

OAH 80-2500-31888
MPUC E-999/CI-14-643

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

In The Matter of the Further Investigation into
Environmental and Socioeconomic Costs
under Minnesota Statute § 216B.2422,
Subdivision 3.

**PROPOSED FINDINGS OF FACT,
CONCLUSIONS OF LAW,
AND RECOMMENDATIONS**

CARBON DIOXIDE

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APPEARANCES

An evidentiary hearing was held before Administrative Law Judges LauraSue Schlatter and J. Jeffery Oxley on September 24-25 and September 28-30, 2105, in St. Paul, Minnesota. The following appearances were made:

Kevin Reuther and Leigh K. Currie, Minnesota Center for Environmental Advocacy (“MCEA”), appeared on behalf of MCEA, Fresh Energy, and Sierra Club (referred to collectively as “Clean Energy Organizations” or “CEOs”).¹

Linda S. Jensen, Assistant Attorney General, appeared on behalf of the Minnesota Department of Commerce, Division of Energy Resources (“Department”), and the Minnesota Pollution Control Agency (“MPCA”) (referred to collectively as “Agencies”).

Tristan L. Duncan, Shook, Hardy & Bacon, LLP, Kansas City, Missouri, and Jonathan S. Massey, Massey & Gail, LLP, Washington, DC, appeared on behalf of Peabody Energy Corporation (“Peabody”).

B. Andrew Brown and Hugh D. Brown, Dorsey & Whitney, LLP, appeared on behalf of Great River Energy, Minnesota Power, and Otter Tail Power Company (“Otter Tail Power”) (referred to collectively as “GRE/MP/OTP”).

Marc A. Al and Andrew J. Moratzka, Stoel Rives, LLP, appeared on behalf of Minnesota Large Industrial Group (“MLIG”).

James R. Denniston, Assistant General Counsel, appeared on behalf of Northern States Power Company, d/b/a Xcel Energy (“Xcel Energy”).

Kevin P. Lee, Attorney at Law, appeared on behalf of Dr. Bruce Synder, Dr. Phillip Murray, Dr. Michael Menzel, Minnesota Public Health Association, and the Twin Cities Medical Society (referred to collectively as “Doctors for a Healthy Environment”).

Jessica Dexter, Environmental Law & Policy Center, appeared on behalf of the Wind on the Wires, Midwest Renewable Energy Association, and Solar Energy Industries Association (referred to collectively as “Clean Energy Business Coalition”).

Tricia DeBleekere and Sean Stalpes participated as representatives of the staff of the Minnesota Public Utilities Commission (“Commission”).

¹ Although they were among the petitioners who requested the reopening of the investigation into environmental cost values, Center for Energy and the Environment and Will Steger Foundation withdrew as parties on November 4, 2014, and Izaak Walton League of America – Midwest office withdrew as a party on October 30, 2015. *See* Amended Notice of Appearances (Nov. 4, 2014), and Amended Notice of Appearance (Oct. 30, 2015).

STATEMENT OF ISSUES

This proceeding was bifurcated into two phases. Testimony regarding the appropriate values for carbon dioxide (“CO₂”) was filed separately from testimony regarding the appropriate values for three criteria pollutants -- sulfur dioxide (“SO₂”), nitrogen oxides (“NO_x”) and particulate matter less than 2.5 microns in diameter (“PM_{2.5}”). Separate evidentiary hearings were also held for each phase. The issues addressed in this CO₂ phase of the proceeding are:

1. Whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO₂ under Minn. Stat. § 216B.2422.
2. If the Federal Social Cost of Carbon is not reasonable and the best available measure to determine the CO₂ environmental cost value, what measure is better supported by the evidence.

Based upon the proceedings herein, the Administrative Law Judge (“ALJ”) makes the following:

FINDINGS OF FACT

I. PROCEDURAL HISTORY

1. On October 9, 2013, CEOs -- at that time composed of MCEA, Fresh Energy, Sierra Club, Izaak Walton League of America – Midwest Office, Will Steger Foundation, and Center for Energy and the Environment -- filed a petition in Docket No. E-999/CI-00-1636 requesting the Commission update the environmental cost values established under Minn. Stat. § 216B.2422, subd. 3. Notice of Motion and Motion to Update Externality Values of Use in Resource Decisions, Docket No. E-999/CI-00-1636 (Oct. 9, 2013). The CEOs alleged the established environmental cost values were “no longer supported by scientific evidence,” and requested the investigation be reopened. *Id.* at 1. The CEOs also recommended that the Commission adopt the Federal Social Cost of Carbon developed for use in analyzing proposed federal regulations to determine Minnesota’s CO₂ environmental cost value. Memorandum in Support of CEOs’ Motion to Update Externality Values for Use in Resource Decisions, Docket No. E-999/CI-00-1636 (Oct. 9, 2013) at 18-19.

2. On February 10, 2014, the Commission issued an order that reopened its investigation into the environmental costs of different methods of generating electricity under Minn. Stat. § 216B.2422, subd. 3. *See* Order Reopening Investigation and Convening Stakeholder Group to Provide Recommendations for Contested Case Proceeding, Docket No. E-999/CI-00-1636 (Feb. 10, 2014) at 2 (“Reopening Order”). In doing so, the Commission concluded there was an “adequate basis to consider updating or expanding the environmental cost values established under Minn. Stat. § 216B.2422, subd. 3.” *See id.* at 5. The Commission confirmed that the scope of the investigation would not include a reexamination of its earlier decision not to apply the CO₂ environmental cost value to facilities in North Dakota. *Id.* The Commission also determined it would refer the matter to the Office of Administrative Hearings (“OAH”). *Id.* The Commission requested, however, that prior to the formal referral of the matter, that the Agencies convene a stakeholder group to provide further recommendations on the scope of an investigation, whether the Commission should engage an expert as authorized by Minn. Stat. § 216B.62, subd. 8, and the possible role of such an expert. *Id.*

3. On April 1, 2014, the Agencies issued notice that a stakeholders meeting would be held on April 24, 2014. *See* Notice of Stakeholder Group Meeting, Docket No. E-999/CI-00-1636 (Apr. 1, 2014).

4. The stakeholder meeting was convened by the Agencies on April 24, 2014. *See* Agencies Comments, Docket No. E-999/CI-00-1636 (June 10, 2014). The meeting was attended by representatives of the Commission, the Agencies, MCEA, Fresh Energy, Izaak Walton League, Minnesota Power, Otter Tail Power Company, Great River Energy, Sierra Club, MLIG, Chamber of Commerce, Lignite Energy Council, and Xcel Energy, among others. *Id.* at 4-5. The Agencies and the stakeholders discussed the possible role of an expert, potential criteria for use in evaluating potential options for the scope of a contested case proceeding, and possible scenarios for such a proceeding. *See id.* at Attachment C.

5. On June 10, 2014, the Agencies filed their report on the conclusions reached by the stakeholder group. *Id.* They reported there was little consensus among the stakeholders regarding the scope and processes for the investigation, or on the need and role for an expert. *Id.* at 3. In addition, the Agencies recommended, without consulting with or obtaining the support of the stakeholders, that the Commission adopt the Federal Social Cost of Carbon mid-point values for CO₂, which had been recently adopted by the federal government for use in federal regulatory impact analyses. *Id.* at 15. The Agencies urged the Commission to adopt the Federal Social Cost of Carbon for the following reasons: (1) it would not be an efficient use of ratepayer funds to hire a consultant to develop a CO₂ externality value when values developed by the federal government exist; (2) the Agencies were unaware of any different data sets or computational methods that would yield results different than the Federal Social Cost of Carbon or that would provide more refined results for an individual state; (3) a Minnesota contested case proceeding would be extremely costly, time consuming and duplicative; (4) the Federal Social Cost of Carbon measured global damages, in conformance with existing commission precedent; and (5) the Federal Social Cost of Carbon used a marginal cost approach, in accordance with established practice in resource plan development in Minnesota. *See id.* at 14-15.

6. On June 16, 2014, the Commission requested comments on the Agencies' report and recommendations. *See* Notice of Comment Period on Agencies' Report, Docket No. E-999/CI-00-1636 (June 16, 2014) at 1. Comments were received from the State of North Dakota, CEOs, Peabody, GRE/MP/OTP, Lignite Energy Council, Xcel Energy, MLIG, and Minnesota Chamber of Commerce. *See* Notice and Order for Hearing, Docket No. E-999/CI-00-1636 (Oct. 15, 2014) ("Order for Hr'g"). The State of North Dakota requested clarification that North Dakota facilities would not be included in the scope of the investigation. *See* North Dakota Comments, Docket No. E-999/CI-00-1636 (June 25, 2014) at 2. CEOs supported the Agencies' recommendation that the Commission adopt the Federal Social Cost of Carbon without a contested case proceeding. *See* CEOs Comments, Docket No. E-999/CI-00-1636 (June 26, 2014) at 2. The remaining parties – Peabody, GRE/MP/OTP, Lignite Energy Council, MLIG, Xcel Energy, and Minnesota Chamber of Commerce – urged the Commission to proceed with a contested case. *See* Minn. Chamber of Commerce Comments, Docket No. E-999/CI-00-1636 (June 26, 2014) at 3; GRE/MP/OTP Comments, Docket No. E-999/CI-00-1636 (June 26, 2014) at 1; LEC Comments, Docket No. E-999/CI-00-1636 (June 26, 2014) at 2; Peabody Comments, Docket No. E-999/CI-00-1636 (June 26, 2014) at 3; MLIG Comments, Docket No. E-999/CI-00-1636 (June 26, 2014) at 2; Xcel Energy Comments (June 26, 2014) at 3.

7. On September 4, 2014, the matter of what further determinations the Commission should make with respect to its referral of the docket to the OAH came before the Commission. Order for Hr’g, *supra*, at 2. Thereafter, on October 15, 2014, the Commission issued an order referring the issue of the appropriate value for CO₂, as well as for the criteria pollutants PM_{2.5}, SO₂, NO_x, under Minn. Stat. § 216B.2422, subd. 3 to the OAH for contested case proceedings. *Id.* at 8.

8. In its October 15, 2015 Order, the Commission stated that it would investigate the appropriate cost values for PM_{2.5}, SO₂, NO_x, and CO₂, and that it had decided not to further investigate non-CO₂ greenhouse gases. Order for Hr’g, *supra*, at 4. The Commission further determined it would be premature to adopt the Federal Social Cost of Carbon values for CO₂ and affirmed its earlier decision to refer the issue of the appropriate values for CO₂, as well as criteria pollutants, to the OAH for contested case proceedings. *Id.* Accordingly, the Commission ordered the parties to “specifically and thoroughly address” the following issues with respect to updating the CO₂ value: (1) “whether the Federal Social Cost of Carbon is reasonable and the best available measure to determine the environmental cost of CO₂ ...”, and (2) “if not, what measure is better supported by the evidence.” *Id.* at 8. The Commission further ordered the parties to evaluate costs using a damage cost approach. *Id.* at 4. The Commission noted: “Where a damage cost can be reasonably estimated, it represents a superior method of evaluating an emission’s environmental cost.” *Id.* at 5. The Commission also observed that it had concluded in the last proceeding that “the damage-cost approach was superior because it focused on actual damages from uncontrolled emissions” and that nothing justified a different conclusion now. *Id.* at 4-5.

9. The matter was referred to the OAH and was assigned to Administrative Law Judge LauraSue Schlatter. Administrative Law Judge Jeffrey Oxley was also later assigned to the matter.

10. Following a prehearing conference on November 14, 2014, the ALJ issued the first pre-hearing order on December 9, 2014. First Prehr’g Order, Docket No. E-999/CI-14643 (Dec. 9, 2014) (“First Prehr’g Order”). This order separated the contested case proceeding into two phases so that testimony concerning the CO₂ value would be filed separately from the testimony concerning the environmental cost values for the criteria pollutants. *Id.* at 3-4. In her order, the ALJ also ordered briefing on the question of the burden of proof, developed a public notice plan, and adopted a schedule for the filing of written testimony, the evidentiary hearing, and post-hearing briefing. *See id.* at 3-7. The ALJ recognized the CEOs (composed of MCEA, the Izaak Walton League of America – Midwest Office, Fresh Energy, and Sierra Club), Minnesota Department of Commerce, Division of Energy Resources, and Peabody Energy Corporation as parties to this matter as named in the Commission’s Notice and Order for Hearing issued on October 15, 2014. *Id.* at 2. The ALJ also admitted to this proceeding the following parties, in order of the date of their petitions to intervene: Otter Tail Power Company, Minnesota Power, Lignite Energy Council, Northern States Power d/b/a Xcel Energy, Minnesota Large Industrial Group, Great River Energy, and Minnesota Chamber of Commerce. *Id.*

11. On February 4, 2015, several parties submitted memoranda addressing the question of the burden of proof. *See generally*, First Prehr’g Order, *supra*, at 4 (initial proceeding schedule). Responsive memoranda were filed on February 18, 2015.

12. On March 5, 2015, the ALJ issued a Protective Order. Protective Order, Docket No. E-999/CI-14-643 (Mar. 5, 2015).

13. On March 11, 2015, the ALJ issued a Recommendation for Public Hearings and Public Notice Plan, wherein she recommended that the public should be offered the opportunity to provide input in writing as well as through public hearings. Recommendation for Public Hr'g and Public Notice Plan, Docket No. E-999/CI-14-643 (Mar. 11, 2015) at 2. She also stated her request that the Commission agree to implement and bear the cost of the public notice plan and the public hearings in this matter. *Id.* at 3.

14. On March 20, 2015, the ALJ granted the MPCA's petition to intervene as a party. Order Granting Intervention to MPCA, Docket No. E-999/CI-14-643 (Mar. 20, 2015).

15. On March 27, 2015, the ALJ issued her Order Regarding Burdens of Proof. Order Regarding Burdens of Proof, Docket No. E-999/CI-14-643 (Mar. 27, 2015). The ALJ ordered that a party proposing the Commission adopt a new CO₂ value "bears the burden of showing, by a preponderance of the evidence, that the value is reasonable and the best available measure of the environmental cost of CO₂." *Id.* at 2. A party opposing a proposal for environmental cost values (including the adoption of a new CO₂ value), the ALJ held, "must demonstrate, at a minimum, that the evidence offered in support of the proposed values is insufficient to amount to a preponderance of the evidence." *Id.* at 3. The ALJ further held that a party proposing to retain an existing environmental cost value bears the burden of showing, by a preponderance of the evidence, that the current value is reasonable and the best available measure. *Id.* at 2-3. In addition, the ALJ found that an environmental cost value currently being applied by the Commission is presumed to be practicable, as required by Minn. Stat. § 216B.2422, subd. 3, and that a party "challenging an existing cost value on the grounds that it is not practicable bears the burden of demonstrating impracticability by a preponderance of the evidence." *Id.* at 3.

16. In her Third Prehearing Order issued on April 16, 2015, the ALJ encouraged the parties to file pre-filed testimony, briefs, or other pleadings jointly to the extent appropriate and consistent with their positions and interests. Third Prehr'g Order, Docket No. E-999/CI-14-643 (Apr. 16, 2015) at 1. The ALJ also encouraged the parties to share responsibility for cross examination of witnesses. *Id.* Finally, the ALJ stated that "[t]estimony regarding the efficacy of renewable energy or renewable energy policy is presumed to be irrelevant" to the issues raised in the Commission's Notice and Order for Hearing. *Id.* at 2. She held that "[a]ny such testimony will be excluded unless its relevance is specifically demonstrated." *Id.*

17. On April 16, 2015, the ALJ granted the petitions to intervene as parties of Dr. Bruce Synder, Dr. Phillip Murray, Dr. Michael Menzel, Minnesota Public Health Association, and the Twin Cities Medical Society (referred to collectively as "Doctors for a Healthy Environment"), Wind on the Wires, Midwest Renewable Energy Association, and Solar Energy Industries Association (referred to collectively as "Clean Energy Business Coalition") and Interstate Power and Light. Order Granting Intervention to Doctors for a Healthy Env't, Clean Energy Bus. Coal., and Interstate Power and Light Co., Docket No. E-999/CI-14-643 (Apr. 16, 2015).

18. On May 27, 2015, following its April 23, 2015 meeting, the Commission issued its Order Requiring Public Hearing, as recommended by the ALJ. Order Requiring Public Hr'g, Docket No. E-999/CI-14-643 (May 27, 2015) at 1.

19. The following parties filed direct CO₂ testimony on June 1, 2015: CEOs, the Agencies, Peabody, GRE/MP/OPT, MLIg, and Xcel Energy.

20. On June 2, 2015, the Commission issued its Notice of Public Hearing and Comment Period. Notice of Public Hr'g and Comment Period, Docket No. E-999/CI-14-643 (June 2, 2015). The Notice covered both the CO₂ and criteria pollutant phases of this proceeding. *See id.* at 2. The Notice advised that a public hearing would be held on August 26, 2015, at 2 p.m. in the Commission's Large Hearing Room in St. Paul, Minnesota. *Id.* at 1. It further stated this investigation was focused on three technical questions: (1) "Is the Federal Social Cost of Carbon reasonable and is it the best available measure to determine the environmental cost of CO₂?;" (2) "If not, what measure is better?;" and (3) "What are the appropriate environmental costs values for PM_{2.5}, SO₂, NO_x, and why?" *Id.* at 2. The Notice also confirmed that comments could be made verbally at the public hearing or in writing. *See id.* The deadline for written comments was September 18, 2015. *Id.*

21. On August 4, 2015, the ALJ issued her Fourth Prehearing Order, identifying the evidentiary hearing dates for the CO₂ matter as September 24-25 and 28-30, 2015 and scheduled a prehearing conference for August 14, 2015. Fourth Prehr'g Order, Docket No. E-999/CI-14-643 (Aug. 4, 2015) at 1.

22. The following parties filed CO₂ rebuttal testimony on August 12, 2015: CEOs, the Agencies, Peabody, GRE/MP/OTP, MLIg, Xcel Energy, Doctors for a Healthy Environment, and Clean Energy Business Coalition.

23. On August 13, 2015, Interstate Power and Light withdrew as a party. *See* Interstate Power and Light Withdrawal of Intervention, Docket No. E-999/CI-14-643 (Aug. 13, 2015).

24. On August 14, 2015, the ALJ held a prehearing conference.

25. On August 26, 2015, the public hearing was held. *See* Tr. of Public Hr'g, Docket No. E-999/CI-14-643 (Aug. 26, 2015). Thirty four members of the public presented testimony at the public hearing.

26. On August 28, 2015, the ALJ issued her Fifth Prehearing Order, which moved back the date of the final CO₂ prehearing conference from September 17, 2015 to September 21, 2015, and set deadlines for objections to pre-filed testimony and witnesses and for responses to such objections. *See* Fifth Prehr'g Order, Docket No. E-999/CI-14-643 (Aug. 28, 2015) at 2.

27. On September 3, 2015, the Agencies filed a motion to strike direct and rebuttal testimony of the following Peabody witnesses: Dr. William Happer, Dr. Richard Lindzen, Dr. Roger Bezdek, and Dr. Richard Tol.

28. On September 3, 2015, Peabody filed a motion to exclude the rebuttal testimony

of Clean Energy Business Coalition's witnesses Shawn Rumery and Christopher Kunkle, and a separate motion to exclude the direct and rebuttal testimony of the Department's witness Dr. Michael Hanemann and the CEOs' witness Dr. Stephen Polasky in their entirety, and the statistical opinions of Xcel Energy's witness Mr. Nicholas Martin.

