 2.
[435] Ex. 601, Martin Rebuttal, at 47.

Two main issues with the IWG's extrapolations are, first, whether they were reasonable and, second, whether any extrapolations should have done at all. Both, according to some, raise questions of adding speculative content unnecessarily. Dr. Smith argued, "Reasonable or not, these extrapolations of the IWG beyond 2100 are highly speculative and not supported by facts, available evidence, or peer-reviewed analyses."[436] Dr. Smith also point out that, whereas the EMF-22 ended its projections in 2100, the IWG made projections through 2300. Staff raised a similar point about the IPCC Assessment Reports and its SRES and RCPs used in the Fourth and Fifth Assessments, respectively.

Dr. Hanemann responded that, [t]he whole focus of the EMF-22 was to look at abatement costs to meet a goal specifically in 2100. … It therefore sheds no light on the relative merits of damage projections that terminate before or after 2100."[437]

As discussed in the Time Horizon section of this briefing paper, a critical issue in this will be the reasonableness of IWG's extrapolations.

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[436] Ex. 300, Smith Direct, Expert Report, at 68.
[437] Ex. 801, Hanemann Rebuttal, at 24-25.

Decision Options

- Adopt the ALJ's Report and recommendation in its entirety.

- Adopt the ALJ's Report and recommendations with modification to one or more of the following issues and to the extent the ALJ's Report is consistent with the decisions made by the Commission at this meeting.

ALJ FINDINGS AND CONCLUSIONS ON CLIMATE CHANGE

- Affirm the ALJ's Findings and Conclusions on Climate Change, as outlined in Sections II.I and II.J. of the ALJ Report.

ALJ CONCLUSIONS ON THE FSCC

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

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

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

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

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

3b (MLIG EXCEPTION). Strike ALJ Conclusion 3.b. in its entirety.

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

I. Use of IAMS as Damage Cost Models

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

5.   The Administrative Law Judge concludes that taking the cost of emissions abatement into account when calculating damages is contrary to the Commission's understanding of a damage-cost approach, which focuses "on actual damages from uncontrolled emissions."

6.   The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that the IWG's use of the DICE, PAGE, and FUND models to calculate the FSCC is a damage-cost approach consistent with the Commission's Notice and Order for Hearing in this docket.

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

8.   The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that it was reasonable for them to rely on an environmental cost valuation for CO_2 based on the use of the DICE, PAGE and FUND models, given the combined requirements of a damage-cost approach and reduced-form modeling.

9.   The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence, that the IAMs' damage functions were based on empirical studies. However, the Administrative Law Judge further concludes that the empirical evidence on which the IWG relied to calculate damage functions for the FSCC consisted of fewer than fifty empirical studies, which were neither up-to-date nor comprehensive, adding to the uncertainty of the FSCC estimates, particularly in the areas of catastrophic damages and the treatment of the distant future.

10. The Administrative Law Judge concludes that more studies, using new approaches, have been published since the last update of the FSCC and that the IWG has expressed a commitment to continuing to pursue the most current research and to incorporate it as appropriate into future FSCC updates. The Administrative Law Judge concludes that, if the Commission adopted the FSCC, the Commission could update its CO_2 environmental cost values in the future as the IWG revised the FSCC based on more current research.

10 (MLIG EXCEPTION). The Administrative Law Judge concludes that more studies, using new approaches, have been published since the last update of the FSCC and that the IWG has expressed a commitment to continuing to pursue the most current research and to incorporate it as appropriate into future FSCC updates. ~~The Administrative Law Judge concludes that, if the Commission adopted the FSCC, the Commission could update its CO_2 environmental cost values in the future as the IWG revised the FSCC based on more current research~~.

10 (XCEL EXCEPTION). The Administrative Law Judge concludes that more studies, using new approaches, have been published since the last update of the FSCC and that the IWG has expressed a commitment to continuing to pursue the most current research and to incorporate it as appropriate into future FSCC updates. The Administrative Law Judge concludes that, if the Commission adopted the FSCC, the Commission could decide to open a separate proceeding to update its CO_2 environmental cost values in the future, including evaluating whether the Commission agrees with the scientific and public policy basis of the IWG's latest update. ~~as the IWG revised the FSCC based on more current research.~~ However, the Administrative Law Judge does not recommend an automatic adjustment to CO2 environmental values each time the FSCC is updated or revised.

11. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the FSCC underestimates the negative effects that increased warming will have on human health.

11 (MLIG EXCEPTION). Strike ALJ Conclusion 11 in its entirety.

12. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that the IAMs damage functions do not account for a significant number of important environmental impacts which will occur as a result of climate change.

13. The Administrative Law Judge concludes that, based on unreported and underreported health and environmental impacts, along with the IWG's acknowledgement that the FSCC is not based on the most current research, the preponderance of the evidence demonstrates that the FSCC understates the full environmental cost of CO_2.

13 (MLIG EXCEPTION). The Administrative Law Judge concludes that, based on unreported and underreported health and environmental impacts, along with the IWG's acknowledgement that the FSCC is not based on the most current research, an overstatement of the equilibrium climate sensitivity, the erroneous inclusion of a 2.5 percent discount rate, the erroneous exclusion of a 7 percent discount rate, the use of a time-modeling horizon that is entirely unreliable and not supportable by any empirical evidence, and reliance on an incorrect marginal ton, the preponderance of the evidence demonstrates that the FSCC misstates ~~understates~~ the full environmental cost of CO_2 even at a global geographic scope.

13 (XCEL EXCEPTION). The Administrative Law Judge concludes that, based on unreported and underreported health and environmental impacts, along with the IWG's acknowledgement that the FSCC is not based on the most current research, the preponderance of the evidence demonstrates that the FSCC may understates the full environmental cost of CO2. some of the future damages from climate change. However, a preponderance of the evidence also demonstrates that the IWG's methodology may fail to account fully for global coordination on CO2 mitigation, adaptation to climate change, and endogenous technological change in response to climate change.

II. IWG's Choice and Application of Discount Rates

14. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that both the three percent discount rate and the five percent discount rate are recognized as consumption rates of discount and it is reasonable to apply the three- and five- percent discount rates to the SCC.