29. On September 3, 2015, MLIG filed a motion to strike testimony of Dr. Hanemann, Dr. Polasky, and certain testimony of Mr. Martin.

30. The following parties filed surrebuttal testimony on September 10, 2015: the Agencies, CEOs, Peabody, GRE/MP/OTP, MLIG, and Xcel Energy.

31. On September 11, 2015, Peabody, Clean Energy Business Coalition, the Agencies, and Xcel Energy filed responses to motions to strike or exclude testimony.

32. On September 15, 2015, Peabody filed a motion to exclude the surrebuttal testimony of the CEOs' witness Dr. Peter Reich in its entirety, and certain testimony of the CEOs' witnesses Dr. John Abraham and Dr. Andrew Dessler, and the Agencies' witness Dr. Kevin Gurney.

33. On September 15, 2015, MLIG filed a motion to strike the surrebuttal testimony of Dr. Peter Reich.

34. On September 15, 2015, the ALJ issued an order that denied the Agencies' motions to strike direct and rebuttal testimony of Dr. Lindzen, Dr. Bezdek, and Dr. Tol; granted the Agencies' motion to strike certain rebuttal testimony of Dr. Happer; and denied Peabody's motions to exclude the testimony of Mr. Rumery and Mr. Kunkle. Order on Motions by Peabody and the Agencies to Exclude and Strike, Docket No. E-999/CI-14-643 (Sept. 15, 2015) at 2.

35. On September 15, 2015, the ALJ issued an order that denied the motions of MLIG and Peabody to exclude all testimony of Dr. Hanemann and Dr. Polasky, as well as their motions to exclude certain parts of Mr. Martin's testimony dealing with Mr. Martin's statistical approach to determining the CO₂ environmental cost value. Order on Motions by MLIG and Peabody to Exclude and Strike, Docket No. E-999/CI-14-643 (Sept. 15, 2015) at 2.

36. On September 18, 2015, the Agencies filed their response to Peabody's motion to exclude surrebuttal testimony of Dr. Gurney.

37. On September 18, 2015, the CEOs filed their responses to MLIG's motion to strike surrebuttal testimony of Dr. Peter Reich, and to Peabody's motion to exclude Dr. Peter Reich and certain testimony of Dr. Abraham and Dr. Dessler.

38. On September 21, 2015, the ALJ issued an order that denied the motions brought by MLIG and Peabody to exclude the testimony of Dr. Reich with limited exception, and denied the motions brought by MLIG and Peabody to exclude the testimony of Dr. Abraham, Dr. Dessler, and Dr. Gurney. Order on Motions by MLIG and Peabody to Exclude and Strike, Docket No. E-999/CI-14-643 (Sept. 21, 2015) at 2.

39. On September 21, 2015, the Agencies filed a Motion to Amend Protective Order to accommodate discovery by the Agencies and to identify the MPCA as one of the government agencies that possesses protected data in this matter.

40. On September 23, 2015, the ALJ granted the Agencies' Motion to Amend Protective Order and issued an Amended Protective Order. Am. Protective Order, Docket No. E-999/CI-14-643 (Sept. 23, 2015) at 1.

41. The evidentiary hearing was conducted over five days: September 24-25, 2015 and September 28-30, 2015. Thirteen witnesses testified during the evidentiary hearing. The following parties appeared at the evidentiary hearing: the Agencies, CEOs, Peabody, GRE/MP/OTP, MLIG, Xcel Energy, Doctors for a Healthy Environment, and Clean Energy Business Coalition.

42. On November 12, 2015, the parties who appeared at the evidentiary hearing filed their CO₂ Issues Lists.

43. The following parties submitted initial briefs in this matter on November 24, 2015: CEOs, the Agencies, Peabody, GRE/MP/OTP, MLIG, Xcel Energy, Clean Energy Business Coalition, and Doctors for a Healthy Environment.

44. Reply briefs and proposed findings of fact were submitted by _____ on December 15, 2015. On the same date, comments on the CO₂ Issues Lists were filed by _____.

II. COMMENTS FROM THE PUBLIC

45. On August 26, 2015, approximately thirty four members of the public presented testimony at a public hearing held in St. Paul, Minnesota.²

46. Several members of the public urged the adoption of a very high number for Minnesota's environmental cost values for CO₂. *See e.g.*, Public Hearing Transcript, Docket No. E-999/CI-14-643 (Aug. 26, 2015) at 36:17-20 (Lutz). Some members of the public stated the current value for CO₂ was too low. *See e.g.*, *id.* at 38:17-19 (Lutz). Concerns were raised regarding the effects of climate change, including warmer seasons, the increases severity of floods, droughts, hotter cities, and other byproducts of higher temperatures. *See id.* at 39:22-25 (Boxer), 63:9-17 (Foushee), 77:24-78:9 (Kerr).

47. Several members of the public supported the adoption of the Federal Social Cost of Carbon. *See* Public Hearing Transcript, Docket No. E-999/CI-14-643 (Aug. 26, 2015), at 42:20-44-17 (Bourgoin), 57:22-58:6 (Yonjon), 66:22-67:5 (Hietala), 108:4-9 (Ruckheim), 112:14-17 (Downing). They noted loss of biodiversity, ocean acidification, more frequent and severe storms, and other side effects of climate change. *Id.* at 42:20-44-17 (Bourgoin), 111:13-23 (Asher). The effects of rising sea levels and ocean acidification on low-lying countries like Sri Lanka were also mentioned. *Id.* at 47:13-20 (Herath). Members of the public expressed

² These Findings of Fact address only the public comments offered with respect to the CO₂ environmental cost values.

concern that the Federal Social Cost of Carbon may underestimate the true cost of CO₂. *Id.* at 49:5-8 (Ross), 99:23-100-9 (Walhof), 105:18-24 (Drennen). In addition to the comments delivered orally on the record, the Sierra Club delivered approximately 2000 petitions to the ALJ, which advocated adoption of the Federal Social Cost of Carbon. *See* Ex. 10 (Sierra Club Petitions).

48. A representative of the Minnesota Rural Electric Association (“MREA”), who reported that MREA represents the 44 electric distribution cooperatives operating in Minnesota, recommended the CO₂ environmental cost values should be based on damages that can be readily identified and quantified based on credible scientific and economic analysis. Public Hearing Transcript, Docket No. E-999/CI-14-643 (Aug. 26, 2015) at 102:4-9 (Horan). He also expressed concern that if the Commission were to set an unrealistically high externality value, it could lead to increased energy prices, with little or no benefit. *Id.* at 102:19-24 (Horan).

49. The Izaak Walton League of Minnesota submitted written comments urging the Commission to accept the Federal Social Cost of Carbon as a “transparent, well-vetted value for carbon dioxide” Public Comment, Izaak Walton League, Docket No. E-999/CI-14-643 (Sept. 18, 2015) at 2.

50. In written comments, MREA recommended the Commission reject the Federal Social Cost of Carbon, stating “measured damages that Minnesotans are accountable for on a “global level” rather than a “state and/or national level” and that this measure represented an “unrealistically high value . . . for carbon dioxide emissions.” MREA Comments, Docket No. E-999/CI-14-643 (Sept. 17, 2015) at 3, 5.

III. LEGAL STANDARDS AND PRIOR PROCEEDINGS

51. In 1993, the Legislature directed the Commission “to the extent practicable” to “quantify and establish a range of environmental costs associated with each method of electricity generation.” Minn. Stat. § 216B.2422, subd. 3(a). The Legislature further required that utilities shall use these environmental cost values “in conjunction with other external factors, including socioeconomic costs, when evaluating and selecting resource options in all proceedings before the commission, including resource plan and certificate of need proceedings.” *Id.* In its entirety, the statute requiring the establishment and use of environmental cost values in resource planning and certificate of need proceedings, Minn. Stat. § 216B.2422, subd. 3, provides:

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

(b) The commission shall establish interim environmental cost values associated with each method of electricity generation by

March 1, 1994. These values expire on the date the commission establishes environmental cost values under paragraph (a).

52. After passage of this statute, the Commission initiated a proceeding to establish environmental cost values in Docket No. E-999/CI-93-583 (the “1993 Proceeding”). To meet the statutory deadline, the Commission initiated an expedited process to establish interim environmental cost values. By order dated March 3, 1994, the Commission established a range of interim values for five emissions, including CO₂. Order Establishing Interim Env'tl. Cost Values, Docket No. E-999/CI-93-583 (Mar. 3, 1994) at 7. The interim range established for CO₂ was \$5.99 to \$13.60 per ton. *Id.* at 9

53. Following the establishment of interim values, the Commission ordered the initiation of formal evidentiary hearings to set final environmental cost values. Order Establishing Interim Env'tl. Cost Values, Docket No. E-999/CI-93-583 (Mar. 3, 1994) at 7. On March 14, 1994, the Commission referred the matter under the same docket to the OAH for contested case proceedings. Findings of Fact, Conclusions, Recommendations and Mem., Docket No. E-999/CI-93-583 (Mar. 22, 1996) at 4 (“ALJ Findings”). The case was assigned to ALJ Allan W. Klein. *See id.* at 1. Due to the complexity of the issues, the proceedings were protracted. *See generally, id.* at 3-8. After extensive scoping of the issues, three rounds of prefiled testimony were filed by approximately 18 parties between November 29, 1994 and May 19, 1995. *Id.* at 6. From April 18 to April 27, 1995, six public hearings were held throughout the state, including a three-city videoconference. *Id.* Over 160 people presented testimony at the public hearings. The evidentiary hearing was conducted over 27 days from May 8 to June 28, 1995. *Id.* The parties presented testimony from over 50 witnesses. *Id.* The post-hearing briefing addressed both substantial evidentiary and legal issues, and the record was not closed until February 23, 1996. ALJ Klein filed his Findings of Fact, Conclusions, Recommendation and Memorandum on March 22, 1996. Exceptions to the ALJ’s recommendation, and response to those exceptions were filed between April 15 and April 29, 1996. On September 16 and 17, 1996, the Commission met to hear oral argument and to deliberate. The Commission held additional deliberations on September 19, 1996. The Commission issued its Order Establishing Environmental Cost Values on January 3, 1997. Docket No. E-999/CI-93-583 (“January 3, 1997 Order”).

54. The Commission’s environmental cost values were finalized after reconsideration on July 2, 1997. *See* Order Establishing Env'tl. Cost Values, *supra*; Order Affirming in Part and Modifying in Part Order Establishing Env'tl. Cost Values, Docket No. E-999/CI-93-583 (Jul 2, 1997) at 7-8 (“July 2, 1997 Order”). In its July 1997 Order, the Commission also stated that it would not apply the environmental cost value for CO₂ to facilities outside the territorial boundaries of Minnesota. *Id.* at 5. The final range of value established for CO₂ was \$0.28 to \$2.92 per ton, considerably lower than the interim range.

55. The Commission’s January 1997 and July 1997 Orders were affirmed on appeal by the Minnesota Court of Appeals. *In re Quantification of Env'tl. Costs*, 578 N.W.2d 794, 801 (Minn. Ct. App. 1998).

56. In preparing his Findings of Fact, Conclusions, Recommendation and Memorandum, ALJ Klein undertook a substantial analysis of the legal requirements and the

policy concerns relating to the establishment and quantification of environmental cost values. The Commission adopted the decisions and analysis in ALJ Klein’s Findings with respect to the CO₂ environmental cost value, and his analysis provides important guidance for updating the environmental costs values in this proceeding.

57. The Legislature has required the Commission to “quantify and establish” environmental cost values only “to the extent practicable.” The question as to what is “practicable” was a major issue in the initial investigation establishing the current environmental cost values. In his 1997 analysis, ALJ Klein held that the term “practicable” as used in Minn. Stat. § 216B.2422 describes the evidentiary standard to be applied to the establishment of environmental costs. *See* ALJ Findings, *supra*, at ¶ 29.

58. ALJ Klein found that “the term ‘practicability,’ as it is used in Section 216B.2422, must be construed according to its common and approved usage. ALJ Findings, *supra*, at ¶ 29 (citing Minn. Stat. § 645.08 (1994)). He also noted that “[t]he common and approved usage of ‘practicability’ is ‘feasible,’ or capable of being accomplished.” *Id.* (citing Webster’s New Universal Unabridged Dictionary (2d Ed. 1983)). Applied to the establishment of environmental cost values, ALJ Klein found that the phrase “to the extent practicable” should be held to refer to “consideration of the sufficiency of the data or level of uncertainty involved in quantifying values.” *Id.* at 16.

59. ALJ Klein also grappled with the issue that inevitably arises in connection with the establishment of environmental cost values for use in resource planning: how much uncertainty can be tolerated in the effort to monetize future damages. He recognized that “there are certain pollutants which are “impossible to value, in the sense that there is just not enough data in the record to establish a value for them.” ALJ Findings, *supra*, at 29. He also observed that “[a]t some point, the range of uncertainty associated with a proposed value becomes so great that there is insufficient evidence to meet the preponderance standard, and the value cannot be adopted.” *Id.* at 31.

60. ALJ Klein developed the following criteria for establishing environmental cost values:

- Only the most significant and relevant environmental impacts should be quantified.
- Only impacts created during the operational phase should be quantified.
- The adopted values should be conservative.
- Whenever possible, a damage-cost approach should be used.
- At least some of the adopted values should be geographically sensitive.

ALJ Findings, *supra*, at ¶ 36.

61. In support of his recommendation that the Commission adopt “conservative” values, ALJ Klein explained :

While using reasonably accurate estimates is better than imputing no values, not all estimates are better than zero. For instance, valuing an impact at more than twice its 'true' residual damage may lead to a worse allocation of resources than imputing no value. In other words, the possibility of utilities paying more for resources than their environmental benefits justify is just as bad as paying less than their benefits justify. Given the current uncertainty regarding the estimation process, overestimating the damages is a distinct possibility. The Commission would then be forced to order reductions in future proceedings. This "yo-yo" pattern of values would be more confusing and disruptive than a pattern of gradual increases. A better alternative is to err on the side of conservatism initially, then increase the values gradually if better information in the future confirms the need for higher values.

ALJ Findings, *supra*, at 17-18.

62. ALJ Klein recognized that in certain cases not all damages could be quantified. ALJ Findings, *supra*, at ¶ 29. He noted, however, that "the lack of quantification for a specific environmental cost is not equivalent to ignoring it for resource evaluations." *Id.* at 17. Quantification was desirable when it was practicable because it "allows for a more rigorous assessment of impacts that the Commission previously considered qualitatively." *Id.* However, when the level of uncertainty or the insufficiency of the data was too great, the Commission could "continue to consider unquantified impacts on a qualitative basis." *Id.*

63. Based on his analysis of the evidence, ALJ Klein recommended environmental cost values for particulate matter, nitrogen oxides, lead, carbon monoxide, and sulfur dioxide, as well as carbon dioxide, all of which were later adopted by the Commission. ALJ Klein, however, did not recommend the establishment of an environmental cost value for mercury. ALJ Findings, *supra*, at ¶ 144. Although he recognized that coal fired power plants were the leading source of mercury in Minnesota, he also noted "significant omissions and uncertainties in data regarding the effect of mercury emissions from electrical generators." *Id.* at ¶ 125. He concluded that, notwithstanding the fact that mercury emissions undoubtedly caused damages, there was insufficient evidence in the record to support a quantified range of environmental cost values for mercury emissions. *Id.* at ¶ 102-144.

64. To establish the range of environmental cost values for CO₂, ALJ Klein relied upon the testimony offered by Mr. Peter Ciborowski of the MPCA. Mr. Ciborowski conducted a damage-cost study based on an average cost per ton of CO₂ emissions through 2100 on a global basis. He used discount rates of 3 percent and 5 percent to discount these damages back to present value. ALJ Findings, *supra*, at 102-114.

65. Mr. Ciborowski's methodology relied on damage-cost studies which estimated global damages as a percentage of GDP. ALJ Klein found that studies which calculated damages as 1 percent of global GDP were reasonable based on the available evidence. However, ALJ Klein rejected the use of a damage calculation based on 2 percent of global Gross Domestic Product ("GDP"). He noted that, although Ciborowski sought to justify this figure based on the basis of omitted costs, assumptions, and risks, those omitted costs, assumptions, and risks had

not been valued by any witness. Accordingly, he held that the 2 percent figure was “factually unsupported by the record” and “highly speculative given the available evidence.” ALJ Findings, *supra*, at ¶ 106.

66. ALJ Klein also rejected the use of discount rates below 3 percent. Although such rates had been claimed to be “appropriate when discounting across generations,” ALJ Klein found that there was “insufficient support for this position in the record” and rejected such rates as being “unreasonably low.” ALJ Findings, *supra*, at ¶ 111-12.

67. The Commission agreed with ALJ Klein’s conclusion that damages could only be quantified where practicable. Specifically, it agreed with ALJ Klein that mercury undoubtedly causes damage, but also recognized “the legislature’s directive that the Commission is to quantify values only if (to the extent) it is feasible (practicable) to do so.” January 3, 1997 Order, *supra*, at 29, 31. The Commission explained that some level of uncertainty may be acceptable and in such a case it may be “practicable” to quantify environmental values, but that “there is also a point on the uncertainty continuum where it becomes infeasible to quantify environmental costs even though the Commission is convinced that such costs exist.” *Id.* at 30.

68. The Commission also accepted the ALJ’s recommendations with respect to the appropriate value for CO₂, and adopted a range of \$0.28 to \$2.92 per ton. January 3, 1997 Order, *supra*, at 26. The Commission agreed with the ALJ’s rejection of a damage function based on 2 percent of GDP, which was proposed to account for unquantified risks and damages, as factually unsupported and highly speculative. *Id.* at 27. It also held that there was insufficient support in the record for discount rates below 3 percent. *Id.* Consequently, the Commission adopted values based on Mr. Ciborowski’s approach. *Id.*

69. The Commission ordered that the values adopted should be used by utilities in resource plans by providing estimates of cost of resource options at three levels: (1) without regard to environmental externalities; (2) the direct cost plus the minimum values in the specified ranges; and (3) the direct cost plus the maximum values in the specified ranges. January 3, 1997 Order, *supra*, at 33. These findings were affirmed by the Commission after reconsideration in July 1997. *See* July 2, 1997 Order, *supra*.

70. On May 3, 2001, the Commission ordered that the externality values be updated to the extent possible by the Gross National Product Price Deflator Index as data becomes available from that index. Order Updating Externality Values and Authorizing Comment Periods on CO₂, PM_{2.5}, and Application of Externality Values to Power Purchases, Docket No. E-999/CI-00-1636 (May 3, 2001). The values have been updated regularly since that time, most recently on May 27, 2015. *See* Notice of Updated Environmental Externality Values, Docket No. E-999/CI-00-1636 (May 27, 2015) at 1. The current range of CO₂ values is \$0.44 to \$4.53 per short ton. *Id.* at 3.

IV. WHETHER THE FEDERAL SOCIAL COST OF CARBON IS REASONABLE AND THE BEST AVAILABLE MEASURE TO DETERMINE THE ENVIRONMENTAL COST OF CO₂ UNDER MINN. STAT. § 216B.2422

A. IWG's Development of the Federal Social Cost of Carbon

71. In general terms, the Federal Social Cost of Carbon is meant to be a comprehensive estimate of damages caused by climate change. More specifically, the Federal Social Cost of Carbon is “an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year.” Ex. 100, Schedule 2 at 1 (Polasky Direct) (“2010 TSD”).³

72. The Federal Social Cost of Carbon was developed for use in federal rulemaking. The federal agencies are required as a matter of law to assess the potential climate change impacts associated with proposed federal regulations. The impetus for the establishment of the Federal Social Cost of Carbon came from a Federal Appeals Court decision directing the Department of Transportation to update one of its Regulatory Impact Analyses⁴ to include an estimate of the Federal Social Cost of Carbon. Ex. 302 at 32 (A. Smith Report); Ex. 800 at 44 (Hanemann Direct). This requirement originated with federal Executive Order 12866 issued by President Clinton in 1993, which requires federal agencies, to the extent permitted by law, “to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” 2010 TSD at 1.