15. The Administrative Law Judge concludes that Peabody, and the Utilities and MLIG failed to demonstrate by a preponderance of the evidence that a Ramsey rule discount rate that adjusts over time is reasonable to use in calculating the SCC. That approach is not appropriate because it is based on the concept that climate policy can be viewed through the metaphor of a single, infinitely-lived individual rather than the changing views of societies as they evolve over generations. The Administrative Law Judge concludes that the Ramsey rule fails to take into account the idea that priorities and preferences of people and societies will change over an extended period of time and does not address issues of equity between generations. Furthermore, the Administrative Law Judge concludes the Ramsey rule is not appropriate in this proceeding because it begins with a higher discount rate which declines with time. In addition to the intergenerational nature of the FSCC damage calculation, due to the uncertainties associated with the possibility of catastrophic damages from a "tipping point" event which may occur at an unknown time, and the understatement of impacts in the IAMs' damage functions, the Administrative Law Judge concludes that an approach that is designed to begin with a higher discount rate and gradually declines is neither reasonable nor the best approach to for the purpose of calculating an SCC.

15 (MLIG EXCEPTION). The Administrative Law Judge concludes that Peabody, and the Utilities and MLIG has failed to demonstrated by a preponderance of the evidence that a Ramsey rule discount rate that adjusts over time is also reasonable to use in calculating the SCC. That approach is not appropriate because it is based on the concept that climate policy can be viewed through the metaphor of a single, infinitely-lived individual rather than the changing views of societies as they evolve over generations. The Administrative Law Judge concludes that the Ramsey rule fails to take into account the idea that priorities and preferences of people and societies will change over an extended period of time and does not address issues of equity between generations. Furthermore, the Administrative Law Judge concludes the Ramsey rule is

~~not appropriate in this proceeding because it begins with a higher discount rate which declines with time. In addition to the intergenerational nature of the FSCC damage calculation, due to the uncertainties associated with the possibility of catastrophic damages from a "tipping point" event which may occur at an unknown time, and the understatement of impacts in the IAMs' damage functions, the Administrative Law Judge concludes that an approach that is designed to begin with a higher discount rate and gradually declines is neither reasonable nor the best approach to for the purpose of calculating an SCC.~~ The Ramsey rule takes into consideration that some countries that have high rates of growth also have low incomes, and that the appropriate discount rate for them should be higher than the discount rate for slower growing but wealthier countries. The propriety of application of the Ramsey rule is explained in Finding of Fact 189.

16. The Administrative Law Judge concludes that the preponderance of the evidence demonstrated that the OMB Circular A-4 does not require the IWG to use the seven percent discount rate to calculate the FSCC, because the Circular A-4 is advisory and not mandatory in nature. The Administrative Law Judge concludes that the OMB participated in the IWG's development of the FSCC and there was no evidence that the OMB objected to the IWG's choice not to use a seven percent discount rate in calculating the FSCC.

16 (MLIG EXCEPTION). Strike ALJ Conclusion 16 in its entirety.

17. The Administrative Law Judge concludes that the proposal advanced by the Utilities and MLIG to increase the upper end of the discount rate range to incorporate the opportunity cost of emissions reductions in the IWG's IAMs would be a "cost-of-control" approach, contrary to the Commission's required damage-cost approach.

17 (MLIG EXCEPTINON). Strike ALJ Conclusion 17 in its entirety.

18. The Administrative Law Judge concludes 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.

18 (MLIG EXCEPTION). The Administrative Law Judge concludes 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.~~

19. The Administrative Law Judge concludes that Peabody failed to demonstrate, by a preponderance of the evidence, that the IWG's discount rates are arbitrary.

III. 95th Percentile Value at 3 Percent Discount Rate

20. The Administrative Law Judge concludes that the CEOs and the Agencies demonstrated by a preponderance of the evidence that the FSCC likely understates damages and that the risk of a "tipping point" is not well-represented within the scope of the 2.5, 3.0 and 5.0 percent rate of discount.

20 (MLIG EXCEPTION). The Administrative Law Judge concludes that the CEOs and the Agencies demonstrated by a preponderance of the evidence that ~~the FSCC likely understates damages and that~~ the risk of a "tipping point" is not well-represented within the scope of the 2.5, 3.0, ~~and~~ 5.0, and 7.0 percent rates of discount.

21. Nonetheless, the Administrative Law Judge concludes that the CEOs and the Agencies failed to demonstrate, by a preponderance of the evidence, that the 95th percentile value at a three percent discount is a reasonable means of representing the high side of the FSCC distribution. The Agencies and the CEOs failed to demonstrate a reasonable basis for choosing the 95th percentile at three percent to represent the uncertainties regarding understated damages and a potential "tipping point." The 95th percentile value provided a larger damages number but was not supported by specific evidence or reasoning to demonstrate that the number is a meaningful estimate of the uncertainties it represents.

IV. Equilibrium Climate Sensitivity

22. The Administrative Law Judge concludes that Peabody failed to demonstrate, by a preponderance of the evidence, that an ECS value of 1 or 1.5 degrees centigrade is correct and that an ECS of more than 2 degrees centigrade is "extremely unlikely."

22 (MLIG EXCEPTION). The Administrative Law Judge concludes that Peabody failed to demonstrate, by a preponderance of the evidence, that an ECS value of ~~1 or 1.5 degrees centigrade is correct and that an ECS of~~ more than 2 degrees centigrade is "extremely unlikely."

23. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the ECS doubling ranges as reported by the IPCC in the IPCC AR4 (2.0-4.5 °C) and the IPCC AR5 (1.5-4.5°C) are more accurate ECS ranges than the range advanced by Peabody because the IPCC ranges are representative of a comprehensive, peer-reviewed body of scientific study based on multiple lines of evidence.

23 (MLIG EXCEPTION). The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the ECS doubling range~~s~~ as reported by the IPCC in ~~the IPCC AR4 (2.0-4.5 °C) and t~~he IPCC AR5 (the lower part of the 1.5°C-4.5 °C range) is ~~are~~ a more accurate ECS range~~s~~ than the range advanced by Peabody because the IPCC range~~s~~ is ~~are~~ representative of a comprehensive, peer-reviewed body of scientific study based on multiple lines of evidence.

24. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates the IWG had a reasoned basis to refrain from adopting the IPCC AR5 ECS values in the IWG's 2013 FSCC update. While the IWG could have chosen to adopt the updated values at that time, it stated that it viewed that IPCC AR4 ECS values as the most authoritative at the time of the 2013 update and affirmed its intention to update the ECS values as appropriate in the future, based on the latest science and external expert advice.

24 (MLIG EXCEPTION). Strike ALJ Conclusion 24 in its entirety. Replace with: The preponderance of the evidence shows that the likely ECS is in "the lower part of the range from 1.5°C to 4.5°C," which would equate to a conservative average or central ECS of 2.5°C if one were to use one number for computational purposes.

25. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that it was reasonable for the IWG to adopt the ECS range of 2.0-4.5 °C as stated in the IPCC AR4.

25 (MLIG EXCEPTION). Strike ALJ Conclusion 25 in its entirety.

V. Marginal Ton

26. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that the proposal to value CO_2 emissions by using baselines in which there are no additional emissions of CO_2 after the incremental emission is a reasonable approach to measuring damages in this proceeding. The Utilities and MLIG based this approach on the idea that incremental emissions reduction costs should be balanced with societal damage costs in calculating the SCC. This approach is contrary to the Commission's understanding of a damage-cost approach because, by incorporating the cost of emissions reductions, the Utilities' and MLIG's proposal incorporates a "cost-of-control" approach.

26 (MLIG EXCEPTION). The Commission used an average ton approach in the first Externalities case. The Administrative Law Judge concludes that the Utilities and MLIG ~~failed to~~ demonstrated, by a preponderance of the evidence, that the proposal to value CO2 emissions by using an average ton approach is warranted because use of the last marginal ton incorrectly assumes that a particular ton of CO2 emitted in the near future would be the last ton to be decided on as part of a 300-year "business as usual" baseline of otherwise unconstrained future emissions. Many of the tons emitted that contribute to the FSCC value will not be emitted until much later than the Minnesota tons in question and by others than Minnesota, while the carbon emitted in Minnesota is no more or less harmful than carbon emitted elsewhere and is also no more or less harmful than any of the tons assumed to be emitted in the future. Further, the use of a "last ton" approach assumes zero abatement, ever, by any country. All parties agreed that some adaptation and technological change will occur in the future to mitigate

losses and reduce emissions, and the IAMs are actually designed to account for future adaptation, but the IWG modified the damage functions in the models to eliminate consideration of adaptation for the FSCC. Not accounting for adaptation caused the IWG to overestimate the social cost of carbon. The IWG itself acknowledged that "the IAMs do not provide compelling treatments of adaptation and technological change." ~~using baselines in which there are no additional emissions of CO2 after the incremental emission is a reasonable approach to measuring damages in this proceeding. The Utilities and MLIG based this approach on the idea that incremental emissions reduction costs should be balanced with societal damage costs in calculating the SCC. This approach is contrary to the Commission's understanding of a damage-cost approach because, by incorporating the cost of emissions reductions, the Utilities' and MLIG's proposal incorporates a "cost-of-control" approach.~~

27. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that the proposal to value CO_2 emissions by using baselines in which there are no additional emissions of CO_2 after the incremental emission is a reasonable approach because this approach presumes an effective global emissions reduction program will be in effect. The Utilities and MLIG failed to present any evidence of such a program.

27 (MLIG EXCEPTION). Strike ALJ Conclusion 27 in its entirety.

28. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate by a preponderance of the evidence that the proposal to value CO_2 emissions by using an average ton approach is a reasonable approach in this proceeding. The Administrative Law Judge concludes that by averaging the first and last tons to calculate the average ton, the Utilities' and MLIG's average ton incorporates the cost of emissions reductions. Therefore, the Utilities' and MLIG's proposal incorporates a "cost-of-control" approach. In addition, the Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate that the Commission used an average ton approach in the first Externalities case.

28 (MLIG EXCEPTION). The Administrative Law Judge concludes that the Utilities and MLIG ~~failed to~~ demonstrated, by a preponderance of the evidence, that the proposal to value CO2 emissions by using an average ton approach is a reasonable approach in this proceeding, and continues the Commission's practice since the first Externalities case. ~~The Administrative Law Judge concludes that by averaging the first and last tons to calculate the average ton, the Utilities' and MLIG's average ton incorporates the cost of emissions reductions. Therefore, the Utilities' and MLIG's proposal incorporates a "cost-ofcontrol" approach. In addition, the Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate that the Commission~~ to ~~used~~ an average ton approach ~~in the first Externalities case~~.

29. The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated, by a preponderance of the evidence that the FSCC's approach to counting the last ton of CO_2 emitted as the marginal ton is reasonable and the best approach to calculate

damages. This is the best and most reasonable approach because it most closely matches the scientific understanding of what is known about the nature of CO_2, which is that each ton of CO_2 emitted has a cumulative impact, both with respect to the CO_2 emitted in the past and the CO_2 emitted in the future, as long as that ton of CO_2 remains in the atmosphere.

29 (MLIG EXCEPTION). The Administrative Law Judge concludes that the Agencies and the CEOs failed to demonstrated, by a preponderance of the evidence, that the FSCC's approach to counting the last ton of CO_2 emitted as the marginal ton is reasonable and the best approach to calculate damages. ~~This is the best and most reasonable approach because it most closely matches the scientific understanding of what is known about the nature of CO2, which is that each ton of CO2 emitted has a cumulative impact, both with respect to the CO2 emitted in the past and the CO2 emitted in the future, as long as that ton of CO2 remains in the atmosphere.~~

VI. Modeling Time Horizon

30. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that a ton of CO_2 released into the atmosphere will not be fully absorbed into the land or the oceans for a minimum of two hundred years. The Administrative Law Judge finds that it will be hundreds of years before that ton will be fully absorbed.

31. The Administrative Law Judge concludes that a preponderance of the evidence demonstrates that CO_2 will continue to have a cumulative impact on the climate for as long as it remains in the atmosphere.

32. The Administrative Law Judge concludes that the CEOs and Agencies failed to demonstrate that the IWG's prediction of damages from the year 2100 to the year 2300 meet the same standards of reliability as the IWG's predictions of damages from the present to the year 2100. The IWG used the peer-reviewed EMF-22 emissions scenarios, which were constructed through the year 2100. The IWG extrapolated the EMF inputs to the year 2300 based on limited data, without the benefit of peer review.

32 (AGENCIES EXCEPTION). The Administrative Law Judge concludes that the CEOs and Agencies failed to demonstrated that the IWG's prediction of damages from the year 2100 to the year 2300 meets the same standards of reliability as the IWG's predictions of damages from the present to the year 2100. The IWG used the ~~peer reviewed~~ EMF-22 emissions scenarios, which were constructed based on varying assumptions ~~through~~ for the year 2100. The IWG extrapolated the EMF ~~inputs~~ scenarios to the year 2300 based on ~~limited data, without the benefit of peer review~~ reasonable assumptions.

33. The Administrative Law Judge concludes the Utilities and MLIG demonstrated by a preponderance of the evidence that approximately 50 percent of the FSCC estimates at a three percent rate are in the post-2100 era.

33 (AGENCIES EXCEPTION). Strike ALJ Conclusion 33 in its entirety.

34. The Administrative Law Judge concludes that the Agencies and the CEOs failed to demonstrate by a preponderance of the evidence that a modeling time horizon extending to the year 2300 is reasonable. An additional two-hundred years will add increased numbers of cost values at lower interest rates and accelerating rates of damages with the passage of time and increased temperature. Therefore, the Administrative Law Judge finds that an extrapolation extending two-hundred years beyond the year that the EMF-22 scenarios were constructed to end is a degree of uncertainty that is not reasonably supported by adequate evidence.

34 (AGENCIES EXCEPTION). The Administrative Law Judge concludes that the Agencies and the CEOs ~~failed to~~ demonstrate~~d~~ by a preponderance of the evidence that a modeling time horizon extending to the year 2300 selected by the IWG is reasonable. ~~An additional two-hundred years will add increased numbers of cost values at lower interest rates and accelerating rates of damages with the passage of time and increased temperature. Therefore, the Administrative Law Judge finds that an extrapolation extending two-hundred years beyond the year that the EMF-22 scenarios were constructed to end is a involves degree of uncertainty that is not reasonably supported by adequate evidence.~~

34 (MLIG EXCEPTION). The Administrative Law Judge concludes that the Agencies and the CEOs failed to demonstrate by a preponderance of the evidence that a modeling time horizon extending to the year 2300 is reasonable. An additional two-hundred years will add increased numbers of cost values at lower interest rates and accelerating rates of damages with the passage of time and increased temperature. Because, as concluded above, the IWG's prediction of damages for the year 2100 to the year 2300 does not meet the same standards of reliability as the IWG's predictions of damages from the present to the year 2100 ~~Therefore~~, the Administrative Law Judge finds that an extrapolation extending two-hundred years or even one-hundred years beyond the year that the EMF-22 scenarios were constructed to end is a degree of uncertainty that is not reasonably supported by adequate evidence.

35. However, weighing the importance of accounting for the CO_2 that will remain in the atmosphere beyond the year 2100, and the understated nature of the FSCC, the Administrative Law Judge concludes that it is reasonable to implement the IWG's extrapolation for 100 years, to the year 2200. While the evidentiary underpinning is no greater for this extrapolation than it would be to extend the model to the year 2300, this approach lessens the danger of multiplication of errors within the extrapolation while providing a response to the strong evidence of damage from CO_2.

35 (AGENCIES EXCEPTION). Strike ALJ Conclusion 35 in its entirety.

35 (MLIG EXCEPTION). Strike ALJ Conclusion 35 in its entirety. Replace with: Because there is no evidentiary underpinning for the IWG's extrapolation of the EMF-22 scenarios, the FSCC values should be recalculated to reflect a shortened time horizon extending to the year 2100.

VII. Geographic Scope

36. The Administrative Law Judge concludes that the preponderance of the evidence in this docket demonstrates that CO_2 emissions emitted in one location on the Earth mix with GHGs emitted from all other locations on the planet, with each GHG molecule contributing to climate change experienced everywhere. In addition, in the first Externalities proceeding the Minnesota Court of Appeals held that, "[r]egardless of its emission point, CO_2 is believed to contribute to global warming, which in turn adversely impacts the global environment."

37. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that limiting damages to the United States or Minnesota will capture all of the damage caused by CO_2 emissions released from electric power generating facilities within Minnesota.

37 (MLIG EXCEPTION). The Administrative Law Judge concludes that ~~the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that~~ limiting damages to the United States or Minnesota will not capture all of the damage caused by CO_2 emissions released from electric power generating facilities within Minnesota.

38. The Administrative Law Judge concludes that MLIG improperly framed the calculation of the environmental cost value of CO_2 as a question of economic standing by stating the question in terms of who pays the costs of the policy and who receives the benefits.

38 (MLIG EXCEPTION). Strike ALJ Conclusion 38 in its entirety.

39. The Administrative Law Judge concludes that Minn. Stat. § 216B.2442, subd. 3, and the Commission's requirement that the parties use a damage-cost analysis compel that the question of the geographic scope of damages be viewed in terms of the source of the CO_2 emissions and all their damaging impacts, wherever they are experienced. Therefore, the Administrative Law Judge concludes that this proceeding requires a global scope for damages.

39 (MLIG EXCEPTION). Strike ALJ Conclusion 39 in its entirety. Replace with: The question of geographic scope a worldwide geographic scope is complex in the absence of reciprocity and was not addressed in detail in the original 1996 proceedings. Reciprocity plays a role in the quantity of the value to be assigned to the environmental cost value of CO2 and the absence of reciprocity on both a national and international level means that a global geographic damages scope leads to an overstatement of damages caused by Minnesota-produced CO2. Addressing global greenhouse gas emissions in a meaningful way requires all major emitting nations to reduce their emissions significantly, not just the U.S. emitters. Importantly, this fact leads to exactly the opposite conclusion about inclusion of global benefits in the SCC value from what the IWG concluded. The IAMs compute a high $/ton value for a ton of U.S. emission not

because the U.S.'s emissions are causing such high damages, but rather the SCC estimate is driven upwards by the effect of all of the other nations' uncontrolled CO2 emissions. Otherwise stated, if no other nation emitted greenhouse gasses, then the SCC estimate would be entirely due to U.S. emissions; however, that SCC estimate would be lower than what the IWG has computed. The ALJ accordingly concludes that unless and until there is a national and international reciprocal system in force, the calculation of the environmental cost value of CO2 should be made on a local, *i.e.*, Minnesota, damages assessment.