73. The Federal Social Cost of Carbon was developed by an interagency working group (“IWG”) organized in 2009. 2010 TSD at 2-3. The IWG is comprised entirely of staff of the following Federal agencies: Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of the Treasury. *See id.* The identities of the specific government personnel on the IWG is not in evidence in this proceeding, and is not publicly available. Evidentiary Hearing (Sept. 24, 2015) Vol. 1 at 87:17-88:12 (Polasky).

74. The IWG first published the Federal Social Cost of Carbon values in a Technical Support Document (“TSD”) in February 2010. *See* 2010 TSD at 1. A second TSD was published in May 2013, reflecting changes to the underlying models made in new versions of those models. Ex. 100, Schedule 3 at 1 (Polasky Direct) (“2013 TSD”). The May 2013 revisions did not contain any modifications to the IWG’s methodology or modeling choices. *Id.* at 1.

75. Neither the Federal Social Cost of Carbon values published in the 2010 TSD nor

³ Technical Support Documents are publications prepared by the IWG in which it publishes the values for the Federal Social Cost of Carbon, and explains the process and rationale for those values. *See* 2010 TSD at 1.

⁴ “Regulatory Impact Analysis” is a detailed and systematic appraisal of the potential impacts of a proposed regulation. *See* Executive Order 12866 (available at http://reginfo.gov/public/jsp/Utilities/EO_12866.pdf).

those published in the 2013 TSD were subject to public comment or peer review. *See* 2013 TSD, at 1; 2010 TSD at 2-3. The first and only notice soliciting public comments on the Federal Social Cost of Carbon was issued by the federal Office of Management and Budget (“OMB”) on November 26, 2013. Ex. 101, Schedule 1, at 2 (Polasky Rebuttal) (“Response to Comments”). Over 100 comments were received. *Id.* at 4. In July 2015, the IWG published a Response to Comments, in which it summarized and responded to these comments. *See generally, id.*

76. In developing the Federal Social Cost of Carbon, the IWG relied on three Integrated Assessment Models (“IAMs”). 2010 TSD at 5. IAMs are models which “combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework.” *Id.* The IAMs used by the IWG are known as DICE, PAGE, and FUND. *Id.* The DICE model (Dynamic Integrated Climate and Economy) was first developed in 1990 by William Nordhaus. *Id.* at note 2. The PAGE model (Policy Analysis of the Greenhouse Effect) was first developed in 1992 by Chris Hope. *Id.* The FUND model (Climate Framework for Uncertainty, Negotiation, and Distribution) was developed by Richard Tol in early 1990. *Id.* DICE was originally constructed as an optimization model, the purpose of which is to determine the optimal levels of investment in emissions reduction so as to maximize wellbeing, (i.e., the levels where marginal costs are equivalent with marginal benefits). *See* Ex. 800 at 37 (Hanemann Direct). FUND and PAGE were originally designed as simulation models, which calculate likely values for CO₂ damages based on external inputs but they cannot determine the optimal levels of emission reductions. *See id.* at 38; Ex. 214 at 10 (Mendelsohn Direct).

77. The primary virtue of the DICE, PAGE, and FUND IAMs is that all contain “simplified” representations of economic models, climate models, and impact models that allow integration of climate processes, economic growth, and interaction between climate and the economy. *See e.g.,* Ex. 800 at 42 (Hanemann Direct).

78. The IWG also noted that, despite their usefulness, the IAMs suffer from significant drawbacks:

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult.

2010 TSD at 5.

79. The Federal Social Cost of Carbon is an estimate of damages due to the emission

of an incremental unit of CO₂ – not just total damages from existing atmospheric CO₂ levels. Ex. 600 at 15 (Martin Direct). The underlying calculation involves “comparing the incremental emission to a reference case without that emission.” *Id.* In other words, the damages caused by CO₂ emissions projected to occur over the next 285 year period (2015 to 2300) are compared with the damages estimated to be caused over that same period of time by the “baseline” level of emissions plus one additional unit of emissions. *See* 2010 TSD at 24. The two damage estimates (i.e., baseline vs. baseline plus one incremental unit) are converted to net present value at various discount rates. Ex. 600 at 15 (Martin Direct). The SCC is then the difference in damages, per ton of CO₂ emission, between the two cases. *Id.*

80. There are three basic analytical steps involved in using IAMs to calculate an environmental cost value for CO₂. Ex. 600 at 16-17 (Martin Direct).

81. The first step involves forecasting future emissions based on assumptions about population growth, GDP growth, and the CO₂ intensity of the technologies that fuel GDP growth. Ex. 600 at 15 (Martin Direct).

82. The second step involves translating the emissions estimate calculated in step one into temperature change. Ex. 600 at 15 (Martin Direct). This step is performed within the IAMs, and depends on assumptions about the global carbon cycle, radiative forcing, and equilibrium climate sensitivity, which is the increase in global average surface temperature resulting from a doubling of the atmospheric CO₂ concentration relative to pre-industrial levels. Ex. 600 at 16-17 (Martin Direct).

83. The third step involves translating the estimated temperature changes into estimated climate damages. In this step, the IAMs are using “damage functions,” or formulas which model the assumed relationship between temperature increase and economic damages. Ex. 600 at 17 (Martin Direct).

84. The IWG made two types of significant modifications to the models so that they could be used together in developing the Federal Social Cost of Carbon. First, it removed the optimization feature in the DICE model so all of the models were operated in a simulation mode. *See* Ex. 800 at 47 (Hanemann Direct). Second, it standardized certain key inputs. To do so, the IWG replaced certain inputs selected by the models’ creators with alternative inputs selected by the IWG. *See id.* at 47-50. These inputs included the underlying socioeconomic data, and the framing assumptions employed for the modeling horizon, the climate sensitivity parameter, and the discount rate. *See id.* at 47-54.

85. The socioeconomic data necessary to run the IAMs includes estimates of future population, income, emissions, and non-CO₂ radiative forcing. 2010 TSD at 15. For this data input, the IWG used five sets of GDP, population, and carbon emissions trajectories based on the Stanford Energy Modeling Forum’s 22nd model inter-comparison study (“EMF-22”). *Id.* Four of the five scenarios chosen represent future trajectories in which no significant changes in the current CO₂ emissions trajectory is achieved. *Id.* The fifth scenario represents an emissions pathway that achieves stabilization at 550 parts per million CO₂ in 2100. *Id.*

86. For the modeling horizon, the IWG selected the year 2300; in other words, the

models were adjusted to calculate climate damages through the year 2300. *See* 2010 TSD at 25. As originally designed, each of the models had a different default end year: 2200 for PAGE, 2595 for DICE, and 3000 for FUND. *Id.* The IWG determined that its multi-model approach required a common modeling horizon because “differences in SCC estimates may arise simply due to the model time horizon.” *Id.* The IWG selected 2300, noting that “[m]any consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting.” *Id.*

87. The use of a 2300 time horizon also required the IWG to make additional assumptions about the GDP, population, and greenhouse gas emission trajectories because the EMF-22 socioeconomic projections used ran only through the year 2100. As a result, the IWG extrapolated the inputs from 2100 to 2300 using its own assumptions about declining population growth rates, GDP per capita growth rates, decline in carbon intensity, net land use CO₂ emissions, and non-CO₂ radiative forcing. 2010 TSD at 43-44.

88. The IWG also selected a climate sensitivity parameter distribution to standardize the IAMs. 2010 TSD at 12-13. This distribution represents the effect of increased CO₂ concentrations on global temperatures. *Id.* Equilibrium climate sensitivity is expressed in degrees, and refers to the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO₂ concentration relative to pre-industrial levels. *Id.* at 12.

89. The IWG concluded that the most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate (“IPCC”) (the “IPCC Fourth Assessment”). 2010 TSD at 12. The IPCC Fourth Assessment concluded that the ECS was likely to lie in the range 2°C to 4.5°C, with a mostly likely value of about 3°C (concluding, in other words, that the likely temperature increase from a doubling in CO₂ levels was between 2 °C and 4.5 °C). *Id.* at 12-13. The IWG consulted with several authors of the IPCC Fourth Assessment and selected an ECS distribution prepared by Roe and Baker (2007). *Id.* at 13.

90. The IWG also selected a common set of discount rates to use to discount future values of emissions damages back to present value. 2010 TSD at 23. The IWG replaced the discount rates used by the modelers with three discount rates: 2.5 percent, 3 percent, and five percent. *Id.* The IWG acknowledged that this approach was a departure from standard federal practice. *See id.* at 17. OMB Circular A-4, which was issued by OMB in 2003 to provide guidance to federal agencies on the development of regulatory impact analyses,⁵ states that “[f]or rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4.” *Id.* The IWG, however, omitted the 7 percent value and included a 2.5 percent value. *See generally, id.* at 17-23.

91. The IWG recognized that the three percent value is consistent with estimates provided in the economics literature and OMB’s circular A-4 guidance for the consumption rate of interest. 2010 TSD at 23. It pointed out that three percent corresponds to the after-tax interest rate. *Id.* The IWG also noted that the upper value of five percent is included “to represent the

⁵ Ex. 800, Schedule 6, at 4 (Hanemann Direct).

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.” *Id.*

92. The IWG’s decision to include a 2.5 percent discount rate, notwithstanding the absence of such a rate in OMB Circular A-4, has been very controversial. The IWG justified the inclusion of this lower rate due to “concern that interest rates are highly uncertain over time.” 2010 TSD at 23 (citing Newell and Pizer (2003)). It also noted that “[u]se of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher” as placing too little value on the welfare of future generations. *Id.*

93. Notably, the IWG’s Federal Social Cost of Carbon values are based on global damages, not U.S. Damages. *See* 2010 TSD at 10. The IWG acknowledged that “[u]nder current OMB guidance contained in circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional.” *Id.* However, the IWG noted that “the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve.” *Id.* For these reasons, the IWG concluded that using a global rather than a domestic value was the appropriate approach. *See id.* at 11.

94. A significant feature of the way the IAMs are designed is that they compute the damages value for a given ton as if that ton was the very last ton to be emitted during the chosen modeling horizon. *See* Ex. 602 at 52-53 (Smith Report). In other words, the IAMs calculate damage for a given increment of CO₂ by computing the marginal damage from injecting one additional increment, or unit, of CO₂ into the atmosphere in a single given year, while leaving all future years’ emissions fixed at their baseline levels. *See id.* Therefore, the incremental damages for emissions changes in the year in question are treated as if they are emitted after all baseline emissions have been emitted, regardless of when those emissions are projected to actually occur. *See id.*

95. Having selected its models and model inputs, the IWG ran the models repeatedly, each time randomly selecting values for uncertain parameters with specified probability distributions – most significantly, for the ECS value. Ex. 600 at 18 (Martin Direct). The IWG assumed a probability distribution for ECS and ran the IAMs in “Monte Carlo” mode, obtaining 10,000 values for each of the 15 scenarios. *Id.* The IWG then discounted these distributions back to present value using each of its three selected discount rates. *See id.* Accordingly, it obtained three distributions of 150,000 values – one for each discount rate. 2010 TSD at 1.

96. The IWG published the average of all 150,000 model outputs at each of the three discount rates. Ex. 600 at 19 (Martin Direct). It also published the 95th percentile value of the three percent discount rate. *Id.* The IWG published four values for each emission year in its 2010 TSD. *See id.* For emission year 2010, these values (in 2007 dollars) were \$4.70, \$21.40,

\$35.10, and \$64.90 per metric ton. 2010 TSD at 1.

97. Under the IWG’s approach, separate values apply for each year in which emissions occur. *See* 2010 TSD at 1. For each successive, year, these values increase. *See id.* For example, values in 2050 are \$26.00, \$71.00, \$97.00, and \$220.00 – significantly higher than the 2010 values. *See id.* These values increase because the IAMs assume that a ton of CO₂ emitted in a later year will cause more damage than a ton emitted earlier, since in a later year the climate system is projected to be more stressed due to higher future atmospheric concentrations, and larger societies are projected to have greater climate damage vulnerability. Ex. 600 at 20 (Martin Direct).

98. In 2013, the IWG adopted a second Technical Support Document (the “2013 TSD”), in which it updated these values based on new versions of DICE, PAGE, and FUND. *See generally* 2013 TSD. The new values for 2013, based (as was done for the 2010 values) on the average value of all model outputs at each discount rate, along with the 95th percentile at the 3 percent discount rate, were \$11, \$33, \$52, and \$90 (in 2007 dollars) per metric ton. *See id.* at 13.

99. In 2015, the IWG revised its 2013 TSD, and again updated the Federal Social Cost of Carbon. *See* Ex. 601, Schedule 1 (Martin Rebuttal). The new values for 2015 were \$10, \$31, \$50, and \$86, in 2007 dollars per metric ton of CO₂ and thus somewhat less than the values calculated in 2013. *Id.* at 3.

B. Disputed Issues Regarding Use of the Federal Social Cost of Carbon

100. The contested issues with respect to the use of the Federal Social Cost of Carbon as the measure to determine Minnesota’s CO₂ value related primarily to (1) the suitability of the Federal Social Cost of Carbon for state-level resource planning, (2) the reasonableness of the IWG’s approach and process, including standardization, (3) the reliability of the damage functions used in the IAMs, (4) the scientific basis for the equilibrium climate sensitivity value used in the Federal Social Cost of Carbon, and (5) the theoretical and evidentiary bases for the economic framing assumptions used in the Federal Social Cost of Carbon.

1. Use in Resource Planning

101. The IWG has described the purpose of the Federal Social Cost of Carbon estimates as allowing “[federal] agencies to incorporate the social benefits of reducing carbon dioxide (CO₂) emissions into cost-benefit analyses of regulatory actions that have small, or ‘marginal’ impacts on cumulative global emissions.” 2010 TSD at 1. The purpose of the Federal Social Cost of Carbon process was to “ensure that agencies were using the best available information and to promote consistency in the way agencies quantify the benefits of reducing CO₂ emissions, or costs from increasing emissions, in regulatory impact analyses.” 2015 Response to Comments at 3.

102. The IWG has not endorsed the use of the Federal Social Cost of Carbon in state utility integrated resource planning. *See* Ex. 400, Appendix 2 at 6 (Gayer Report). In fact, the IWG has not addressed the use of the Federal Social Cost of Carbon estimates “outside the regulatory context, such as in NEPA analysis, state level decision making, and ‘pricing’ carbon

in the marketplace.” 2015 Response to Comments at 41.

103. Some witnesses – including Dr. Anne Smith,⁶ Dr. Ted Gayer⁷ and Mr. Nicholas Martin⁸ – testified that serious questions were raised regarding whether it was reasonable and appropriate to use the Federal Social Cost of Carbon for the fine-grained decision-making that occurs in resource planning. *See* Ex. 300 at 32 (Smith Direct); Ex. 400, Appendix 2 at 6 (Gayer Report); Ex. 600 at 6 (Martin Direct); *see also* Evidentiary Hearing (Sept. 24, 2015) Vol. 1 at 120:14-24 (Polasky) (noting that Federal Social Cost of Carbon was designed for use in regulatory impact analysis).

104. Mr. Martin characterized the use of the Federal Social Cost of Carbon in regulatory impact analysis as “inherently different” from use of the Federal Social Cost of Carbon for integrated resource planning and other Commission resource-related decisions. Ex. 600 at 6 (Martin Direct). In regulatory impact analysis, according to Mr. Martin, “great precision” is not required because it is only necessary to determine if the net benefits are positive; it is not necessary that the benefits be “precisely quantified.” *Id.* at 12-14. Mr. Martin further testified:

In contrast, if used in integrated resource planning and other Commission decisions, the imprecise SCC would not help determine whether to regulate, but rather how to make individual resource allocation decisions. These decisions – such as whether to operate or retire a power plant, what type of generation capacity to invest in, how to set solar tariffs, how to evaluate Conservation Improvement Program (CIP) benefits – are sometimes binary, difficult to reverse, and often have large and long-term implications for electricity rates, environmental impacts, and reliability.

Id. at 13:13-20.

105. To make his point, Mr. Martin considered the case of when EPA conducted its regulatory impact analysis on the Federal Clean Power Plan and concluded that benefits of the

⁶ Dr. Smith testified on behalf of GRE, MP, OTP, and the MLIG. Dr. Smith has a Ph.D. in economics from Stanford University, during which she concentrated on decision sciences. She is currently an economist and Senior Vice President at NERA Economic Consulting. Ex. 300 at 3 (Smith Direct); Ex. 301 (Smith Curriculum Vitae). Dr. Smith has extensive experience in decision analysis in the field of climate policies. *Id.* at 10. She has created and operated several integrated assessment models to assess environmental policies. She was a contributing participant in several of the Stanford University Energy Modeling Forums, which was relied upon by the IWG in preparing input data for the IAMs used for the Federal Social Cost of Carbon. *Id.* at 6-7. Dr. Smith is familiar with, and has prepared assessments of, the Federal Social Cost of Carbon, including those submitted on behalf of the American Petroleum Institute, Texas Commission on Environmental Quality, and Utility Air Regulatory Group, during the comment period on the Federal Social Cost of Carbon. *Id.* at 6-7.

⁷ Dr. Gayer testified on behalf of MLIG. Dr. Gayer has a Ph.D. in Economics from Duke University and is the Vice President and Director of the Economic Studies Program at the Brookings Institution. Ex. 400 at 1-2 (Gayer Direct). Dr. Gayer’s research and writing focuses on regulatory policy, environmental policy, and benefit-cost methodology. *Id.* at 2. Dr. Gayer has written on the IWG’s focus on global benefits in a paper cited in this proceeding. *Id.* at 7.

⁸ Nicholas F. Martin is Environmental Policy Manager for Xcel Energy and testified on behalf of Xcel Energy. Mr. Martin holds a M.S. in Energy and Resources from University of California at Berkeley, and is lead carbon policy expert for Xcel Energy. He also is responsible for advising Xcel Energy on preparing for compliance with the Federal Clean Power Plan. Ex. 600 at 1 (Martin Direct); Ex. 600, Schedule 1 at 1 (Martin Curriculum Vitae).

rule would exceed costs at all four levels of the Federal Social Cost of Carbon. As Mr. Martin testified, “precision was not important: it was immaterial whether the ‘correct’ value of damages from an incremental ton of CO₂ is \$12 or \$120, since benefits exceeded costs either way and therefore the regulation was in EPA’s view warranted.” Ex. 602 at 8 (Martin Surrebuttal). By contrast, a much greater level of precision is needed for cost estimates used in resource planning, when an individual resource allocation issues is at stake. *See* Ex. 600 at 6, 13-14 (Martin Direct). As Mr. Martin pointed out, “whether the ‘correct’ value of the SCC is \$12 or \$120 matters a great deal in integrated resource planning: these two values could point to dramatically different resource mixes” Ex. 602 at 8 (Martin Surrebuttal).