VIII. Leakage

40. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that calculating leakage of increased CO_2 emissions is not properly a part of this proceeding.

IX. Uncertainty

41. The Administrative Law Judge concludes that the preponderance of the evidence shows that the task of predicting the SCC is highly uncertain, because it is an exercise in predicting impacts of CO_2 emissions many years into the future. The process involves forecasting such uncertainties as changing temperatures, global GDP far into the future, and the possible occurrence of a "tipping point" event leading to irreversible, catastrophic damages.

41 (XCEL EXCEPTION). The Administrative Law Judge concludes that the preponderance of the evidence shows that the task of predicting the SCC is highly uncertain, because it is an exercise in predicting impacts of CO_2 emissions many years into the future. The process involves forecasting such uncertainties as changing temperatures, global GDP far into the future, adaptation and mitigation, and the possible occurrence of a "tipping point" event leading to irreversible, catastrophic damages.

42. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates the IWG partially accounts for uncertainty in the FSCC by using three IAMs, five different socioeconomic emissions projections and probability distributions for the ECS values, as well as a number of parameters in the FUND and PAGE IAMs.

43. The Administrative Law Judge concludes that the Agencies and CEOs demonstrated by a preponderance of the evidence that, given the increased scientific certainty of the link between CO_2 emissions and climate change, uncertainties such as the potential danger of a "tipping point" catastrophe reasonably require an initially high SCC until more is known about such uncertainties.

43 (MLIG EXCEPTION). Strike ALJ Conclusion 43 in its entirety.

43 (XCEL EXCEPTION). The Administrative Law Judge concludes that ~~it has been~~ ~~the Agencies and CEOs~~ demonstrated by a preponderance of the evidence that the FSCC models incompletely tipping points, catastrophic damages, and some other factors that could increase the damage values. ~~, given the increased scientific certainty of the link between CO2 emissions and climate change, uncertainties such as the potential danger of a "tipping point" catastrophe reasonably require an initially high SCC until more is known about such uncertainties.~~

X. Adaptation and Mitigation

44. The Administrative Law Judge concludes that the Agencies and CEOs demonstrated by a preponderance of the evidence that the IWG adequately accounted for adaptation and mitigation in the FSCC. No other party demonstrated by a preponderance of the evidence that it is reasonable to account for adaptation or mitigation to any extent beyond that included in the FSCC. There was no specific evidence presented regarding the efficacy of any specific mode of adaptation or mitigation.

44 (MLIG EXCEPTION). The Administrative Law Judge concludes that the Agencies and CEOs failed to demonstrate~~d,~~ by a preponderance of the evidence, that the IWG adequately accounted for adaptation and mitigation in the FSCC. In fact, the record shows that the IWG removed the adaptation and mitigation elements from the IAMs. The MLIG, Peabody, and others ~~No other party~~ demonstrated, by a preponderance of the evidence, that it is reasonable and necessary to account for adaptation or mitigation ~~to any extent~~ beyond that included in the FSCC. While t~~T~~here was no specific evidence presented regarding the efficacy of any specific mode of adaptation or mitigation, the Utilities and the MLIG showed that future generations will be far wealthier and have far higher consumption than is the case in the present. In fact, by 2100, real consumption will be 3 to 5 times higher than we have today. By 2300, when the largest amount of climate impact (with unreduced business-as-usual emissions) will have occurred, consumption will be between 7 and 25 times higher than today. Thus, the IAM scenarios that the IWG has used to compute the SCC of a ton of emission today are also implying that any cost incurred today will reduce present consumption while adding to the vastly higher welfare of future generations.

44 (XCEL EXCEPTION). The Administrative Law Judge concludes that it has been ~~the Agencies and CEOs~~ demonstrated by a preponderance of the evidence that the FSCC models incompletely global coordination on CO2 mitigation, adaptation to climate change, and endogenous technological change, which if captured could decrease the damage values. This is true in part because even though the IAMs attempt to account for some types of adaptation and mitigation, the IWG methodology did not use the IAMs in their native format, and some aspects of its methodology – for example the IWG's decision to use exogenous, fixed emission trajectories and not allow these to change in response to experienced damages – results in the IWG's methodology not capturing adaptation and endogenous technological change even when the IAMs themselves do. ~~IWG adequately accounted for adaptation and mitigation in the FSCC. No other party demonstrated by a preponderance of the evidence that it is reasonable to account for adaptation or mitigation to any extent beyond that included in the FSCC. There was~~

~~no specific evidence presented regarding the efficacy of any specific mode of adaptation or mitigation.~~

45. The Administrative Law Judge concludes that approaching the damage calculation to achieve an "optimal mitigation level" such as Peabody recommended is not consistent with the cost-damage approach required by the Commission.

XI. Use of FSCC Outside of Federal Regulatory Setting

45 (MLIG EXCEPTION). Strike ALJ Conclusion 45 in its entirety.

46. The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the IWG has not taken a position regarding whether it is appropriate for a state to adopt the FSCC for purposes such as those outlined in Minn. Stat. § 216B.2422, subd. 3. The Administrative Law Judge concludes that the FSCC could provide the Commission with the information it requires to implement Minn. Stat. § 216B.2422, subd.3. There was no evidence offered in this proceeding to demonstrate that the IWG's FSCC values are different than they would have been had the IWG developed an SCC specifically for the purpose of complying with Minn. Stat. § 216B.2422, subd.3.