106. The IWG itself has acknowledged the large degree of uncertainty and imprecision in the estimates derived from use of the IAMs. In one of its Technical Support Documents, the IWG cited approvingly from a report from the National Academies of Science (NRC 2009) that noted the inherent deficiencies in IAM-based analyses:

[A]ny assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

2010 TSD at 2.

107. The IWG has stressed that decision makers should be very cautious in their reliance on IAMs:

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects.

2010 TSD at 4.

108. All experts who appeared in this proceeding, as well as those cited from the academic literature, share the view that the Federal Social Cost of Carbon values are highly uncertain. Dr. Robert Pindyck, Professor at MIT, has written that IAM-based analyses create an “illusory and misleading” appearance of knowledge and precision about the benefits of reducing CO₂ emissions. Ex. 302 at 2 (Smith Report). With regard to the damage function specifically, Dr. Pindyck notes that “we know almost nothing, so developers of IAMs can do little more than make up functional forms and corresponding parameter values. And that is pretty much what

they have done.” *Id.*

109. Similarly, Nicholas Stern, Professor at London School of Economics, has explained that analysis done with IAMs has “very serious weaknesses” and “must not be taken too literally.” Ex. 230 at 95 (Bezdek Direct). Accordingly, “[IAM-derived] estimates of marginal social costs of damages provide a very weak foundation for policy.” *Id.*

110. Dr. Stephen Polasky⁹ stated that “[u]ncertainty plays a major role in this process. Estimating the SCC is difficult in part because we are attempting to predict impacts far into the future for temperature changes that are potentially outside the range of recent historical experience.” Ex. 100 at 15-16 (Polasky Direct). Dr. Polasky also noted that the Federal Social Cost of Carbon represented a “best estimate” of future damages. Evidentiary Hearing (Sept. 24, 2015) Vol. 1, 81:13-16 (Polasky). When asked at what point it would no longer be feasible to monetize economic damages, Dr. Polasky stated that the “further out in time you go, the more uncertain one would expect [the Federal Social Cost of Carbon] be. *Id.* at 121:9-10.

111. Dr. Michael Hanemann¹⁰ noted that “[b]y the sheer nature of projections into the far future, [the IWG’s projections] cannot be evidentiary or fact based, they are based on reasonable assumptions.” Ex. 801 at 25 (Hanemann Rebuttal). Dr. Hanemann, however, never specifically identified what “reasonable assumptions” he had in mind and he testified that he was prepared to extrapolate the levels of CO2 emissions after 2100. *See also id.* at 17-19.

112. Dr. Smith noted that the IAMs “reflect available scientific and economic evidence that is subject to varied interpretations, and hence are uncertain. Other assumptions are entirely judgmental. Some judgments are made by modelers when relevant scientific evidence does not exist but some numerical value is needed to complete the SCC calculation. Other judgmental inputs reflect normative concepts that are impossible to evaluate in an empirical manner.” Ex. 302 at 4 (Smith Report).

113. Mr. Martin agreed that the Federal Social Cost of Carbon is inherently uncertain and speculative. Ex. 600 at 3 (Martin Direct).

114. Dr. Hanemann and Dr. Polasky did not dispute the uncertainty and imprecision of the IAM process but contended there was no viable alternative. Dr. Hanemann also testified that state-level resource planning is a form of cost-effectiveness analysis, and therefore similar to the cost-benefit analysis for which the Federal Social Cost of Carbon was designed. Ex. 801 at 17 (Hanemann Rebuttal). Dr. Polasky testified that any differences between resource planning and regulatory impact analysis are irrelevant, because the same fundamental goal of informing decision-makers about the relative difference of choices applies in either situation. Ex. 101 at 33

⁹ Dr. Polasky, who testified on behalf of the CEOs, is Regents Professor at the University of Minnesota and holds a Ph.D. in economics from the University of Michigan. Ex. 100 at 1-2 (Polasky Direct). Dr. Polasky’s research focuses on ecology and economics. *Id.*

¹⁰ Dr. Hanemann testified on behalf of the Agencies. He is a Professor of Economics and the Julie A. Wrigley Professor of Sustainability in the Department of Economics at Arizona State University. Ex. 800 at 1 (Hanemann Direct). Dr. Hanemann holds a Ph.D. in Economics from Harvard University, and his work and subsequent research have been in the field of environmental economics. *Id.* Dr. Hanemann assisted in drafting the IPCC’s 5th Assessment Report, and testified that he is familiar with the literature in IAMs, and the social cost of carbon. *Id.* at 2.

(Polasky Direct).

115. The evidence shows that use of environmental cost values in resource planning demands greater precision than the use of the Federal Social Cost of Carbon in regulatory impact analysis. As the Commission has recognized, environmental costs that are set too high or too low can have serious long-term consequences for the State of Minnesota and its ratepayers. Thus, the significant degree of uncertainty and speculation associated with the use of Federal Social Cost of Carbon to determine Minnesota CO₂ value cannot be ignored. Before the Commission can adopt the Federal Social Cost of Carbon, it must take a hard look at the processes used and assumptions made by the IWG to determine the Federal Social Cost of Carbon is reasonable and the best available measure to determine Minnesota's CO₂ values, especially in view of the extent of the uncertainty and imprecision inherent in the Federal Social Cost of Carbon, as well as the undisputed fact that the Federal Social Cost of Carbon was not designed for use in resource planning.

2. Standardization

116. Standardization refers to the process used to put the models on a common footing by (1) using a common set of projections for certain model inputs, and (2) changing DICE from an optimization model (i.e., a model designed to determine the price necessary to reach an optimal level of emissions) to a simulation model (i.e., a model designed to accurately determine the likely damage cost of CO₂ given certain projections of actual future conditions). *See* Ex. 800 at 47-48 (Hanemann Direct).

117. The IWG standardized the Federal Social Cost of Carbon by undertaking two steps. First, it standardized the projections of future population, income, emissions, parameters for non- CO₂ radiative forcing, climate sensitivity values, and discount rates. Ex. 800 at 49, 54 (Hanemann Direct). Second, it removed the optimization feature in DICE. *Id.* at 47.

118. The witnesses for the Agencies and CEOs testified that the IWG acted reasonably when it standardized the inputs. *See e.g.*, Ex. 100 at 24-25 (Polasky Direct). Dr. Polasky testified that the IWG made a reasonable decision when it decided that the models should be comparable. *See id.* Dr. Hanemann testified that the IWG's work was in the nature of a model inter-comparison exercise, and that standardization is common practice in model inter-comparison exercises. Ex. 802 at 11 (Hanemann Surrebuttal).

119. Despite agreeing with Dr. Hanemann that standardization was common practice in model inter-comparison exercises, Dr. Polasky acknowledged that standardization can create internal inconsistency in a model and can "lose some of the way in which the model was intended to run in the first place." Evidentiary Hearing (Sept. 24, 2015) Vol. 1 at 94:17-24; 95:16-20; 96:14-18 (Polasky).

120. Dr. Smith disagreed with Dr. Hanemann that the IWG's work was in the nature of a model inter-comparison exercise, in which modelers run models side-by-side in order to evaluate the weaknesses and strengths of different models. Evidentiary Hearing (Sept. 25, 2015) Vol. 2A, 108:20-109:5 (Smith). A model inter-comparison exercise serves a different purpose than the IWG models, which are used to predict future outcomes for use in policymaking. *Id.* at

108:19-109:23. Dr. Smith also testified that, although model standardization is useful in model inter-comparison exercises, it is less useful when the models are being run in the situation in which the IWG used the models. *Id.* at 108:20-109:5. In particular, she stated that standardization in the model inter-comparison context can help understand how models perform and which models perform better than others. *Id.* She further testified that when using models to predict future outcomes or for making policy, the rationale for standardization no longer applies. *Id.* at 109:11-111:1. Specifically, Dr. Smith found that when standardizing the models, the IWG altered the judgments made by the original modelers, in ways that fundamentally affected the operation of the models. *See id.* As a result, even assuming that the IWG selected the three best available models, it then transformed them into different models. *Id.*

121. Dr. Mendelsohn¹¹ testified that the IWG's standardization involved substituting many of its own assumptions in place of the modelers' original assumptions, and that several of the modelers' substituted assumptions are inconsistent with each other. Ex. 214 at 16 (Mendelsohn Direct). For example, the different GDP paths used by the IWG should imply different discount rates, which the IWG failed to take into account. Ex. 218 at 4-6 (Mendelsohn Rebuttal). In Dr. Mendelsohn's opinion, the IWG's standardization exercise violates the assumptions of the IAMs' modelers, and renders the models less reliable. *Id.*

122. Dr. Mendelsohn testified that the IWG "ruined both the FUND model and the DICE model by harmonizing the inputs." Evidentiary Hearing (Sept. 28, 2015) Vol. 3B at 38:9-11 (Mendelsohn). The IWG "made substantial changes to the IAMs that effectively ruined their internal integrity." *Id.* at 37:16-18. He compared the error to putting gasoline in a diesel car. *Id.* at 37:22-38:6.

123. Standardization of the DICE, PAGE, and FUND models compromised the reliability of these models for use in determining Minnesota's CO₂ environmental cost value. Dr. Hanemann and Dr. Polasky may be correct that model standardization has value in the model inter-comparison context. However, as Dr. Smith testified, the IWG was not conducting a model inter-comparison exercise; the IWG was not using the results of all models to discern differences between the models and to evaluate the relative strengths and weaknesses of each, but instead to determine the appropriate environmental cost of CO₂. The evidence shows that standardization of the models significantly altered the assumptions made by the modelers and compromised the internal consistency of the models. The standardization of the DICE, PAGE, and FUND models is a source of additional uncertainty that the Commission must take into account in determining whether the Federal Social Cost of Carbon is suitable for adoption in Minnesota.

3. Damage Functions

124. The damage functions used in the IAMs are simplified formulas which calculate a monetary estimate of the loss of value to society directly from temperature change levels. *See* Ex. 302 at 3, 5 (Smith Report).

¹¹ Dr. Mendelsohn testified on behalf of Peabody. He holds a Ph.D. from Yale University, and is the Edwin Weyerhaeuser Davis Professor at the School of Forestry. Ex. 214 at 1 (Mendelsohn Direct). Dr. Mendelsohn's research focuses on measurement of the benefits of mitigating greenhouse gas emissions. *Id.* Dr. Mendelsohn has extensive experience regarding the DICE model (developed by his colleague William Nordhaus at Yale). *Id.* at 6, 7-10.

125. The criticisms of these damage functions related to the following issues: (1) the damage functions do not represent a true “damage cost” approach, (2) the damage functions extrapolate from limited data, (3) the damage functions do not adequately account for carbon fertilization, and (4) the damage functions do not adequately account for adaptation to climate change.

126. The IWG relied on the IAM modelers’ best judgments of how to represent the effects of climate change on global GDP by retaining the IAMs’ original damage functions. 2010 TSD at 8. It recognized that the representations were “incomplete and highly uncertain.” *Id.* However, it stated that “given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.” *Id.*

Damage Cost Approach

127. Dr. Smith stated that the IAMs do not represent a true damage cost approach. *See* Ex. 300 at 19 (Smith Direct). She contended that the damage functions used in a traditional damage-cost approach would first ascertain changes from projected emissions, estimate the physical impacts on a variety of resources and amenities due to the climatic changes, and finally estimate the societal value of the physical changes in the resources and amenities. *Id.* However, the IAMs “largely skip the detailed steps involved in determining how particular physical resources will be impacted by climatic changes” *Id.* She also noted that “[o]nly portions of the IAMs’ SCC damage estimates are based on specific resource impact projections. *Id.*

128. Dr. Smith stated that this aggregation is not necessarily inappropriate when the structure of the underlying relationships is well understood; however, it introduces a degree of speculation that is problematic in the context of resource planning where more precision is necessary. *See* Ex. 300 at 19-20 (Smith Direct). This aggregation renders it very difficult to know what types of damages are included in a particular estimate. *See id.*

129. Dr. Hanemann took issue with Dr. Smith. Dr. Hanemann argued that no dose-response functions were available to value CO₂ emissions and that the computer infrastructure and resource required to run a model based on a dose-response function would be prohibitive. Ex. 800 at 32 (Hanemann Direct); Ex. 801 at 39-40 (Hanemann Rebuttal). He concluded that it was not reasonable to expect the use of conventional dose-response functions on the scales required for an IAM damage function. Ex.801 at 40 (Hanemann Rebuttal).

130. Mr. Martin opined that the use of aggregated damage functions is consistent with the Commission’s direction to use a damage cost approach. He stated “[n]othing in [the Commission’s definition of damage cost approach] requires disaggregated damage functions or an explicit step estimating physical impacts on resources.” Ex. 602 at 32 (Martin Surrebuttal).

131. Although the Commission has not ruled out the use of aggregated damage functions, the more relevant issue is the extent to which the use of aggregated functions adds to the already high level of uncertainty and imprecision associated with the use of the Federal Social of Carbon to determine cost values for resource planning.

Empirical Data

132. Dr. Smith observed that the IAMs' damage functions were based on a relatively small number of studies of the economic impact of warming of 3°C or less. Ex. 302 at 70-71 (Smith Report). As a result, the damage functions which underlie the IAMs are "simple smoothed curves" which are fitted to limited empirical evidence of the damage that is associated with temperature changes of 3°C or less. *Id.* In her testimony, Dr. Smith produced a list of the 17 empirical studies which were used to calibrate the DICE model. *See id.* at 27, Fig. 3. These studies were conducted between 1991 and 2006, and each measured the damage associated with temperatures ranging between one and 3°C. *See id.*

133. Dr. Smith pointed out that damage estimates are "virtually non-existent for temperature increases above 3°C." Ex. 302 at 7 (Smith Report). Because data showing damages above 3°C is not available, the shape of the curve obtained by extrapolating from the available data completely determines the monetary value of damages. Most of the estimated damages after 2100 are based upon projected temperature increases above 3°C. But there is no empirical basis to support these estimates. As Professor Pindyck noted, due to the lack of empirical data underlying the damage functions: "[W]e know almost nothing, so developers of IAMs can do little more than make up functional forms and corresponding parameter values. And that is pretty much what they have done." *Id.* at 5.

134. In a candid admission, Dr. Polasky characterized the extrapolation involved in the IAMs' damage functions as a "best guess." Evidentiary Hearing (Sep. 24, 2015) Vol. 1 at 124:7-13 (Polasky).

135. Mr. Martin also agreed that the IAM damage functions lack empirical calibration for greater temperature changes. Ex. 601 at 34-35 (Martin Rebuttal); Ex. 602 at 6 (Martin Surrebuttal).

136. The level of extrapolation in the IAMs' damage functions leads to wide variability in the possible estimates generated by these damage functions. Dr. Smith noted, "[a]lthough the mathematical form of the damage function is relatively simple, plausible parameters for this mathematical formulation lead to very different estimates of global damages." Ex. 302, Attachment, at 1 (Smith Report Attachment, API Report). She also found that "possible damage estimates at a given point in time can differ by a factor of 20 or more" *Id.*; *see also* Ex. 302, Attachment at Figure ES-1, (Smith Report Attachment, API Report).

137. Dr. Hanemann testified that the damage functions in DICE, FUND and PAGE reflect the economic literature on climate impacts as of about 2001, and thus is out of date. Evidentiary Hearing (Sep. 25, 2015) Vol. 2B at 91:15-25 (Hanemann) (stating that the models are still tied mainly to literature from the 1990s or 2000). Dr. Hanemann, however, did not produce or even identify more recent studies of the economic impacts of climate change, did not describe their conclusions or the data upon which they relied in any reasonable detail, and did not explain why the IWG did not take them into account. His testimony on this issue deserves little or no weight.

138. CEOs pointed out that the IWG defended the damage functions on the grounds

that they were “not simply arbitrary representations” and were “based on a review by the modelers of the currently available literature.” CEOs’ Brief at 23. Dr. Hanemann argued that, while the literature is highly incomplete, there is a reasonable empirical basis for the IAMs’ damage functions. Ex. 801 at 63 (Hanemann Rebuttal). He also contended that the newer literature generally indicated more severe damage than the earlier literature. *Id.* However, Dr. Hanemann did not cite or describe any specific newer studies or indicate that any of them provided empirical data of the impacts of temperature increases of more than 3°C. *Id.*

139. Relatedly, Dr. Hanemann argued that the Federal Social Cost of Carbon estimates may underestimate damages, and fails to account for tipping points and a degree of risk aversion. Ex. 801 at 60-62 (Hanemann Rebuttal). Similarly, Dr. Rom¹² testified that the IAMs used in the Federal Social Cost of Carbon do not account for various health impacts. Ex. 500 at 10 (Rom Rebuttal). However, neither Dr. Rom nor Dr. Hanemann proposed any adjustment to the Federal Social Cost of Carbon. *Id.* at 9-12, 15-19.

140. The evidence shows there is no empirical basis for the IAMs’ damage functions with respect to warming greater than over 3°C. It also shows that the significant variations that may result in projections above that level are troubling.

141. Even if Dr. Hanemann and Dr. Rom are assumed to be correct that the Federal Social Cost of Carbon, and the IAMs on which it is based, omit important categories of damages, no witness in this proceeding has offered a method to quantify these damages, and the inclusion of unquantified damages as a ‘hedge’ against possible underestimation would be clearly inconsistent with the applicable statutory standard as well as the approach taken by the Commission in establishing values. It would be arbitrary and capricious to overlook the speculation involved in the IAMs’ damage functions on the basis of unquantified damages for which there is no empirical support in the record.

Fertilization Effect

142. Dr. William Happer,¹³ Dr. Richard Lindzen,¹⁴ and Dr. Bezdek¹⁵ each testified that the IAMs fail to account adequately for the CO₂ fertilization effect. See Ex. 200 at 9-10 (Happer Direct); Ex. 207 at 7 (Lindzen Direct); Ex. 228 at 2-3 (Bezdek Direct). CO₂ benefits plants and agriculture by extending growing seasons, increasing photosynthetic efficiency of plants, decreasing water dependency of plants, and increasing tree growth rate. See Ex. 200 at 10-11 (Happer Direct); Ex. 204 at 3 (Happer Rebuttal Report); Ex. 220 at 4 (Mendelsohn Surrebuttal).

¹² Dr. Rom, who testified on behalf of Doctors for a Healthy Environment, is a Professor of Medicine and Environmental Medicine at the NYU School of Medicine. Ex. 500 at 1 (Rom Rebuttal). He received an M.D. from the University of Minnesota. *Id.*

¹³ Dr. Happer testified on behalf of Peabody. He holds a Ph.D. in physics from Princeton University, and is Professor Emeritus at Princeton. Ex. 200 at 1 (Happer Direct).

¹⁴ Dr. Lindzen testified on behalf of Peabody. Dr. Lindzen is a meteorologist and the Alfred P. Sloan Professor of Meteorology in the Department of Earth, Atmospheric and Planetary Sciences at the Massachusetts Institute of Technology. Ex. 207 at 1 (Lindzen Direct). He holds a Ph.D. in applied mathematics from Harvard University. *Id.*

¹⁵ Dr. Bezdek testified on behalf of Peabody. He is president of Management Information Services, Inc., (MISI), an economic research firm specializing in energy, environmental, and regulatory issues. Ex. 228 at 1 (Bezdek Direct). He holds a Ph.D. in Economics from the University of Illinois. *Id.*

143. Dr. Bezdek testified that the economic benefit of the fertilization effect is significant, and could total nearly \$10 trillion between 2012 and 2050. Ex. 228 at 3 (Bezdek Direct). Dr. Bezdek also pointed out that the benefits of CO₂ emissions are not included in the IAMs' damage functions. *Id.* at 3-4. The "IWG implicitly undervalued CO₂ fertilization." Ex. 261 at 3 (Mendelsohn Opening Statement).

144. In response, Dr. Hanemann and Dr. Polasky contended the IAMs account for potential benefits to agriculture from increased CO₂ concentrations, but those benefits are outweighed by other costs. Ex. 101 at 54-55 (Polasky Rebuttal); *see also* Ex. 801 at 4 (Hanemann Rebuttal). Moreover, they suggested that the fertilization benefit is not as simple as Peabody's witnesses assume. Under controlled or laboratory conditions, CO₂ may fertilize plants. Ex. 101 at 53 (Polasky Rebuttal); Ex. 803 at 19 (Gurney Rebuttal). But increases in atmospheric CO₂ affect other aspects of plants' and crops' real-world habitats, so the net effect is extremely variable and reflects conflicting results. *See* Ex. 101 at 53-54 (Polasky Rebuttal); Ex. 107 at 4 (Reich Surrebuttal); Ex. 801 at 12 (Hanemann Rebuttal); Ex. 803 at 3, 20 (Gurney Rebuttal).

145. The Fifth Assessment Report of the IPCC ("IPCC 5th Assessment Report") was published in 2014. Ex. 800 at 34 (Hanemann Direct). It concluded that "there is a net negative impact on crop yields, inclusive of the CO₂ fertilization effect." Ex. 803 at 21 (Gurney Rebuttal). Dr. Gurney notes that "the IPCC [5th Assessment Report] review represents the most comprehensive assessment of research on this topic, to date." *Id.*

146. Moreover, Dr. Hanemann testified that the developers of DICE and FUND both acknowledge the existence of a CO₂ fertilization effect, and account for it within the modeling. Ex. 801 at 4 (Hanemann Rebuttal). It is not clear whether that effect is accounted for in PAGE. *Id.*

147. As Dr. Gurney¹⁶ testified, the IPCC has evaluated climate impacts on agriculture and found a net negative impact. Ex. 803 at 21 (Gurney Rebuttal). The evidence, particularly the assessment of the IPCC, shows that the academic literature on which the IAMs are based has accounted for the CO₂ fertilization effect in their assessment of the impact of anthropogenic climate change on plants. In addition, the evidence shows carbon fertilization is taken into account in the DICE and FUND models.

Adaptation

148. Dr. Mendelsohn and Mr. Martin claimed the damage projections used by the IWG fail to account for potential adaptation to climate change. *See* Ex. 600 at 29 (Martin Direct). Mr. Mendelsohn testified that early studies of climate change did not take adaptation into account and predicted very large damages. *See* Ex. 220 at 17-18 (Mendelsohn Surrebuttal). Specifically, these studies predicted that cities would take no precautions against rising sea levels, farmer would not adjust their crops, and people would not cool their homes to protect against heat waves. *Id.* However, because climate change is a slow process, it is "very obvious" that people will react. *Id.* at 18. Adaptation will cause the actual damage from climate change to be a "small

¹⁶ Dr. Gurney testified on behalf of the Agencies. He is a professor at Arizona State University and holds a Ph.D. in ecology from Colorado State University. Ex. 803 at 1 (Gurney Rebuttal).

fraction” of potential damage. *Id.* at 19.

149. Similarly, Mr. Martin cited an article by Greenstone, Kopits, and Wolverton (2013), which stated that the IAMs do not fully capture adaptation to climate change, and that this could lead them to over-estimate damages. Ex. 600 at 29 (Martin Direct).

150. The IWG’s damage functions fail to adequately account for adaptation, and accordingly, whether their projection of damages becomes unduly speculative. Because the evidence shows that some degree of adaptation is likely, and because there the evidence shows that that adaptation is not accounted for in the damage functions of the IAMs, the reliability of the damage functions in the IAMs is called into further doubt.

The Damage Functions are a Significant Source of Uncertainty

151. The evidence offered in this proceeding shows that the damage functions used in the IAMs suffer from many sources of uncertainty. While representing a “damage cost approach” within the meaning of the Commission’s direction, the aggregation of climate impacts in the damage functions renders it difficult to determine what impacts have been included. Moreover, the extrapolation relied upon by the damage functions for temperatures above 3°C cannot be empirically validated and can vary widely depending on the functional form assumed by the modeler. The damage functions also do not adequately account for adaptation to climate change. For these reasons, the damage functions used by the IAM modelers are a significant source of uncertainty in this proceeding.

4. ECS Value

152. The equilibrium climate sensitivity (“ECS”) is defined as the “long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO₂ concentration relative to pre-industrial levels” 2010 TSD at 12. The IWG used a probabilistic distribution of ECS values. *See id.* at 24. In selecting its distribution, the IWG consulted the IPCC Fourth Assessment Report, which it determined was the “most authoritative statement about equilibrium climate sensitivity.” *Id.* at 12. The IPCC Fourth Assessment Report stated that climate sensitivity is likely to lie in the range of 2°C to 4.5°C, with a most likely value of about 3°C. *Id.*

153. The IPCC is an intergovernmental scientific body under the auspices of the United Nations, established in 1988 at the request of member governments. Ex. 800 at 33 (Hanemann Direct). The IPCC is tasked with producing reports that support the United Nations Framework Convention on Climate Change (“UNFCCC”), which is the main international treaty on climate change. *Id.* at 33-34.

154. Dr. Hanemann explained that IPCC Assessment Reports are internationally regarded as authoritative on the topics covered. Ex. 800 at 34 (Hanemann Direct). The IPCC has published five comprehensive assessment reports reviewing the latest climate science. *Id.* Each assessment report is in three volumes, produced by Working Group I (The Physical Science), Working Group II (Impacts), and Working Group III (Mitigation). *Id.* The First Assessment Report was published in 1990, the 2nd in 1995, the 3rd in 2001, the 4th in 2007, and the 5th in 2014. *Id.*

155. The IWG selected distributions of ECS values described by Roe and Baker (2007), which were calibrated to the three statistical constraints from the IPCC Fourth Assessment Report; specifically, a median equal to 3°C to reflect what the IPCC Fourth Assessment Report described as a most-likely value of about 3°C, and a two-thirds probability that the ECS lies between 2 and 4.5°C. 2010 TSD at 13. The IWG has indicated that it would “continue to follow and evaluate the latest science on the equilibrium climate sensitivity and seek external expert advice on the technical merits and challenges of potential approaches prior to updating the ECS distribution in future revisions to the SCC estimates, including (but not limited to) using the AR5 [IPCC Fifth Assessment Report] climate sensitivity distribution for the next update of the SCC.” 2015 Response to Comments at 12. However, the current Federal Social Cost of Carbon values rely on the Fourth Assessment Report only.

156. The ECS value was called into question in two respects: first, whether the IWG should have adopted an ECS range that takes into account the IPCC Fifth Assessment Report, which lowered the bottom end of the range from 2°C to 1.5°C; and second; whether the IPCC report overestimates climate sensitivity.

157. Dr. Bezdek argued that the IWG should have adopted an ECS value that takes into account the IPCC Fifth Assessment Report, which states that the ECS is likely to range from 1.5°C to 4.5°C, not the 2°C to 4.5°C that was used by the IWG. Ex. 232 at 23-28 (Bezdek Rebuttal). However, at the time the 2010 TSD and the 2103 TSDs were released, the Fourth Assessment Report was the most authoritative statement on the ECS value. Response to Comments at 12. Dr. Hanemann also noted that the IWG attempted to account for the uncertainty in the ECS value by making the value of ECS a random variable with the same probability distribution for all three IAMs. Ex. 800 at 46 (Hanemann Direct).

158. Certain witnesses testified that the climate sensitivity values are overestimated in the IPCC report. Specifically, Dr. Happer stated that the true ECS value is somewhere between 0.5 and 1.5, which a most likely value of approximately 1. Ex. 200 at 8 (Happer Direct). Dr. Lindzen testified that an ECS value of more than 2°C is highly unlikely. Ex. 207 at 5, 8-9 (Lindzen Direct). However, Dr. Abraham¹⁷ testified that the ECS used by the IWG is consistent with the consensus position of climate scientists and other professionals. Ex. 102 at 28 (Abraham Rebuttal).

159. The IWG’s use of an ECS value of 3 is reasonable and supported by the evidence. First, there is evidence in the record that there is a substantial overlap between the IPCC Fourth Assessment value and the IPCC Fifth Assessment value. Ex. 103 at 2-3 (Dessler Rebuttal). Second, as Dr. Dessler¹⁸ noted, there was almost no evidence in opposition to the bulk of the range used by the IWG. Evidentiary Hearing (Sept. 28, 2015) Vol. 3A at 17 (Dessler). Third, any uncertainty in the ECS is mitigated by the use of a probability distribution of ECS values in the calculation of the Federal Social Cost of Carbon. Finally, the IWG has noted that, “[a]t the time the 2013 SCC update was released, the most authoritative statement about ECS appeared in

¹⁷ Dr. Abraham, who testified on behalf of the CEOs is a Professor of thermal sciences, University of St. Thomas School of Engineering. Ex. 102 at 1 (Abraham Rebuttal). He holds a Ph.D. from the University of Minnesota in Mechanical Engineering. Ex. 102, Schedule 2 at 1 (Abraham Curriculum Vitae).

¹⁸ Dr. Dessler, who testified on behalf of the CEOs, is a Professor in the Department of Atmospheric Sciences at Texas A&M University and holds a Ph.D. in chemistry from Harvard University. Ex. 103 at 1 (Dessler Rebuttal).

the IPCC's AR4." Response to Comments at 12. Accordingly, the IWG's use of the Fourth Assessment Report was reasonable, particularly in light of the IWG's statement that it intends to update the Federal Social Cost of Carbon on the basis of the IPCC Fifth Assessment Report in future updates of the Federal Social Cost of Carbon. *Id.*

5. Socioeconomic Scenarios

160. The IWG selected five sets of projections of population, wealth, and emissions from EMF-22. 2010 TSD at 15-16. It noted four of these represent potential business-as-usual growth in population, wealth, and emissions and are associated with CO₂ (only) concentrations ranging from 612 to 889 ppm in 2100. *Id.* at 15. The fifth scenario represents an emissions pathway that achieves stabilization at 550 ppm CO₂ in 2100. *Id.* The fifth scenario represents lower emissions than the business-as-usual scenarios represented by the other four projections. *Id.*

161. The IWG acknowledged that its socioeconomic scenarios represented a limited range of potential future scenarios. It stated that the scenarios "represent the modelers' judgment of the most likely pathway *absent mitigation policies to reduce greenhouse gas emissions*, rather than the wider range of possible outcomes." 2010 TSD at 16 (emphasis added).

162. To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300. 2010 TSD at 43 (Appendix).

163. Dr. Smith criticized the IWG's emissions projections for implausibly assuming no future response to climate change. She stated that the IWG's emissions trajectories contain no "options for learning or response, no matter what signals emerge that increases in temperature will be on the pessimistic end of the range." Ex. 302 at 73 (Smith Report). Dr. Smith testified:

This is an unrealistic assumption even over 100 years and is implausible when assessing societal damages in a period 200 to 300 years from now. It assumes no use of technologies that are feasible even today, such as geoengineering to either remove carbon from the atmosphere, or to create atmospheric changes that will have a countervailing cooling effect. It also assumes no unforeseen technological advances in the next 100 to 300 years that may either provide better solutions or more effective forms of adaptation than the models assume, which is hardly likely given the remarkable advances that have occurred in the past 100 years. Such lack of responsiveness is particularly unrealistic to assume given that the IWG socioeconomic scenarios assume that (in terms of real consumption per capita) global society will be 3 to 5 times wealthier by 2100, and between 7 and 25 times wealthier by 2300.

Id.

164. Dr. Mendelsohn agreed with Dr. Smith, and testified that, "[b]y assuming zero

future mitigation, the IWG is exaggerating the damage of carbon emissions.” Ex. 220 at 25 (Mendelsohn Surrebuttal).

165. Dr. Hanemann disagreed with Dr. Smith and Dr. Mendelsohn. He stated that the IWG estimates do, in fact, account for a degree of societal response because they do not assume continuous emissions growth through 2300. *See* Ex. 801 at 23 (Hanemann Rebuttal).

166. Dr. Smith noted, however, that the IWG socioeconomic scenarios contemplate temperatures continuing to climb until the year 2300, and emissions levels continue to climb until 2200, notwithstanding temperature changes of 4 °C by 2100. *See* Ex. 302 at 30 (Smith Report); Ex. 302 at 68, n.96 (Smith Report). Accordingly, the IWG’s scenarios assume that emissions will continue to climb for up to 100 years after temperature increases of 4°C are reached. Even under the Fifth Scenario, stabilized to 550 ppm, temperature increases of 2°C occur by 2100. Ex. 302 at 72 (Smith Report). Dr. Hanemann agrees that temperature increases of this level would be unacceptable. *See* Ex. 801 at 23 (Hanemann Rebuttal). In other words, the IWG has assumed that carbon emissions will continue to rise for approximately 100 years after unacceptable temperature increases occur.

167. The IWG’s scenarios forecast unacceptable temperature changes well before emissions level off and decline, and that such a scenario is implausible.

168. Dr. Hanemann also argued that problems with collective action render a societal response such as that contemplated by Dr. Smith or Dr. Mendelsohn unlikely. Ex. 801 at 26 (Hanemann Rebuttal). As Dr. Smith points out, it may be true that collective action is difficult at present. However, faced with unacceptable temperature increases “it is unreasonable to assume nations across the globe will even then be unresponsive, and allow temperatures to reach dangerously high levels without acting to protect themselves. Even if such efforts are slow, it is unlikely that no such efforts will occur.” Ex. 304 at 16-17 (Smith Surrebuttal).

169. The emissions scenarios relied upon by the IWG unrealistically assume that society will not conduct any significant adaptation or mitigation for 100 years after unacceptable temperature increases occur. This assumption is simply implausible.

6. Economic Framing Assumptions

170. Another set of critical choices made by the IWG relates to four economic framing assumptions used in the IAMs: the appropriate discount rate, time horizon, geographic scope, and marginal ton of CO₂ to be measured.

171. In its choice of framing assumptions, the IWG exercised an extraordinarily large degree of control over the final value of the Federal Social Cost of Carbon. Dr. Smith demonstrated that the choices made regarding the appropriate discount rate, time horizon, geographic scope of damages, and marginal ton of CO₂ considered, produce damage estimates that vary by more than \$45 per metric ton. Ex 307 (Smith’s Table 4A).

172. The results of Dr. Smith’s sensitivity analysis reinforce a point made by Professor Pindyck:

With a judicious choice of parameter values (varying the discount rate is probably sufficient), the model will yield an SCC estimate as low as a few dollars per ton, as high as several hundred dollars per ton, or anything in between. Thus a modeler who, for whatever reason, believes that a stringent abatement policy is (or is not) needed, can choose a low (or high) discount rate, or choose other inputs that will yield the desired results.

See Ex. 600 at 46 (Martin Direct).

173. Because the framing assumptions used in the modelling drive the results, careful consideration must be given to the choice of each of these framing assumptions.

a) Discount Rate

174. The IWG selected three discount rates for use in developing the Federal Social Cost of Carbon: 2.5 percent, 3 percent, and 5 percent. 2010 TSD at 23. These rates are used to discount the stream of future damages caused by a unit of CO₂ down to its present value in the year when the additional unit of emissions was released. *See id.* at 28. The discount rate is intended to reflect society's marginal rate of substitution between consumption in different time periods. *Id.* at 17.

175. The IWG noted the uncertainty surrounding the discount rate question, stating that “[t]he choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law.” 2010 TSD at 17. It also acknowledged that the choice of discount rate has a large effect on the final damages number, stating “[a]lthough 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.” *Id.*

176. The choice of discount rate has a significant effect on the final value of the Federal Social Cost of Carbon. In fact, the choice of discount rate has a “greater impact on the Federal Social Cost of Carbon than any other single variable in the methodology.” Ex. 600 at 44 (Martin Direct); *see also* Ex. 232 at 34 (Bezdek Rebuttal); Ex. 100 at 11:9-11 (Polasky Direct) (“Because climate change impacts go so far into the future, what one assumes about the discount rate matters hugely.”); Ex. 800 at 53 (Hanemann Direct) (noting that the choice of discount rate has a huge impact on the result).

177. In the establishing the initial CO₂ values, the Commission rejected the use of discount rates lower than 3 percent which were offered on the basis that lower rates were appropriate when discounting across generations. ALJ Findings at 36. ALJ Klein and the Commission concluded that there was insufficient support in the record for lower rates based on intergenerational concerns. *See id.*

178. Recommendations for the discount rate can be characterized as either prescriptive in nature, reflecting moral or ethical judgments, or descriptive in nature, reflecting market evidence that reveals human preferences. Ex. 302 at 80 (Smith Report); 2010 TSD at 18. The IWG stated that the descriptive approach was “the most defensible and transparent given its consistency with the standard contemporary foundations of benefit-cost analysis and the

approach required by OMB's existing guidance." 2010 TSD at 19.

179. The descriptive approach in determining the correct discount rate is consistent with the Commission's precedent, and with the principles that Minnesota's environmental cost values should be supported by empirical evidence and conservative in the face of uncertainty.

180. The IWG stated that the 3 percent discount rate was consistent with estimates provided in the economics literature and OMB Circular A-4. 2010 TSD at 23. Specifically, it noted that, for rules with both intra and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. *Id.* at 23. Three percent is generally used when a regulation primarily affects private consumption, and this rate is tied to the rate at which people discount their own future consumption. *Id.* at 19. This rate is based on empirical evidence – specifically, the real rate of return on long-term government debt has averaged 3.1 percent. *Id.* at 20, note 17. The IWG included the 5 percent discount rate to “represent the possibility that climate damages are positively correlated with market returns. *Id.* at 23. Additionally, this discount rate may be justified by the high interest rates. *Id.* In other words, the IWG defended its use of 3 percent and 5 percent as being consistent with empirically-observed market rates that are consumption based. *See* Ex. 302 at 84 (Smith Report).

181. Dr. Bezdek and Dr. Smith noted OMB Circular A-4 requires the use of 3 percent and 7 percent. *See* Ex. 232 at 34-35 (Bezdek Rebuttal). The IWG acknowledged the rationale for a 7 percent discount rate, namely, that it is appropriate for use when a regulation is expected to displace or alter the use of capital in the private sector. 2010 TSD at 19. The 7 percent rate is derived from the average before-tax rate of return to private capital in the U.S. economy. Ex. 302 at 83 (Smith Report). This measure approximates the opportunity cost of capital, and should be used when the main effect of a regulation is to displace or alter the use of capital in the private sector. *Id.* As Dr. Smith noted, emissions controls will indeed require private investments. *Id.* at 84. However, the IWG did not explain its omission of a seven percent discount rate.

182. The IWG defended its use of 3 percent and 5 percent as being consistent with empirically-observed market rates that are consumption based. However, it did not defend its use of a 2.5 percent discount rate on an empirical basis. Rather, it states that the 2.5 percent range reflects reasonable judgments under both a descriptive and prescriptive basis. As Dr. Smith points out, part of the IWG's justification for the 2.5 percent rate is based in prescriptive principles and is not a purely descriptive estimate supported by empirical and well-developed theoretical methodologies. *See* 2010 TSD at 23-24; Ex. 302 at 86 (Smith Report).