46 (MLIG EXCEPTION). The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the IWG has not taken a position regarding whether it is appropriate for a state to adopt the FSCC for purposes such as those outlined in Minn. Stat. § 216B.2422, subd. 3. ~~The Administrative Law Judge concludes that the FSCC could provide the Commission with the information it requires to implement Minn. Stat. § 216B.2422, subd.3. There was no evidence offered in this proceeding to demonstrate that the IWG's FSCC values are different than they would have been had the IWG developed an SCC specifically for the purpose of complying with Minn. Stat. § 216B.2422, subd.3.~~

46 (XCEL EXCEPTION). The Administrative Law Judge concludes that the preponderance of the evidence demonstrates that the IWG has explicitly noted, in response to public comments, that it has not recommended use of the FSCC for purposes other than federal regulatory impact analysis, including its use in state level decision making or ~~not taken a position regarding whether it is appropriate for a state to adopt the FSCC~~ for purposes such as those outlined in Minn. Stat. § 216B.2422, subd. 3. Therefore, there is no basis in the evidentiary record to conclude that the IWG would support such an application, nor to conclude that the IWG's methodology and FSCC values would be no different ~~The Administrative Law Judge concludes that the FSCC could provide the Commission with the information it requires to implement Minn. Stat. § 216B.2422, subd.3. There was no evidence offered in this proceeding to demonstrate that the IWG's FSCC values are different than they would have been~~ had the IWG developed an SCC specifically for the purpose of complying with Minn. Stat. § 216B.2422, subd.3.

XII. Scientific Process

47. The Administrative Law Judge concludes that Peabody failed to demonstrate by a preponderance of the evidence that the IWG is neither peer-reviewed nor transparent. While the FSCC itself is not peer-reviewed, a preponderance of the evidence demonstrated that the IWG relied primarily on peer-reviewed literature, particularly the work of the IPCC, which is recognized by the Commission, the Minnesota Court of Appeals and the United States Supreme Court as a credible source of expertise in the area of climate change. The experts in this proceeding reviewed the FSCC process exhaustively, providing extensive analysis and critique. While technically not a peer review, this contested case process has provided a thorough level of scrutiny of the FSCC and the IWG's process in developing the FSCC. The IWG's Technical Support Documents are all part of the record in this proceeding, along with numerous commentaries regarding the IWG's process and the FSCC.

47 (MLIG EXCEPTION). The Administrative Law Judge concludes that Peabody ~~failed to~~ demonstrated, by a preponderance of the evidence, that the IWG is neither peer-reviewed nor transparent. Nevertheless, ~~W~~while the FSCC itself is not peer-reviewed, a preponderance of the evidence demonstrated that the IWG relied primarily on peer-reviewed literature, particularly the work of the IPCC, which is recognized by the Commission, the Minnesota Court of Appeals and the United States Supreme Court as a credible source of expertise in the area of climate change. The experts in this proceeding reviewed the FSCC process exhaustively, providing extensive analysis and critique. While technically not a peer review, this contested case process has provided a thorough level of scrutiny of the FSCC and the IWG's process in developing the FSCC, which has showed that the FSCC is both out-of-date and erroneous. The IWG's Technical Support Documents are all part of the record in this proceeding, along with numerous commentaries regarding the IWG's process and the FSCC.

48. The Administrative Law Judge concludes that Peabody failed to demonstrate by a preponderance of the evidence that the Agencies and the CEOs relied primarily on non-peer-reviewed literature. The Administrative Law Judge was unable to verify Peabody's non-specific assertions that the Agencies and CEOs relied on such literature.

XIII. Xcel Proposal

49. The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that its proposal to calculate the upper and lower SCC values at the 25th and 75th percentiles of the IWG data distribution was reasonable. The Administrative Law Judge concludes that, by choosing the 25th and 75th percentiles, Xcel centered its SCC range around the 50th percentile, which is the median of the distribution. By choosing to center its range around the median value, Xcel unreasonably excluded information about the magnitude, as well as the likelihood of

significant damages, as reflected in the higher end tails of the distribution. These high damage outcomes are of great concern and it would be unreasonable to ignore them.

49 **(XCEL EXCEPTION)**. The Administrative Law Judge concludes that Xcel ~~failed to~~ demonstrated by a preponderance of the evidence that its proposal to calculate the upper and lower bounds of its initial range ~~SCC values~~ at the 25th and 75th percentiles of the IWG data distribution was reasonable, because it reflects an appropriate level of risk tolerance and treats the low and the high damage estimates in an equal manner. Using symmetric percentiles incorporates ~~The Administrative Law Judge concludes that, by choosing the 25th and 75th percentiles, Xcel centered its SCC range around the 50th percentile, which is the median of the distribution. By choosing to center its range around the median value, Xcel unreasonably excluded~~ information about the magnitude, as well as the likelihood of significant damages. ~~, as reflected in the higher end tails of the distribution. These high damage outcomes are of great concern and it would be unreasonable to ignore them.~~

50. The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that it had a reasonable basis on which to average the three FSCC discount rate values at the upper and lower ends of its range of values to establish its final SCC range of cost values. Xcel presented no evidence of theoretical, practical or scholarly support for its idea that averaging the values of the three discount rates for each end of its distribution range is an appropriate way in which to account for the controversy among the parties regarding a proper discount rate in this proceeding.

50 **(XCEL EXCEPTION)**. The Administrative Law Judge concludes that Xcel ~~failed to~~ demonstrated by a preponderance of the evidence that it had a reasonable basis on which to equally weight ~~average~~ the three FSCC ~~discount rate~~ values calculated at different discount rates at the upper and lower ends of its range of values, when ~~to~~ establishing its final SCC range of cost values. This step was a practical decision to remain agnostic on the policy judgment of discount rate choice while still proposing for Commission adoption a true range instead of six separate CO2 values. ~~Xcel presented no evidence of theoretical, practical or scholarly support for its idea that averaging the values of the three discount rates for each end of its distribution range is an appropriate way in which to account for the controversy among the parties regarding a proper discount rate in this proceeding.~~

51. The Administrative Law Judge concludes that Xcel failed to demonstrate by a preponderance of the evidence that the FSCC does not offer a range of values. The FSCC chooses one cost based on an average of the values on the distribution scale, then creates a range of values from the single cost by offering that value at three different discount rates, and adding the 95th percentile as a fourth high-end value.

51 **(XCEL EXCEPTION)**. The Administrative Law Judge concludes that the Agencies and CEO ~~Xcel~~ failed to demonstrate by a preponderance of the evidence that the four FSCC values does not offer constitute a range of values. Four point estimates calculated at different discount rates

remain four point estimates. ~~The FSCC chooses one cost based on an average of the values on the distribution scale, then creates a range of values from the single cost by offering that value at three different discount rates, and adding the 95th percentile as a fourth high-end value.~~

XIV. Reasonable and the Best Available Measure of CO_2

52. The Administrative Law Judge concludes that Peabody failed to demonstrate by a preponderance of the evidence that any of the CO_2 environmental cost values it proposed are reasonable and the best available measure of CO_2 cost values.