183. Dr. Polasky argues that the use of a 2.5 percent discount rate finds support in the economic literature. He cites a study by Lord Stern which used a discount rate of 1.4 percent, and meta-analysis by Dr. Tol which showed that several studies used discount rates below three percent. *See* Ex. 100 at 12 (Polasky Direct); Ex. 101 at 22 (Polasky Rebuttal). Dr. Polasky, however, has not explained or given the Commission any evidence with which it could evaluate the theoretical underpinnings of Lord Stern's rate, or of the rates included in Dr. Tol's meta-analysis. Ex. 304 at 29 (Smith Surrebuttal). He has not provided evidence to show that a discount rate below 2.5 percent can be justified on a descriptive basis.

184. Dr. Hanemann argues that a 2.5 percent discount rate can be supported empirically. Dr. Hanemann noted that a marginal utility factor, which reflects the marginal utility that a person obtains from an additional unit of income in the future, of 1.3 to 2 is realistic, and that a pure rate of time preference, which reflects the extent to which a person prefers consumption today over consumption in the future, of 0.5 is ethically defensible. Ex. 801 at 73, 75, 79 (Hanemann Rebuttal). However, Dr. Hanemann's argument for a 2.5 percent discount rate rests on an ethical judgment – that a rate of time preference of 0.5 is defensible from an ethical point of view. *See id.* at 79. Such an argument is inherently prescriptive. Therefore, Dr. Hanemann has not supported his assertion that a 2.5 percent discount rate can be supported empirically.

185. Dr. Hanemann's defense of a 2.5 percent discount rate focuses on the consumption rate of interest and does not account for the element of use of capital. Ex. 304 at 28 (Smith Surrebuttal). Dr. Smith explained that private sector investments will be required to control emissions, and thus the opportunity cost of those investments must be accounted for in establishing the correct discount rate. Ex. 302 at 84 (Smith Report). Once the opportunity cost of private capital is considered the empirical basis for a 2.5 percent discount rate must be modified to account for the higher discount rate which applies to opportunity cost of capital. *See* Ex. 304 at 30 (Smith Surrebuttal). Similarly, Mr. Martin's argument that Dr. Smith's rejection of a 2.5 percent discount rate is subjective in not persuasive – the 2.5 percent rate fails to take into account the opportunity cost of capital necessary to reduce emissions, which is “purely an empirical issue.” *Id.*

186. Dr. Hanemann has also testified that accounting for hyperbolic discounting would further lower the consumption rate of interest. Ex. 801 at 79 (Hanemann Rebuttal). However, Dr. Smith explained that hyperbolic discounting leads to time inconsistency, i.e., inconsistency between an individual's choices at the present time and in the future. Even if hyperbolic discounting were a compelling reason to adopt a lower discount rate, Dr. Hanemann has not explained why it justifies a discount rate as low as 2.5 percent.

187. Based on Commission precedent, as well as the evidence in this proceeding, the descriptive approach for selection of the discount rate is preferable. However, to the extent that a prescriptive approach were to be considered by the Commission, there is evidence in the record that a 2.5 percent discount rate is not required to achieve intergenerational fairness. Dr. Smith suggested intergenerational equity requires, at most, that each generation enjoy equal consumption on the grounds that “an equal per capita real consumption for all generation is an eminently fair arrangement.” Ex. 302 at 87 (Smith Report) (citing Mishan (1977) at 300-301).

188. Dr. Smith demonstrated that, even taking climate change damages into account, future generations will still enjoy significantly greater consumption than the present generation. Dr. Smith showed that, even under the most pessimistic scenario adopted by the IWG, future generations in the year 2100 will have a real consumption at least three times greater than the present generation. *See* Ex. 302 at 90, Table 12 (Smith Report). This inequality will be exacerbated by any increased spending undertaken by the current generation to reduce emissions. *See id.* Therefore, intergenerational equity does not necessarily require the use of a lower discount rate. The prescriptive approach is adequately accounted without the use of a 2.5 percent discount rate.

189. The evidence in the record further shows that the use of a discount rate unsupported by empirical evidence may distort decision making. As Dr. Mendelsohn pointed out, capital can be invested in various public and private projects which might increase welfare in various ways, including by reducing carbon dioxide emissions. *See* Ex. 216 at 11 (Mendelsohn Direct). Because the discount rate reflects the likely return on these investments, the use of low discount rate implicitly reflects a lower return on related investments. *Id.* Therefore, if a low discount rate is used when analyzing carbon emissions reductions issues in resource planning, but the same low rate is not also used in other private or public investments (including investments in education, national security, or infrastructure), policy makers would be implicitly assuming that it is acceptable to get that lower rate as the rate of return on emission-reduction projects. *Id.* The use of an interest rate below 3 percent can result in investments being made in emissions reductions projects rather than other, potentially more beneficial projects. The criterion of conservatism articulated by ALJ Klein and adopted by the Commission would be poorly served by permitting the distortion of resource planning decisions by adoption of an interest rate less than 3 percent.

190. The evidence does not support the use of a 2.5 percent discount rate. The use of a 2.5 percent discount rate lacks empirical support and does not conform to the statutory requirement that values have an evidentiary basis. The use of a 2.5 percent discount rate would be a departure from current Commission practice with the potential to significantly distort resource planning decisions.

191. The “Ramsey rule” was also proposed as a basis for the correct discount rate. Dr. Tol testified that the Ramsey rule is a more appropriate choice for the discount rate to be used to calculate the environmental cost value of CO₂. Ex. 263 at 3 (Tol Rebuttal). The Ramsey rule relates the 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. *Id.* at 4. The Ramsey Rule is composed of three variables: pure rate of time preference, which measures our preference for consumption today rather than later, diminishing marginal utility, i.e., the relative value of a dollar given a person’s overall income, and the growth rate. *Id.*

192. Because a key variable in the Ramsey rule is the growth rate, the discount rate as calculated by the Ramsey rule changes as the growth rate changes. Accordingly, under the Ramsey rule, the discount rate varies with economic growth. Ex. 263 at 4 (Tol Rebuttal). By using a constant discount rate, therefore, “the IWG puts a premium on the impacts in countries that grow faster than the USA. The effect can be substantial. For instance, using the FUND scenario as used by the IWG, impacts in China are weighted 46% to 87% higher than impacts in the USA.” *Id.* at 6.

193. While the Ramsey rule has theoretical appeal, the evidence does not support the use of the Ramsey rule to calculate Minnesota’s environmental cost value for CO₂. No party has offered the methodology to apply the Ramsey rule as an independent input in calculating an environmental cost value. Moreover, while Dr. Tol provided estimates of the environmental cost value of CO₂ generated using the FUND model with a Ramsey rule-based discount rate, he failed to provide evidence regarding the other assumptions used in the calculation of those cost values.

b) Geographic Scope

194. The IWG adopted a global scope of damages for the Federal Social Cost of Carbon. 2010 TSD at 11. The IWG acknowledged that, under OMB Circular A-4, analysis of economically significant regulations from the domestic perspective is required, and analysis from the international perspective is optional. *Id.* at 10. However, the IWG distinguished the climate change problem from typical regulatory impact analysis contexts in two respects. First, the IWG noted that climate change involves a global externality because greenhouse gases contribute to damages around the world. *Id.* Second, climate change represents a problem that the United States alone cannot solve without participation from other countries. *Id.* Accordingly, the IWG concluded that the use of global damages was appropriate. *Id.* at 11. The IWG also stated that the development of a domestic Federal Social Cost of Carbon is complicated by the relatively few region- or country-specific estimates of the Federal Social Cost of Carbon. Although the IWG calculated a domestic Federal Social Cost of Carbon of between 7 and 23 percent of the global Federal Social Cost of Carbon, it did not report these values in its ultimate recommendation. *Id.* at 1, 11.

195. Dr. Smith disagreed with the IWG's approach. She testified that standard benefit-cost principles support considering the benefits of a policy only within the jurisdiction whose citizens will bear the costs of implementing the policy. Therefore, as applied to the establishment of Minnesota's environmental cost value, she stated, "[g]iven 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." Ex. 300 at 95 (Smith Direct). Similarly, Dr. Gayer testified that, since Minnesotans will accrue all costs of emissions reduction costs, it would be outside the typical practice of benefit-cost analysis for Minnesota to consider the environmental benefits to the entire global population. Ex. 400 at 9 (Gayer Direct); Ex. 401 at 3-4 (Gayer Surrebuttal).

196. Dr. Smith also testified that adopting a global value in the absence of action from other states and countries would harm Minnesota while failing to significantly reduce global warming. She noted that although the Federal government might adopt a global scope in order to induce other countries to reduce their emissions on a reciprocal basis, Minnesota lacks this power. Ex. 302 at 96-97 (Smith Report). Accordingly, the rationale that may have motivated the IWG does not apply in Minnesota's case. Moreover, acting on an altruistic basis would not achieve any significant reduction in global warming because Minnesota's reductions, standing alone, would not have any measurable impact on climate change. *Id.* at 97.

197. Dr. Polasky testified that using only U.S. damages fails from an economic perspective because the theory of correcting externalities requires incorporation of all damages caused by pollution. Ex. 100 at 10 (Polasky Direct Schedule 2). Dr. Smith responded that, although it is true that incorporating only the damages incurred in Minnesota will not account for the full measure of environmental costs associated with CO₂ emissions, incorporation of global damages will also be economically inefficient unless Minnesota is joined in its efforts by other states and countries to reduce CO₂ emissions. In the absence of such concerted action, incorporating global damages would harm Minnesota and fail to help anyone else. This led Dr. Smith to conclude the usual rationale relied upon to take into account global damages does not apply to the establishment of Minnesota's environmental cost value. Ex. 304 at 32 (Smith

Surrebuttal).

198. Dr. Polasky contended that the typical benefit-cost analysis is not applicable to the establishment of an externality value because Minnesota is correcting its own market failure, which is doing harm to others across the planet. Dr. Polasky asserted that remedying this market failure is different from conferring a benefit, and therefore, benefit cost analysis does not apply. Ex. 101 at 27:17-28:04 (Polasky Rebuttal). However, as Dr. Smith testified, “Benefit-cost analysis is commonly considered by economists to be a methodology for assessing policy responses to problems of market failure.” Ex. 304 at 33:19-22 (Smith Surrebuttal) (citing “S-Theory-1” in Farrow 21 and Viscusi, p. 9).

199. Dr. Hanemann testified that the choice of geographic scope was not a matter of economics, but a policy decision and the Commission should defer to its own precedent. Ex. 800 at 15:22-16:6 (Hanemann Rebuttal). The Commission used a global scope of damages in setting its CO₂ value. In the earlier proceeding, ALJ Klein noted that “[t]he CO₂ emitted in any particular place on the plant is well-mixed in the atmosphere. Warming in Minnesota, for example, will be caused not just by Minnesota’s CO₂ emissions, but by the global concentration of CO₂. Similarly, Minnesota’s CO₂ emissions cannot be said to warm Minnesota’s environment any more than they warm the rest of the plant.” ALJ Findings at 31-32, ¶ 83. The Commission agreed, noting that damage caused by CO₂ emissions is experienced globally, and adopted the ALJ Klein’s range. January 3, 1997 Order at 26-27.

200. The witnesses generally agreed that economic principles should inform the establishment of Minnesota’s environmental cost value. *See* Ex. 101 at 10 (Polasky Rebuttal) (noting that the efficient decision occurs where marginal cost equals marginal benefit); *see* Ex. 801 at 17 (Hanemann Rebuttal) (noting that resource planning is a form of cost-benefit analysis). Dr. Smith and Dr. Gayer observed that the inclusion of global damages in Minnesota’s environmental cost value would be inconsistent with those principles. Those principles dictate that the analysis of proposed policies should consider the benefits and costs which occur within the affected jurisdictions. *See* Ex. 300 at 28:4-22 (Smith Direct); Ex. 400 at 7:11-13 (Gayer Direct). Because the costs of higher environmental cost values will be borne by Minnesotans, the benefits of emissions reductions to Minnesotans should be considered. Ex. 304 at 3:12-4:4 (Smith Surrebuttal).

201. As a practical matter, the use of global damages will not benefit Minnesotans in the absence of reciprocal agreements with other states and countries. The use of global damages by Minnesota alone will fail to significantly affect global warming, while imposing significant costs on Minnesotans. *See* Ex. 302 at 95 (Smith Report).

202. Dr. Polasky argued that Minnesota Statute Section 216B.2422 requires all environmental costs associated with a method of electricity generation be included in resource planning decisions. Ex. 100 at 4:17-5:9 (Polasky Direct). But Dr. Polasky is an economist and not a lawyer. And the environmental cost statute does not expressly require accounting for global damages.

203. Finally, the IWG’s concern that there are relatively few regional estimates of the SCC available appears to be unfounded. As Dr. Smith and Dr. Gayer showed, U.S. estimates of

the Federal Social Cost of Carbon can be generated using the same IAMs that the IWG used to prepare the Federal Social Cost of Carbon. *See* Ex. 302 at 62 (Smith Report)

204. Although the Commission used a global scope of damages in its 1997 order, the evidence in this proceeding justifies a reconsideration of this approach. Incorporation of global damages will be economically inefficient unless Minnesota is joined in its efforts by other states and countries to reduce CO₂ emissions. In the absence of such concerted action, incorporating global damages would harm Minnesota and fail to help anyone else. Therefore, the evidence supports the application of principles of benefit-cost analysis, and that those principles cannot support the use of global damages for Minnesota's environmental cost value for CO₂.

c) Time Horizon

205. The IWG measured damages out to 2300 on the grounds that “[m]any consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300.” 2010 TSD at 25.

206. The IWG's use of a 2300 time horizon introduced significant and compounded speculation into the Federal Social Cost of Carbon in at least three ways. First, in order to extend projections so far into the future the damage functions used by the IWG must rely on extrapolation well beyond available empirical studies of damage caused by temperature change. Second, the socioeconomic projections used by the IWG rely to a great extent on the highly questionable assumption that a future society will not act in the face of extreme temperature changes. Third, socioeconomic projections used by the IWG assume the economies of the twenty-second and twenty-third centuries will be affected by temperature changes in the same way that our economy is now. Ex. 302 at 70-75 (Smith Direct).

Damage Functions are based on limited empirical evidence after 3°C

207. The evidence shows that the damage functions underlying the Federal Social Cost of Carbon become increasingly speculative after approximately 2100 or, at most, 2140. The damage functions which underlie the IAMs are “simple smoothed curves” which are fitted to limited empirical evidence of the damage that is associated with temperature changes of 3°C or less. Ex. 302 at 70 (Smith Report); *see also* Ex. 300 at 27, Fig. 3 (Smith Report).

208. Damage estimates are “virtually non-existent for temperature increases above 3°C.” Ex. 300 at 27 (Smith Report) (citing Nordhaus and Sztorc (2013)). Because data above 3°C is not available, the shape of the curve obtained by extrapolating from the available data completely determines the monetary value of damages.

209. A significant portion of the damages resulting from 3°C and over occur after 2100. Accordingly, most of the damages after 2100 are calculated on the result of extrapolation from limited empirical evidence. *See* Ex. 300 at 18:14-19:2 (Smith Direct).

210. The limited evidentiary basis for determining projections after 2140 does not provide a sufficient evidentiary to form a basis for Minnesota's environmental cost value for CO₂.

Failure to account for adaptation and mitigation

211. The IAMs also have a limited ability to account for adaptation or mitigation, particularly after 300 years. *See also* Ex. 235 at 58-60 (Bezdek Surrebuttal) Making economic and technological assumptions out to 2300 is an exercise in “science fiction.” *Id.* at 58:6-8.

212. The IWG’s socioeconomic scenarios are unduly speculative after 2140 because they fail to adequately account for the possibility that society will react to unacceptably high temperature increases of approximately 2 °C. *See* Ex. 302 at 11-12 (Smith Report).

213. The IWG’s emissions projections are adjusted for a measure of social response to rising temperatures, insofar as “the IWG places a 20% weight on the emission projection keyed to climate stabilization at 550 ppm.” Ex. 801 at 23 (Hanemann Rebuttal). Each of the IWG’s socioeconomic scenarios also shows emissions leveling off and/or beginning to decline by about 2200. *Id.* at 19: Fig. 1A, 1B.

214. Although the IWG’s projections show emissions levelling off and declining after a certain point, Dr. Hanemann has recognized that the IWG’s IAMs assume emissions will continue to rise for up to 100 years after unacceptable temperature levels are reached. This remains true even for the “Fifth Scenario,” which is keyed to climate stabilization at 550 ppm, and, like each of the five scenarios reflected in Dr. Hanemann’s figure 1B, is given a 20 percent weight by the IWG. Ex. 304 at 16 (Smith Surrebuttal).

Damage Function Extrapolations fail to account for societal change

215. Dr. Smith criticizes the IAMs because the calculations of societal damages require an implicit assumption that what would be a large welfare loss if it were to occur today would have the same relative impact 200 or 300 years from now. Ex. 302 at 74-75 (Smith Report). The IAMs’ damage functions are based on limited empirical evidence about the current shares of GDP associated with certain sectors, and the extent to which those sectors would be impacted by temperature increases of up to 3°C. *Id.* at 74. Those estimates are extrapolated to obtain likely damages for higher temperature changes. *Id.* That extrapolation assumes that (1) the mix of resources that make up GDP will be similar to what it is today; and (2) those sectors will be as sensitive to temperature changes then as they are now. *Id.* These assumptions are unreasonable.

216. Dr. Polasky defended the use of a 2300 time horizon. He suggested that properly estimating the marginal damages associated with a unit of CO₂ emissions requires accounting for the impact of that unit for as long as it is likely to remain in the atmosphere, and that a 2300 time horizon is necessary to avoid “zeroing out” damages. *See* Ex. 101 at 15:8-16:21 (Polasky Rebuttal). However, the calculation of Minnesota’s environmental cost value does not require that the Commission attempt to account for all possible damages, however speculative. As the Commission has clearly recognized, and as the applicable legal standards require, there comes a point at which the degree of speculative content becomes so significant that reliance on certain projections becomes inappropriate. The calculation of an environmental cost value requires only that the Commission value those impacts which can be quantified using reasonable and sufficient evidence.

217. There is insufficient evidence in the record to support the IWG’s use of

projections from 2140 to 2300. Although a degree of speculation and uncertainty is unavoidable and should not prevent the Commission from fulfilling its statutory mandate to establish environmental cost values, the evidence shows that the degree of speculation after 2140 is excessive and substantially greater than the speculation before that point. *See* Ex. 302 at 11-12 (Smith Report).

d) Marginal Ton

218. The IWG's Federal Social Cost of Carbon values are calculated assuming that the emitted ton of CO₂ being valued would be the last ton to be added to the global CO₂ emissions inventory. The IWG calculated the Federal Social Cost of Carbon by calculating the baseline path of emissions for each year based on forecasted emissions, GDP, and population. 2010 TSD at 24. The IWG then added an additional unit of carbon emissions for the emissions year being valued, and recalculated the temperature changes and damages expected in all future years as a result of the additional unit of emissions. *Id.* It then subtracted the damages computed from the baseline projections from those computed with the additional unit of emissions included, and discounted the resulting damages using fixed discount rates. *Id.*

219. The Federal Social Cost of Carbon treats the ton being valued as if it would be the last ton of emissions added to the entire stream of the IWG's baseline projections between now until 2300. Ex. 302 at 52 (Smith Report). This is because the IWG's emissions projections are fixed in each model run. *Id.* Therefore, because the Federal Social Cost of Carbon values are based on the value of the last incremental unit of emissions added to the baseline projections, the Federal Social Cost of Carbon is calculated as though the ton being valued were the last ton emitted during the nearly 300 years projected by the IWG. *Id.* at 52-53. A significant portion of these emissions will not be emitted for many years after the year for which emissions are being valued. *Id.* at 53.