53. The Administrative Law Judge concludes that MLIG failed to demonstrate, by a preponderance of the evidence, that any of the CO_2 environmental cost values it proposed are reasonable and the best available measure of CO_2 cost values.

53 (MLIG EXCEPTION). The Administrative Law Judge concludes that MLIG ~~failed to~~ demonstrated, by a preponderance of the evidence, that ~~any of~~ the CO_2 environmental cost values it proposed are reasonable and the best available measure of CO_2 cost values.

54. The Administrative Law Judge concludes that the Utilities and MLIG failed to demonstrate, by a preponderance of the evidence, that any of the CO_2 environmental cost values they proposed are reasonable and the best available measure of CO_2 cost values.

54 (MLIG EXCEPTION). The Administrative Law Judge concludes that the Utilities and MLIG ~~failed to~~ demonstrated, by a preponderance of the evidence, that ~~any of~~ the CO_2 environmental cost values they proposed are reasonable and the best available measure of CO2 cost values.

55. The Administrative Law Judge concludes that Xcel failed to CO_2 by a preponderance of the evidence that its proposal for measuring CO_2 cost values is reasonable and the best available measure of CO_2 cost values.

55 **(XCEL EXCEPTION)**. The Administrative Law Judge concludes that Xcel ~~failed to~~ demonstrated by a preponderance of the evidence that its proposal for measuring CO_2 cost values is reasonable and the best available measure of CO_2 cost values.

56. The Administrative Law Judge concludes that the Agencies and the CEOs demonstrated by a preponderance of the evidence that the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO_2, with the exceptions described in these findings regarding the 95th percentile and the time modeling horizon.

56 (MLIG EXCEPTION). The Administrative Law Judge concludes that the Agencies and the CEOs failed to demonstrated, by a preponderance of the evidence, that the Federal Social Cost of

Carbon is reasonable and the best available measure to determine the environmental cost of CO₂, ~~with the exceptions described in these findings regarding the 95ᵗʰ percentile and the time modeling horizon~~.

56 **(XCEL EXCEPTION)**. The Administrative Law Judge concludes that the Agencies and the CEOs failed to demonstrate~~d~~ by a preponderance of the evidence that the Federal Social Cost of Carbon executive summary values are ~~is~~ reasonable and the best available measure to determine the environmental cost of CO₂. ~~, with the exceptions described in these findings regarding the 95th percentile and the time modeling horizon.~~

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

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

ALJ RECOMMENDATIONS

1. The Administrative Law Judge respectfully recommends that the Commission adopt the Federal Social Cost of Carbon as reasonable and the best available measure to determine the environmental cost of CO₂, establishing a range of values including the 2.5 percent, 3.0 percent, and 5 percent discount rates, with the following amendments:

    a. The FSCC values will be re-calculated to reflect a shortened time horizon extending to the year 2200.
    b. The Commission will exclude the value derived from the 95th percentile at a 3 percent discount rate value from the range of values.

1 (AGENCIES EXCEPTION). The Administrative Law Judge respectfully recommends that the Commission adopt the Federal Social Cost of Carbon as reasonable and the best available measure to determine the environmental cost of CO₂, establishing a range of values including the 2.5 percent, 3.0 percent, and 5 percent discount rates, with the following amendment:
~~a. The FSCC values will be re-calculated to reflect a shortened time horizon extending to the year 2200.~~

1 (CEO EXCEPTION). The Administrative Law Judge respectfully recommends that the Commission adopt the Federal Social Cost of Carbon as reasonable and the best available measure to determine the environmental cost of CO₂, establishing a range of values including the 2.5 percent, 3.0 percent, and 5 percent discount rates~~, with the following amendment:~~.
~~a. The FSCC values will be re-calculated to reflect a shortened time horizon extending to the year 2200.~~
~~b. The Commission will exclude the value derived from the 95th percentile at a 3 percent discount rate value from the range of values.~~

1 (MLIG EXCEPTION). The Administrative Law Judge respectfully recommends that the Commission reject the Federal Social Cost of Carbon as reasonable and the best available measure to determine the environmental cost of CO_2.

In the alternative, the Administrative Law Judge respectfully recommends that the Commission adopt modify the Federal Social Cost of Carbon as follows to reach approximately reasonable and the best available measure to determine the environmental cost of CO_2, establishing a range of values including the 2.5 percent, 3.0 percent, and 5 percent discount rates, with the following amendments:

a. The FSCC values will be re-calculated to reflect a shortened time horizon extending to the year 22002100.

b. The FSCC values will be re-calculated using an equilibrium climate sensitivity in "the lower part of the range from 1.5°C to 4.5°C" pursuant to the IPCC's Fifth Assessment Report, which would equate to a conservative average or central ECS of 2.5°C if one were to use one number for computational purposes.

c. The FSCC will be re-calculated using either discount rates of 3, 5, and 7 percent or using a usage-averaged discount rate of 5.66%, based on the 3% consumption rate of interest identified by the IWG[438] (33.3%) and a conservative 7%[439] average before-tax real rate of return to private capital in the U.S. Economy (66.6%). The Commission will exclude the value derived from the 95th percentile at a 3 percent discount rate value from the range of values.

d. The FSCC will be re-calculated using the average ton.

e. The FSCC will be re-calculated using a local, *i.e.*, Minnesota, damages assessment.

1 (XCEL EXCEPTION). The Administrative Law Judge respectfully recommends that the Commission adopt Xcel Energy's proposed CO_2 environmental cost range the Federal Social Cost of Carbon as reasonable and the best available measure to determine the environmental cost of CO_2, as presented below in 2014 dollars per short ton of CO2 emitted.[440]

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[438] Ex. 102 (Polasky Rebuttal) at Schedule 1 (July 2015 IWG Response to Comments) at 22.

[439] As set forth above, the Commission has as recently as May 8, 2015, approved Xcel's capital structure and the rate of return at a weighted pre-tax cost of 7.35% for 2014 and 7.38% for 2015 in Xcel Energy's Minnesota Electric Rate case, using a 9.72% cost of equity. (See May 8, 2015, Findings of Fact, Conclusions, and Order in Docket No. E-002/GR-13-868 at 61-62.)