220. Minnesota's current environmental cost value is based on an average cost per ton of emissions. The Commission in 1997 adopted a value based on testimony offered by Mr. Ciborowski. *See* Ex. 302 at 53-54 (Smith Report). Mr. Ciborowski's change in emissions was to zero out all future CO₂ emissions from the start of his projection (the year 2010) through the end of his modeling horizon (2100). *Id.* at 54. Thus the increment was not 1 Gt (1 billion tonnes)¹⁹ in one decade, but 4,250 to 5,323 Gt spread over 90 years. *Id.* at 51, 54. Thus, Mr. Ciborowski's CO₂ \$/ton estimates represent an average damage cost of all future emissions. *Id.* at 54.

221. Dr. Smith testified that calculating a cost per ton for the last ton to contrary both to principles of sound cost-benefit analysis and to any realistic view of the actual damage caused by Minnesota's emissions.

222. Benefit cost analysis is the standard tool economists use to for assessing the appropriate amount of emissions by balancing the environmental benefits and economic costs of reducing emissions. Ex. 302 at 55 (Smith Report). The principle for finding the optimal level of emissions is that a policy's stringency should be set at a level where marginal costs of meeting that policy's constraints should be equated with the marginal benefits that would thereby be

¹⁹ Smith Report at 51.

gained. *Id.* Dr. Smith demonstrated that the marginal damage of the last ton is higher than the marginal damage estimated at or near the optimum CO₂ emissions target. For this reason, use of the last ton will necessarily set the prices per ton of CO₂ significantly higher than the optimal level.

223. Dr. Smith also testified that a “compensatory damages” perspective similarly indicates that a last ton is inappropriate. The “compensatory damages” perspective reflects an estimate of the damages that might be ascribed in the future to today’s emissions. Ex. 302 at 61 (Smith Report). As Dr. Smith notes, the numerical value of the damages ascribed to Minnesota damages today is heavily influenced by future global emissions. *See id.* Accordingly, “the IWG’s efforts to value the last ton’s damage is conceptually inconsistent with the realities of climate change risks, as no single ton in any single year can be viewed as the last ton in an intertemporal projection of emissions that cumulatively determines the temperature changes that drive the present value of damage estimates.” *Id.* at 54. Therefore, a more appropriate and fair estimate of the damage cause by Minnesota’s power generators would be the average damage per ton of all future manmade tons. *Id.* at 61. Mr. Martin agreed that the IWG’s method of calculating an environmental cost value, based on the value of the last ton, overstates damages from Minnesota’s CO₂ emissions. *See* Ex. 601 at 46 (Martin Rebuttal).

224. The use of the ‘last ton’ is not supported by sound economic principles and it is not consistent with the Commission’s direction to value the actual environmental cost of CO₂. It would also be contrary to Commission precedent. The use of a marginal cost based on the “last ton” of emissions is not reasonable for determining Minnesota’s CO₂ value.

7. Leakage

225. In its July 2015 response to public comments, the IWG acknowledged that emission leakage is an important consideration in determining the net CO₂ reductions to be valued in regulatory impact analysis, but recommends that any estimate of leakage be applied to emission reductions, not to the SCC value itself. *See* Ex. 601 at 52:7-12 (Martin Rebuttal).

226. The evidence shows that the “unilateral application by Minnesota of CO₂ environmental cost values, without corresponding action by other states, is likely to result in shifting of emissions that will at least partially offset emission reductions within Minnesota.” Ex. 601 at 52:14-18 (Martin Rebuttal).

227. This could occur by businesses relocating in search of lower energy costs, or thought re-dispatch of energy through an interconnected system like the Midcontinent Independent System Operator (“MISO”). “For example, if the CO₂ environmental cost values drive the decision to retire a fossil unit, that unit’s generation would be replaced in the short term through the rebalancing of the MISO system with other generation, some of which would likely be fossil generation located outside of Minnesota. This type of emissions leakage, compared to leakage from business relocation, would be relatively immediate, automatic and difficult to avoid.” *Id.* at 52:23-53:2; *see also* Ex. 300 at 27:16-28:2 (Smith Direct).

228. Leakage is not just a theoretical concern. Dr. Smith testified that leakage is likely to occur when one state adopts a policy that drives up the cost of energy production in that state,

while the cost of energy production in neighboring states remains unchanged. Ex. 300 at 28:13-17 (Smith Direct).

229. Dr. Polasky agreed that leakage should be taken into account in resource planning. Evidentiary Hearing (Sept. 24, 2015) Vol. I at 125:20-126:9 (Polasky). Although most witnesses agreed that leakage was concern, most witnesses also agreed that it would not be appropriate to adjust the CO₂ environmental cost value itself, since “leakage affects the total emissions reductions achieved rather than the damages per ton.” Ex. 601 at 53:9-11 (Martin Rebuttal); *see also id.*; Ex. 302 at 100 (Smith Report).

230. Dr. Smith testified that the Commission may estimate leakage in resource planning dockets by “employ[ing] a detailed generation planning model of the Minnesota electricity system and power pools that connect to Minnesota. Such a model can be run with and without a specific change in generation resources in Minnesota (and hence a specific direct change in Minnesota’s electricity sector CO₂ emissions). The ratio of the change in emissions outside Minnesota to the change in emissions within Minnesota would yield the amount of estimated leakage.” Ex. 302 at 102 (Smith Report).

231. Dr. Hanemann advised the Commission should not make an adjustment for leakage, because the Commission is not responsible for regulating the level of GHG emissions in other states or in the U.S. and thus should not account for the corresponding increases in other states of emissions reductions in Minnesota. Ex. 801 at 30:26-31:2 (Hanemann Rebuttal).

232. While it is true that the Commission cannot order emissions reductions in other states, the Commission can account for emissions increases in other states directly caused by actions in Minnesota when evaluating resource decisions in Minnesota. To the extent that leakage is likely to occur, it should be taken into account. To do otherwise would fail to properly account for the full environmental cost and overstate the environmental benefits of resource planning decisions in Minnesota.

C. Use of the Federal Social Cost of Carbon to Determine Minnesota’s CO₂ Environmental Cost Value

233. The evidence offered in this proceeding shows that the IAMs allow the integration of science and economics and may be useful for some types of policy-making, especially when evaluating the international impacts of national polices. But the question in this proceeding is whether the Federal Social Cost of Carbon is reasonable and the best available measure for determining Minnesota’s CO₂ value for use in state-level resource planning.

234. The Federal Social Cost of Carbon was not designed for use in state-level resource planning. As developed by the IWG, the Federal Social Cost of Carbon, especially in its attempt to calculate damages over a 285-year period, allows for levels of uncertainty and speculation that the Commission in the past has found to be unreasonable for setting Minnesota’s environmental cost values. Although this uncertainty and speculation may not render the Federal Social Cost of Carbon unreasonable for use in federal regulatory impact analysis, it raises major issues for the use of the Federal Social Cost of Carbon in determining of Minnesota’s CO₂.

235. It is beyond dispute that the use of environmental costs in resource planning

demands greater precision than the use of Federal Social Cost of Carbon in federal regulatory impact analysis. The decisions made in individual resource plan dockets about continuing to operate, retrofit, or even retire power plants are usually irreversible and tremendously expensive. *See* Evidentiary Hearing (Sept. 29, 2015) Vol. 4 at 75:5-25 (Martin). Commission rate-regulated utilities could perhaps be made whole even if an inefficient decision were to be made as a result of a faulty and imprecise environmental cost value, provided rate recovery is achieved (though there is no certainty on that point and the reactions of regulators in other states must be considered), but Minnesota citizens and consumers could be seriously impacted. Higher environmental cost for CO₂ based on speculative evidence could result in resource decisions that lead to higher bills for consumers. *See* Evidentiary Hearing (Sept. 29, 2015) Vol. 4 at 16:21-18:20. Consumers and industries that use a great deal of electricity, such as those included in the group of large industrial consumers participating in this docket, could be particularly impacted by such rate increases. Moreover, if environmental cost values are set too high and result in relatively expensive resource decisions, “leakage” could result, driving future energy production and jobs to bordering states.

236. Specific decisions made by the IWG in its development of the Federal Social Cost of Carbon, including decisions relating to model standardization, the damage functions, the socioeconomic scenarios, and the environmental climate sensitivity value, added significantly to, and in fact compound over time, the levels of uncertainty and speculation associated with the estimated values.

237. The economic framing assumptions adopted by the IWG relating to discount rate, modeling horizon and the use of last ton of emissions in the year 2300 to calculate marginal cost are not consistent with the statutory directive to “quantify” values “to the extent practicable” or with the approach taken by the Commission to establish “conservative” values based on sufficient evidence and without excessive speculation.

238. Based upon a preponderance of the evidence, the Federal Social Cost of Carbon is not a reasonable measure to determine Minnesota’s CO₂ value.

V. IF THE FEDERAL SOCIAL COST OF CARBON IS NOT REASONABLE AND BEST AVAILABLE MEASURE TO DETERMINE THE CO₂ ENVIRONMENTAL COST VALUE, WHAT IS A BETTER ALTERNATIVE?

239. Dr. Hanemann and Dr. Polasky, as well as Dr. Abraham, Dr. Gurney, Dr. Dessler, Dr. Rom, Dr. Reich, Mr. Rumery, and Mr. Kunkle, proposed the adoption of the Federal Social Cost of Carbon as developed by the IWG. They contended the Federal Social Cost of Carbon is reasonable and the best available measure to determine Minnesota’s CO₂ environmental cost value.

240. Dr. Smith, Dr. Gayer, Dr. Mendelsohn, Dr. Tol,²⁰ and Mr. Martin each offered proposals as an alternative to the Federal Social Cost of Carbon which were based on

²⁰ Dr. Tol testified on behalf of Peabody. He is a professor of climate change at University of Sussex and the Vrije Universiteit Amsterdam. He holds a Ph.D. from Vrije Universiteit. Dr. Tol is the primary author of the FUND model. Ex. 237 (Tol Curriculum Vitae).

adjustments of the Federal Social Cost of Carbon. Dr. Smith, Dr. Gayer, and Mr. Martin each used the results of all three IAMs used by the IWG. Dr. Mendelsohn and Dr. Tol each relied on only one IAM – in Dr. Mendelsohn’s case, DICE, and in Dr. Tol’s case, FUND.

241. Dr. Smith ran DICE, PAGE, and FUND. She obtained from the EPA all files used to generate the Federal Social Cost of Carbon. These files included the three IAMs (DICE 2010, and instructions for obtaining PAGE09 and FUND 3.8), all input files used by the IWG for these models, and instructions on how to replicate the IWG’s results. She then successfully replicated the IWG’s values before adjusting the IAMs to incorporate her own recommended framing assumptions. *See* Ex. 302 at 32-39 (Smith Report).

242. Dr. Mendelsohn ran DICE, and Dr. Tol ran FUND in order to establish their proposed alternative values. *See* Ex. 214 at 6 (Mendelsohn Testimony); Ex. 236 at 2 (Tol Rebuttal Report).

243. Dr. Smith, Dr. Mendelsohn, and Dr. Tol have demonstrated that the IAMs used by the IWG can be used by other qualified modelers, and that DICE, PAGE, and FUND can be run with different assumptions than used by the IWG, to establish Minnesota’s CO₂ environmental cost value.²¹

A. Adjust IWG’S Economic Framing Assumptions

1. Dr. Smith’s Approach (Modeling Horizon, Discount Rate, Marginal Ton, and Geographic Scope)

244. Dr. Smith recommended the Commission adopt a range of costs obtained by altering four key framing assumptions used by the IWG: time horizon, discount rate, which marginal value to use, and geographic scope. Dr. Smith’s recommended range is based on model horizons of 2100 to 2140, discount rates of 3 percent to 5 percent, marginal values from the first to the average of the first and last tons emitted, and for U.S. damages rather than global damages. Ex. 302 at 33:17-34:9 (Smith Direct).

245. Dr. Smith obtained and ran the three IAMs used by the IWG. She was able to replicate the IWG 2020 values. Ex. 302 at 39 (Smith Report). Dr. Smith then used the IAMs to calculate results based on the revised framing assumptions discussed below. These assumptions yield a range of \$1.62 per net tonne to \$5.14 per net tonne, stated in 2014 dollars. Ex. 302 at 13 (Smith Report).

Time Horizon

246. With respect to time horizon, Dr. Smith recommended the Commission adopt a time horizon ending in 2100 or 2140, because the use of timeframe ending in 2300 is overly

²¹ Dr. Smith also testified that DICE, PAGE, and FUND could be updated using the framing assumptions that she recommended. She stated, “[i]f 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.” Ex. 304 at 35:10-15 (Smith Surrebuttal).

speculative and unsupported by the evidence in this proceeding for several reasons. Dr. Smith testified that limiting the time horizon to 2100 or 2140 eliminates the most significant speculative content in the IAMs damage functions and socioeconomic scenarios. Ex. 302 at 22:7-23:9, 33:17-34:9 (Smith Direct).

247. With respect to uncertainty in the damage functions, reduction of the time horizon to 2100 or 2140 reduces the most speculative portion of the damage functions. The damage functions are calibrated using limited empirical evidence, which deals with projections of up to approximately 3°C. Beyond that point, damages are calculated based on extrapolation from this limited empirical evidence based on curves assumed by the modelers. Because the vast majority of the projections associated with temperatures over 3°C occur after 2100, undue speculation could be reduced, though not eliminated entirely, by limiting the modeling horizon to 2100. Ex. 302 at 70-72 (Smith Report).

248. The use of a modeling horizon of 2100 or 2140 also better comports with our ability to measure the damages caused by increases in temperature. As Dr. Smith testified, one way to make projections is to look at the kinds of technology in use. Ex. 302 at 75 (Smith Report). The longest lived technologies, such as power plants, have a life of approximately 80 years. Over this period of time, damage projections can likely be made, because we know how existing technology would be affected by temperature change. That timeframe can also be extended by about 40 years to account for technology which is presently foreseeable, but not yet in service. Therefore, a modeling horizon tied to the technology cycle is more reasonable. Ex. 302 at 74-75 (Smith Report).

249. The use of modeling horizons of 2100 and 2140 eliminate a significant amount of the unduly speculative portions of IWG's damages projections.

Discount Rate

250. With respect to discount rate, Dr. Smith recommended discount rates of 3 percent and 5 percent. She also recommended that the Commission discard the 2.5 percent discount rate used by the IWG in establishing the Federal Social Cost of Carbon. The use of 3 percent and 5 percent discount rates as consistent with empirical evidence. By contrast, the use of a 2.5 percent rate has not been shown to be based on empirical evidence, is excessively speculative and has the potential to distort decision-making. The use of 3 percent and 5 percent discount rates more closely aligns with the Commission's current practice for setting environmental cost values.²² See Ex. 302 23:11-24:16 (Smith Direct).

Marginal Ton

251. With respect to the marginal ton to value, Dr. Smith recommended the use of

²² OMB Circular A-4 recommends the use of a 7 percent rate. The 7 percent rate is derived from the average before-tax rate of return to private capital in the U.S. economy. Ex. 302 at 83 (Smith Report). This measure approximates the opportunity cost of capital, and should be used when the main effect of a regulation is to displace or alter the use of capital in the private sector. *Id.* As Dr. Smith noted, emissions controls will indeed require private investments. *Id.* at 84. Accordingly, Dr. Smith included a 7 percent discount rate in Tables 4 and 4A, and the Commission is free to consider use of such a rate. See Ex. 307 (Table 4A). However, Dr. Smith did not recommend the use of such a rate in establishing her range.

marginal values estimated from the first to the average of the first and last tons emitted. Dr. Smith calculated the value of the first ton of emissions by zeroing out all future emissions after 2020, and calculating the value of the incremental ton of emissions only. She then approximated the value of (1) a “first ton” of emissions in which the harm from given tons is not considered in connection with other projected emissions and (2) the average of the “first ton” and “last ton” which approximates an approach in which Minnesota’s reductions occur along with emissions reductions in other jurisdictions. Ex. 302 at 61, 64 (Smith Report).

252. Dr. Smith concluded that principles of benefit-cost analysis require that the appropriate level of emissions be assessed by balancing the environmental benefits and economic costs of the action. Ex. 302 at 55 (Smith Report). She testified that the goal of benefit cost analysis is to find a level of emissions that maximizes net benefits, which is equal to the estimated societal benefits that would be obtained by reducing emissions from their baseline levels, minus the estimated costs of achieving those lower levels of emissions. *Id.* For this reason, the appropriate estimate of marginal damages to apply is the damages associated with attaining the optimum emissions level. This will be a much lower number than the damages associated with the last ton in the unregulated baseline. Smith used a value between the first and last ton as an approximation of the damages associated with optimum emissions. *Id.* at 55-56; *see also* Ex. 214 at 3:10-22 (Mendelsohn Direct).

253. Dr. Smith noted that, under an approach which considers what actual damage can be attributed to any particular given ton of CO₂ (i.e., the compensatory damages approach), an average of the first and last ton is the appropriate measure. Ex. 302 at 61 (Smith Report). Dr. Smith suggested there are two main reasons that Minnesota should not determine the CO₂ value based on the “last ton” of emissions. First, by applying cost values ahead of most other jurisdictions, Minnesota is acting as an environmental leader and so it is only reasonable to treat the Minnesota tons as among the first incremental tons of emission reductions. Second, there is no reason for Minnesota power generators to be assigned more responsibility for climate damages than all other emitters. The use of an average ton to calculate the marginal cost is more reasonable than the last ton approach. *Id.* at 61-62.

254. Dr. Hanemann and Dr. Polasky contended that valuing the ‘first ton’ to be emitted is inappropriate because it necessarily involves assuming that no emissions occur after 2020, and that because such an assumption is unlikely to be factually accurate, it should not play a part in the commission’s analysis. Ex. 101 at 14:10-14:16 (Polasky Rebuttal); Ex. 801 at 29:9-13 (Hanemann Rebuttal). But these criticisms miss the point of Dr. Smith’s analysis. She testified that valuing the first incremental unit of emissions to occur after 2020 is an analytical device designed to inform the Commission on how much of the IWG’s SCC estimates are due to emissions yet to be emitted, as opposed to those due to historical emissions. Ex. 304 at 22:8-25:7 (Smith Surrebuttal).

255. Dr. Smith’s recommendation to value the first ton and an average of the first and last ton is a reasonable approach. Her use of an average ton is more consistent with sound cost-benefit analysis principles than a last ton approach. The use of a first ton is appropriate to help Minnesota manage its risk as a “first mover” in emissions reductions, and that the use of an average ton between the first and last ton is more consistent with the actual damage likely attributable to Minnesota emissions without inappropriately charging Minnesota for the future

emissions of others.

Geographic Scope

256. With respect to geographic scope, Dr. Smith recommended the use of U.S. damages rather than global damages. Ex. 302 at 26:15-27:11 (Smith Direct). Dr. Smith found the use of global values as being contrary to benefit-cost analysis principles which state the evaluation of the costs or benefits of a policy should be matched to those who bear its costs. *Id.* Additionally, Dr. Smith pointed out that, in the absence of reciprocal agreements with other states, the use of global values will not significantly affect global warming. *Id.* at 15:19-15:21.