[440] Table is from Ex. 601 (Martin Rebuttal) at 8.

Range proposed for Commission adoption	Emission year				
	2010	2020	2030	2040	2050
Low	$9.62	$12.13	$14.29	$16.62	$19.07
High	$33.43	$41.40	$49.02	$57.34	$66.22

2. The Administrative Law Judge respectfully recommends 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, as suggested by Xcel in this proceeding.

2 (MLIG EXCEPTION). The Administrative Law Judge respectfully recommends 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, as suggested by the Utilities, the MLIG, and Xcel in this proceeding, and that the Commission meanwhile express its Order in dollars per (short or metric) *net* ton.

2 **(XCEL EXCEPTION)**. Strike ALJ Recommendation 2 in its entirety.

PEABODY ENERGY PROPOSAL

a. The preponderance of the evidence shows the CO_2 externality cost is zero is proper.

b. If the Commission does not adopt a zero value, then in the alternative, it should use a range near the status quo values of $0.44 To $4.53 (2014$/Ton) – a range of $0.30-$2.00/Ton, and in no case higher than $4.00- $6.00/Ton.

GRE/MP/ OTP PROPOSAL

Adopt a modified version of the FSCC based upon the same economic framing assumptions used by the Commission in setting the current CO_2 ECV – a time horizon extending to 2100, use of an average cost approach to calculate marginal ton, 3.0 percent and 5.0 percent discount rates, and global damages.

WITNESS PROPOSALS

- Mendelsohn Proposal   (Peabody)
- Tol Proposal   (Peabody)
- Bezdek Proposal   (Peabody)
- Smith Proposal   (GRE/MP/OTP, "Utilities")

- Gayer Proposal   (MLIG)
- Martin Proposal   (Xcel)

Attachment 1: Exhibit 307, Table 4A – Revision to Table 4 from the Expert Report of Dr. Anne Smith

TABLE 4A

Summary of SCC Estimates for Alternative Values, Including Average Ton.[1]

	# changes from base inputs	Discount Rate	Time Horizon	Geographic Scope	Which Tonne	2020 SCC Value (2007$ /net tonne)	2020 SCC Value (2014$ /net tonne)
1.	0	3%	2300	Global	Last	$42.14	$46.88
2.	1	3%	2140	Global	Last	$32.53	$36.19
3.	1	3%	2100	Global	Last	$22.14	$24.63
4.	1	5%	2300	Global	Last	$12.03	$13.39
5.	2	5%	2140	Global	Last	$10.70	$11.90
6.	2	5%	2100	Global	Last	$9.03	$10.05
7.	1	7%	2300	Global	Last	$4.84	$5.38
8.	2	7%	2100	Global	Last	$4.26	$4.74
9.	1	3%	2300	U.S.	Last	$6.88	$7.65
10.	2	3%	2140	U.S.	Last	$5.36	$5.96
11.	2	3%	2100	U.S.	Last	$3.97	$4.42
12.	2	5%	2300	U.S.	Last	$2.28	$2.54
13.	3	5%	2140	U.S.	Last	$1.99	$2.22
14.	3	5%	2100	U.S.	Last	$1.77	$1.97
15.	2	7%	2300	U.S.	Last	$1.03	$1.15
16.	3	7%	2100	U.S.	Last	$0.92	$1.03
17.	1	3%	2300	Global	First	$27.59	$30.70
18.	2	3%	2140	Global	First	$21.55	$23.98
19.	2	3%	2100	Global	First	$15.55	$17.30
20.	2	5%	2300	Global	First	$8.43	$9.38
21.	3	5%	2140	Global	First	$7.65	$8.51
22.	3	5%	2100	Global	First	$6.70	$7.45
23.	2	7%	2300	Global	First	$3.65	$4.06
24.	3	7%	2100	Global	First	$3.33	$3.70
25.	2	3%	2300	U.S.	First	$4.83	$5.37
26.	3	3%	2140	U.S.	First	$3.88	$4.32
27.	3	3%	2100	U.S.	First	$3.05	$3.40
28.	3	5%	2300	U.S.	First	$1.76	$1.96
29.	4	5%	2140	U.S.	First	$1.59	$1.77
30.	4	5%	2100	U.S.	First	$1.46	$1.62
31.	3	7%	2300	U.S.	First	$0.87	$0.96
32.	4	7%	2100	U.S.	First	$0.81	$0.90

[1] The Average Ton figures in Table 4A are derived by taking the average of the first and last ton figures for a given discount rate, geographic scope, and time horizon set forth in Table 4 in the Expert Report of Anne Smith. For example, the average ton for a 3% discount rate, 2300 time horizon, and global scope in Line 33 is derived by taking the averages of the first (line 17) and last ton (line 1) for the same discount rate, time horizon, and global scope.

(Cont'd)

	# changes from base inputs	Discount Rate	Time Horizon	Geographic Scope	Which Tonne	2020 SCC Value (2007$ /net tonne)	2020 SCC Value (2014$ /net tonne)
33.	1	3%	2300	Global	Average	$34.87	$38.79
34.	2	3%	2140	Global	Average	$27.04	$30.09
35.	2	3%	2100	Global	Average	$18.85	$20.97
36.	2	5%	2300	Global	Average	$10.23	$11.39
37.	3	5%	2140	Global	Average	$9.18	$10.21
38.	3	5%	2100	Global	Average	$7.87	$8.75
39.	2	7%	2300	Global	Average	$4.25	$4.72
40.	3	7%	2100	Global	Average	$3.80	$4.22
41.	2	3%	2300	U.S.	Average	$5.86	$6.51
42.	3	3%	2140	U.S.	Average	$4.62	$5.14
43.	3	3%	2100	U.S.	Average	$3.51	$3.91
44.	3	5%	2300	U.S.	Average	$2.02	$2.25
45.	4	5%	2140	U.S.	Average	$1.79	$1.99
46.	4	5%	2100	U.S.	Average	$1.62	$1.80
47.	3	7%	2300	U.S.	Average	$0.95	$1.06
48.	4	7%	2100	U.S.	Average	$0.87	$0.97