257. As discussed above, the use of a global geographic scope is not reasonable for the calculation of Minnesota's environmental cost value for CO₂. Therefore, Dr. Smith's recommendation for the use of U.S. damage only is a reasonable approach, and should be adopted.

Conclusion

258. Based on her adjustments of the time horizon, marginal ton, geographic scope, and discount rate, which reflect the revised assumptions listed above, Dr. Smith's proposed range of \$1.62 to \$5.14 per metric ton, measured in 2014 dollars, is reasonable. See Ex. 302 at 13 (Smith Report).

2. Dr. Gayer's Approach (Geographic Scope)

259. Dr. Gayer recommended the calculation of a range for the environmental cost values for CO₂ based only on U.S. or Minnesota damages.

260. Dr. Gayer pointed out that the adoption of an environmental cost value for CO₂ for use in resource planning was a unilateral policy on the part of the State of Minnesota, and was not coordinated in a national or global fashion with any other political entities. Ex. 400 at 9:4-6 (Gayer Direct).

261. Dr. Gayer testified that the typical cost-benefit practice would be to consider the environmental benefits only for the jurisdiction that is undertaking the policy under consideration. Ex. 400 at 4 (Gayer Report). He contended that it would be outside the typical practice of benefit-cost analysis to consider the environmental benefits to the global population while considering a policy that accrues costs only to Minnesota. Ex. 400 at 9:8-11 (Gayer Direct). Dr. Gayer proposed that the Commission adopt an environmental cost value which considered only U.S. or only Minnesota benefits of reducing emissions.

262. Dr. Gayer noted that "there could be altruistic motivations that justify some consideration of benefits to residents outside of the jurisdiction incurring the cost of the policy under consideration." Ex. 400 at 5 (Gayer Report). "The altruistic benefits that stem indirectly through the person with standing are therefore expected to be substantially smaller than the direct benefits to a person with economic standing, and would typically be smaller as the distance increases between the person with standing and the person receiving the altruistic benefit." *Id.*

263. Dr. Gayer estimated that U.S. damages range from 7 percent (based on regional damages included in the FUND model) to 23 percent of global damages (based on the U.S. share of global GDP). Ex. 400 at 18 (Gayer Report). Dr. Gayer also calculated Minnesota damages using a GDP scaling approach which estimated Minnesota damages as 0.04 of global damages. *Id.* He found “using a global SCC measure where a Minnesota state measure is appropriate results in an over-estimate of benefits of more than 200-fold.” *Id.* He concluded that adjusting the IWG’s 2013 global SCC estimates to the state level results in extremely small damage estimates. *Id.* at 17. Specifically, applying the GDP-scaling to the highest SCC estimate of the IWG suggests a Minnesota-specific SCC of only about \$0.37 per metric ton of CO₂ (2010 damage value in 2007 dollars).” *Id.* at 17-18.

264. Dr. Polasky and Dr. Hanemann opposed Dr. Gayer’s approach. Dr. Polasky argued that economic standing should extend to all parties because Minnesota’s ECV is designed to correct a market failure. Ex. 101 at 27:1-28:13 (Polasky Rebuttal). Dr. Hanemann argued that the question of geographic scope is a policy question, on which the ALJ should defer to Commission precedent. Ex. 801 at 15:22-15:25 (Hanemann Rebuttal).

265. If the Commission is inclined to reconsider its approach to the geographic scope of damages, Dr. Gayer offers a reasonable means to estimate U.S.-only damages. However, Dr. Gayer’s proposal retains the other framing assumptions used by the IWG, including the use of a last marginal ton, a 2300 time horizon, and a 2.5 percent discount rate. Because Dr. Gayer’s proposal does not adjust the IWG’s use of these framing assumptions, his proposal fails to remedy the resulting speculation incorporated into the Federal Social Cost of Carbon by those framing assumptions. *See* Ex. 400 at 6-8 (Gayer Report); Ex. 601 at 31:18-32:25 (Martin Rebuttal).

266. Dr. Gayer’s proposal, while more reasonable than the Federal Social Cost of Carbon, is not better supported by the evidence than Dr. Smith’s proposal.

B. Adjust IWG’s Equilibrium Climate Sensitivity and Economic Framing Assumptions

1. Dr. Mendelsohn’s Approach (DICE model only)

267. Dr. Mendelsohn proposed the CO₂ values should be established based on the DICE model (2013 version) in optimization mode, with the damage function modified to reflect no damages below 1.5°C, and 2°C. Ex. 214 at 10-11 (Mendelsohn Direct). He also adopted a lower ECS value than used by the IWG. *Id.*

268. When operated in optimization mode, the DICE model is designed to determine the optimal level of mitigation, i.e., the level that equates marginal cost to marginal damage. Ex. 214 at 10 (Mendelsohn Direct). The calculation of this optimal level will determine the damage cost of CO₂ emissions that, if imposed on emissions, would maximize net benefits to society. *Id.* at 7. When used in optimization mode, DICE accounts for the possibility that society will adopt mitigation strategies to reduce emissions in response to climate change. *Id.* at 5:24-6:4.

269. Dr. Mendelsohn replaced the DICE damage functions with two of his own damage functions. One of his damage functions assumed no damage until temperature rises

1.5°C above 1900 levels, and the other assumed no damages until temperature rises 2°C above 1900 levels. *See* Ex. 214 at 9:8-13 (Mendelsohn Direct).

270. Dr. Mendelsohn supported his decision to assume no damages until temperatures exceed 1.5°C or 2°C based on his observation that there have been limited damages from the 0.8°C of warming that has occurred since the beginning of the industrial period. *See* Ex. 214 at 8:24-9:13 (Mendelsohn Direct). Dr. Mendelsohn concludes that DICE would find damages of approximately \$173 billion based on a temperature increase of 0.8°C. *See id.* at 11 (Mendelsohn Direct Exhibit 2). But Mendelsohn contends that his kind of damage has not occurred. *Id.*

271. Dr. Mendelsohn testified that these damages have failed to materialize because society has benefited from increased warming based on, among other things, CO₂ fertilization, and that the benefit involved outweighs any damages up to 1.5°C or 2°C. *See* Ex. 214 at 10-21 (Mendelsohn Direct Exhibit 2).

272. Dr. Mendelsohn ran DICE using several ECS values, including 1, 1.5, 2, 2.5, and 3. Ex. 214 at 19 (Mendelsohn Direct Exhibit 2). Dr. Mendelsohn used DICE's original emissions and GDP forecasts, and he also used DICE's internal variable discount rate that is a function of the growth of GDP per capita. *Id.* at 21.

273. After making these changes, Dr. Mendelsohn provided the following ranges, based on four different ECS values: When the ECS was set at 3, DICE calculated a range of \$4-\$6. When the ECS was set at 2, DICE calculated a range of \$1.1-\$2. When the ECS was set at 1.5, DICE calculated a range of \$0.3-\$0.8. When the ECS was set at 1, DICE calculated a range of \$0 to \$0.10. Ex. 214 at 19 (Mendelsohn Direct Exhibit 2).

274. Dr. Hanemann and Dr. Polasky criticized Dr. Mendelsohn's use of DICE in its optimization mode, on the basis that optimal emissions levels are unlikely to occur. Ex. 801 at 40-46 (Hanemann Rebuttal); Ex. 101 at 46-52 (Polasky Rebuttal). Dr. Hanemann argues that optimal emissions levels are unlikely to occur in the absence of a single decision maker who controls global emissions. Ex. 801 at 46 (Hanemann Rebuttal). Dr. Polasky agreed, noting that, because no policy exists to make polluters pay for emissions, a higher environmental cost value would not necessarily result in lower emissions. He also noted that society was not on a path to optimal emissions, and therefore, Dr. Mendelsohn's assumption was unrealistic. Ex. 101 at 46:13-21 (Polasky Rebuttal).

275. The use of DICE in optimization mode is intended to identify the most efficient policy, i.e., when marginal cost equals marginal ton, and therefore, the use of an optimal emissions cost is appropriate for use in calculating Minnesota's environmental cost value for CO₂. Ex. 220 at 26:7-8 (Mendelsohn Surrebuttal).

276. Dr. Hanemann also contended that Dr. Mendelsohn's changes to DICE's damage function to assume no damages below 1.5°C and 2°C is supported by insufficient evidence. Ex. 801 at 40-46 (Hanemann Rebuttal).

277. There is insufficient evidence to support Dr. Mendelsohn's modified damage functions. Dr. Mendelsohn's observation that expected damages have not materialized rests on Dr. Mendelsohn's own conclusory observation that damage has not occurred. This is insufficient

to justify such a significant change to DICE's damage functions. Moreover, Dr. Mendelsohn's argument regarding carbon fertilization is inconsistent with the IPCC's conclusion that the net results of increased CO₂ emissions on the ecosystem has been negative, and that the benefits of CO₂ have been adequately accounted for in the IAMs. Accordingly, the evidence does not support Dr. Mendelsohn's revised damage functions.

278. Dr. Mendelsohn's use of ECS values ranging from 1 to 3 is inconsistent with the IPCC 4th Assessment Report and 5th Assessment Report. *See* Ex. 802 at 19 (Hanemann Surrebuttal).

279. Dr. Mendelsohn's proposed values are not supported by the evidence.

2. Dr. Tol's Approach (FUND model only)

280. Dr. Tol ran the FUND model using ECS values between 1 and 3. Ex. 236 at 8:171-176 (Tol Rebuttal).

281. Dr. Tol testified that, using those assumptions, FUND calculates the SCC as negative \$17.97 for an ECS value of 1, negative \$12.06 for a value of 1.5, negative \$4.05 for a sensitivity value of 2.0, \$7.06 for an ECS value of 2.5, and \$20.05 for an ECS value of 3.0. Ex. 236 at 9:179-180 (Tol Rebuttal).

282. Like Dr. Mendelsohn, Dr. Tol's proposed range relies on the use of climate sensitivity values between 1 and 3. Ex. 236 at 8:171-176 (Tol Rebuttal). However, the use of climate sensitivity values between 1 and 3 is inconsistent with both the IPCC Fourth and Fifth Assessment Reports. These reports are regarded as authoritative, and the evidence offered in this proceeding has not altered this conclusion. Therefore, Dr. Tol's proposed values are not supported by the evidence.

3. Dr. Bezdek's Approach (Benefits and Costs)

283. Dr. Bezdek stated that the Minnesota CO₂ values established in 1997 should be retained, or reduced to about \$0.20 to \$2.00 per ton. Ex. 233 at 48 (Bezdek Rebuttal).

284. Dr. Bezdek stated that the values established by the Commission in 1997, translated to 2014 dollars, yield a range of \$0.42 to \$4.43 per ton, and recommended that the Commission retain these values. Ex. 233 at 48 (Bezdek Rebuttal). However, Dr. Bezdek failed to point to any evidentiary or methodological justification for this recommendation.

285. Dr. Bezdek also recommends a lower range of \$0.20 to \$2.00 per ton. Ex. 233 at 48 (Bezdek Rebuttal). Although Dr. Bezdek offered the conclusory statement that these values were justified by his testimony that the costs of CO₂ are far outweighed by the benefits of CO₂, Dr. Bezdek utterly failed to provide a methodology to quantify the CO₂ environmental cost value. *See id.* at Appendix A, page 86.

286. Therefore, Dr. Bezdek's proposed values are not supported by the evidence.

C. Rely on a Limited Range of Federal Social Cost of Carbon Values

1. Mr. Martin's Approach

287. To develop its proposal, Xcel Energy retained The Brattle Group (“Brattle”) to assist with statistical analysis. Mr. Martin and Brattle obtained the IWG’s model run data, and used that data to prepare a narrower range of CO₂ values by conducting a statistical analysis of the IWG’s data. *See* Ex. 600 at 55 (Martin Direct).

288. Mr. Martin obtained from the IWG the results from the November 2013 SCC update, which consisted of 10,000 model runs per emissions scenario for each of the three IAMs, and each of three discount rates for each IAM. Ex. 600 at 55 (Martin Direct). Brattle then aggregated the results into 15 distributions – one for each combination of discount rate and emission year. *Id.* Brattle then calculated summary statistics for each distribution, obtaining the mean, median, and other percentiles for each distribution. *Id.*

289. Brattle calculated the 25th and 75th percentiles for each distribution. Brattle then took the mean of each of the three discount rates used by the IWG at the 25th percentile, and the mean of each discount rate at the 75th percentile. Mr. Martin stated that this was done in order to remain neutral on discount rate choice. Ex. 600 at 59:5-15 (Martin Direct). This method yielded a range of \$12.31 to \$41.80 for emission year 2020, in 2014 dollars per short ton. Ex. 600 at Schedule 3 (Martin Direct).

290. Mr. Martin’s proposal is based on raw data prepared by the IWG, which data is based on the IWG’s assumptions regarding time horizon, geographic scope, and the last marginal ton. *See* Ex. 600 at 54-55 (Martin Direct). Those assumptions were heavily criticized in this proceeding, including by Mr. Martin, who stated that using a last ton, assuming no mitigation, and calculating global damages would likely cause the Federal Social Cost of Carbon to overestimate Minnesota damages. Ex. 601 at 28 (Martin Rebuttal). For the reasons described above, the evidence shows that the framing assumptions on which the IWG relied are not reasonable. Therefore, Mr. Martin’s proposal, which rests on those same assumptions, is similarly flawed.

291. Additionally, the statistical analysis presented by Mr. Martin is not founded on sound statistical methods, and fails to cure the flaws inherent in the underlying data.

292. First, by combining each of the three discount rates used by the IWG into a single range, Mr. Martin deprives the Commission of the ability to exercise choice on the appropriate discount rate. Unlike the IWG, which presented the mean of each discount rate for separate consideration in its final result, Martin suppresses, rather than presents, qualitative information regarding discount rates by combining disparate rates into two values. Ex. 240 at ¶¶ 13, 18 (Wecker Rebuttal Ex. 2). Mr. Martin’s statistical approach has the effect of obscuring important information from the Commission by taking the average of the 25th and 75th percentiles at each discount rate. Based on the testimony of Dr. William Wecker as well as Dr. Smith, Mr. Martin’s proposal is contrary to sound statistical methodology. *See id.* at ¶¶ 7.

293. Second, Mr. Martin fails to demonstrate that the statistical methodology that he uses is appropriate. Dr. Wecker testified that, under statistical decision theory, the choice of

descriptive statistics should take into account how these statistics will be employed, and how the choice of statistics will affect the use for which they are generated. *See* Ex. 240 at ¶¶ 24-25 (Wecker Rebuttal Ex. 2). The explicit consideration of these factors is a necessary conceptual foundation for a statistically sound approach. *Id.* at ¶ 27. Mr. Martin did not demonstrate how his statistical methodology was appropriate. Nor is there any evidence that the statistical method used by Mr. Martin is appropriate. As Dr. Smith noted, Mr. Martin's method could be used to obtain ranges that have narrower and lower ranges that have the same probability as Mr. Martin's range, and they could be used to identify wider and higher ranges that have the same probability as Mr. Martin's range. Ex. 303 at 6-7 (Smith Rebuttal).

294. The proposal by Mr. Martin failed to address the deficiencies in the economic framing assumptions used by the IWG. Moreover, the evidence in this proceeding shows that the statistical adjustments made by Mr. Martin and the Brattle Group are arbitrary and fail to generate useful descriptive statistics. Accordingly, Mr. Martin has failed to show that his proposal is reasonable.

D. Use of an Alternative Proposal to Determine Minnesota CO₂ Environmental Cost Value

295. Based on the preponderance of the evidence, the Federal Social Cost of Carbon, as developed by the IWG for use in federal regulatory impact analysis, is not reasonable and the best available measure to determine Minnesota's CO₂ environmental cost values.

296. Based on a preponderance of the evidence, a better alternative is to use an adjusted version of the Federal Social Cost of Carbon, as proposed to Dr. Smith, whereby certain economic framing assumptions used by the IWG are replaced with ones designed to reduce the uncertainty and speculation inherent in the Federal Social Cost of Carbon estimates and more tailored to the needs of Minnesota's resource planning process.

297. Under this approach, the following adjustments should be made to the Federal Social Cost of Carbon: (1) modeling horizon should be adjusted to be 2100 for the low-end of the range and, 2140 for the high-end of the range, (2) the discount rate should be set at 5 percent for the low-end of the range and 3 percent for the high-end of the range, (3) the marginal ton evaluated would be the first ton for the low end of the range, and an average of the first and last ton for the high end of the range; and (4) U.S. damages would be used.

298. The first ton would be determined by running the same IAMs as the IWG used, adjusted so that the baseline scenario represents no manmade emissions occurring after 2020. *See* Ex. 302 at 62 (Smith Report). An incremental unit of emissions should then be added, and the difference between the two scenarios calculated. *Id.*

299. Under this approach, the geographic scope of the damages would be the U.S., and calculated as proposed by Dr. Smith by using the region-specific damages generated by PAGE and FUND. *See* Ex. 302 at 98, 99, Table 15 (Smith Direct).

300. In all other major respects, including the selection of the ECS value, the decisions and assumptions made by the IWG for development of the Federal Social Cost of Carbon would be adopted.

301. This approach comports with this Commission's past decisions, and with sound principles of benefit-cost analysis.²³

302. A significant amount of credible evidence was offered in this proceeding to support adjustment of equilibrium climate sensitivity value used by the IWG. However, the preponderance of the evidence favors use of the assumptions for the ECS set out in the IPCC's Fourth Assessment.

303. By a preponderance of the evidence, the record shows that leakage is likely to occur and that it would be reasonable and appropriate to incorporate a leakage adjustment factor into the resource planning process.

CONCLUSIONS OF LAW

1. Any of the foregoing Findings of Fact more properly designated as Conclusions of Law are hereby adopted as such.

2. The Administrative Law Judge and the Minnesota Public Utilities Commission have jurisdiction over the subject of this proceeding pursuant to Minn. Stat. §§ 216B.2422 and 14.50.

3. The Commission gave proper notice of the hearing in this matter, has fulfilled all relevant substantive and procedural requirements of law or rule, and has the authority to take the action proposed herein.

4. The evidentiary rules which apply in this case are those which govern contested cases, Minn. Rule. Pt. 1400.7300.

5. The Federal Social Cost of Carbon is not reasonable or the best available measure to determine the environmental cost of CO₂ under Minn. Stat. § 216B.2422.

6. Based on the foregoing findings and conclusions, the Administrative Law Judge makes the following Recommendations:

RECOMMENDATIONS

1. As the measure for determining the CO₂ environmental cost value, adopt the Federal Social Cost of Carbon but with adjustments of the economic framing assumptions for discount rate, geographic scope, marginal ton, and time horizon.

2. Consistent with this measure, adopt a range of costs for CO₂ to be used in proceedings subject to Minn. Stat. § 216B.2422 of \$1.42 per net ton to \$5.14 per net ton, measured in 2014 dollars and per metric ton of CO₂.

²³ The ALJ also notes that the Commission is not limited to accepting or rejecting the four framing assumptions used by Dr. Smith. If the Commission wishes to adopt different framing assumptions from those adopted by Dr. Smith and recommended by the ALJ, it may use Table 4A to select a different range based on different combinations of framing assumptions. *See* Ex. 307 (Smith Table 4A).

3. Apply the CO₂ values only to the net tons of reduced CO₂ emissions, calculated as the direct reduction of emissions in Minnesota, minus potential increases in emissions that are projected to occur outside of Minnesota as a result of Minnesota's control efforts.

Dated: _____

LAURASUE SCHLATTER
Administrative Law Judge